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INSIDE

Comings and Goings of Global Glaciations on a Neoproterozoic Tropical Platform in Namibia

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ABSTRACT

An enduring enigma of Neoproterozoic Earth history is the intimate association of glacial diamictites with typical warm-water carbonates. Among the many hypothesized explanations for this paleoclimatic dichotomy are high orbital obliquity, true polar wander, reduced solar luminosity, snowball albedo, CO_2 drawdown, stagnant ocean overturn, and reinterpretation of diamictites as mega-impact ejecta. The Otavi carbonate platform on the Congo craton in Namibia contains two discrete intervals of diamictite and associated glaciomarine deposits, sandwiched by thick carbonates from which we have obtained detailed carbon-isotopic records. From subsidence analysis, we estimate maximum rates of shallow-water sediment accumulation. The magnitude and duration of isotopic variations permit critical assessment of the existing hypotheses.

INTRODUCTION

Louis Agassiz's (1840) apocalyptic vision of ice ages so severe that continents were glaciated in the tropics and organic activity was stilled on land and sea was overwrought for the Quaternary, but what about the extraordinary events of the late Neoproterozoic (750–543 Ma)? Brian Harland (1964) first drew attention to the global distribution of infra-Cambrian glacial deposits and postulated that they extended into the tropics. This view was not widely accepted, however, because multiple glaciogenic intervals occur in some sections, making the extent of any individual glaciation dependent on correlation. Reliable paleomagnetic tests have been difficult to perform, but there is now strong evidence for equatorial glaciation at sea level in South Australia at ~600 Ma (Schmidt and Williams, 1995; Sohl, 1997) and with less certainty in northwestern Canada at ~720 Ma (Park, 1997). Tropical glaciation has also been advocated because many Neoproterozoic glacial deposits are rich in carbonate debris and are directly overlain by carbonates containing structures indicative of sea-floor precipitates (Fig. 1)(Roberts, 1976; Fairchild, 1993; Kennedy, 1996)—a climatological or geochemical paradox, given that inorganic

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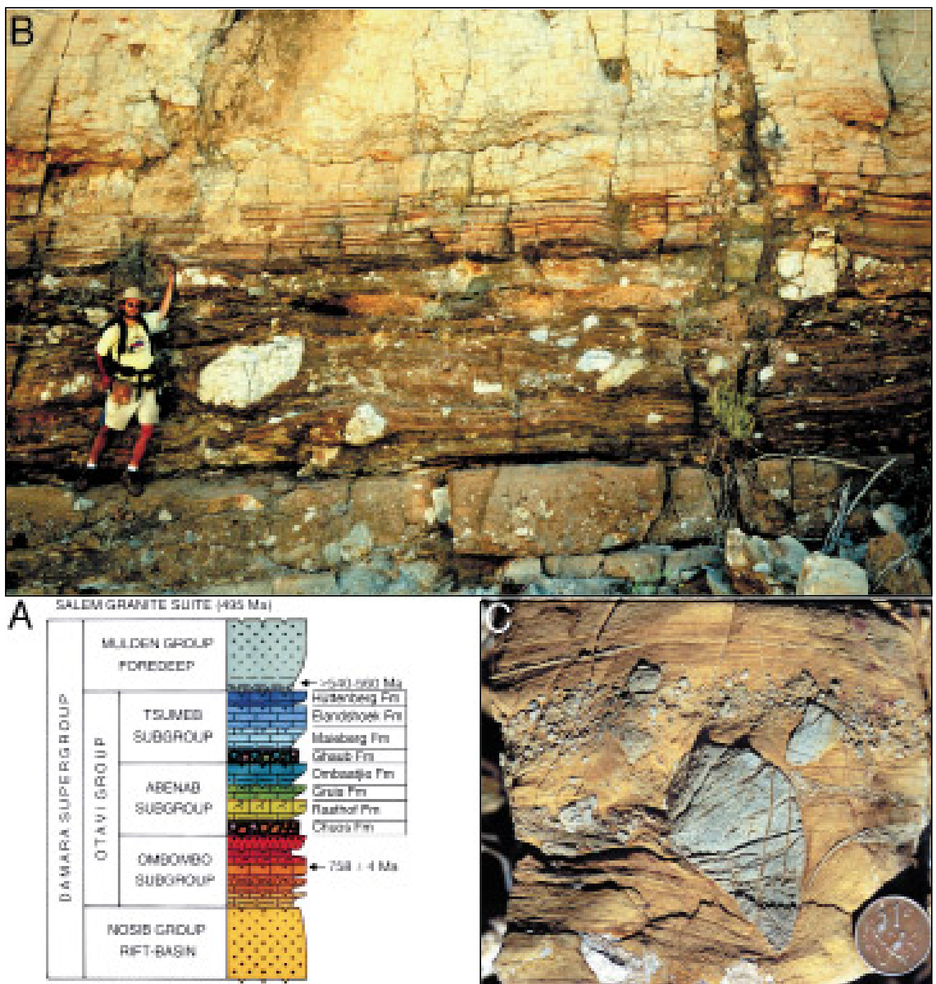

Figure 1. A: Generalized stratigraphy (Hoffmann and Prave, 1996) of Neoproterozoic cover on the Congo craton in northern Namibia, showing geochronological constaints. B: Galen Halverson points to the sharp contact between Ghuab diamictite and Maieberg cap carbonate. Below him is a graded debris flow, behind him is laminated dololutite with numerous dropstones, and above him are deep-water rhythmites with undulations due to isopachous cement sheets. All three units are composed entirely of dolomite. C: Ice-rafted dolomite dropstone pierces underlying laminae in glaciomarine Ghaub dololutite. Coin is 2 cm in diameter.

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IN THIS ISSUE

In Memoriam

W. Hilton Johnson
Las Cruces, New Mexico
November 3, 1997

John F. Mann, Jr.
La Habra, California
March 9, 1998

Duncan A. McNaughton
Austin, Texas
January 15, 1998

Samuel P. Welles
Berkeley, California
August 6, 1997

Correction

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.

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carbonate precipitation is normally a warm-water phenomenon.

Accompanying the late Neoproterozoic ice ages are huge negative carbon-isotopic excursions, unique in the past 2 b.y. (Fig. 2). Carbonates are very strongly enriched in ^{13}C between the ice ages but plunge to extremely depleted values in lithologically distinctive transgressive carbonate units that "cap" the glacial deposits and commonly extend far beyond them, aiding regional-scale correlations (Knoll et al., 1986; Kaufman and Knoll, 1995; Kaufman et al., 1997). Such large isotopic shifts signify a combination of changes in (1) fractional organic to total carbon burial rates (Scholle and Arthur, 1980), (2) biological productivity in the surface ocean (Broecker, 1982), (3) vertical circulation rate for the whole ocean (Brass et al., 1982), (4) isotopic composition of carbon sources (Derry and France-Lanord, 1996; Dickens et al., 1997), and (5) isotopic fractionation related to carbonate ion concentration (Spero et al., 1997). All are linked to global climate change. Here we describe the stratigraphic relations of two Sturtian (750–700 Ma) glacial intervals on a carbonate-dominated platform in northern Namibia and suggest a means of estimating the time scale of their associated isotopic anomalies. Such data gain sway only in the arena of ideas; thus, we begin with a partial review of current hypotheses.

CONTENDING HYPOTHESES

A welter of hypotheses contend to shed light on the Neoproterozoic climate puzzle. Seeking primarily to explain the paleomagnetic data, Williams (1975, 1993) proposed that Earth's axial tilt (the obliquity of the ecliptic) exceeded 54° until the end of the Proterozoic, after which it stabilized at much lower values (23.5° today). Accordingly, Earth's climatic zonation would have been reversed in the Proterozoic, meaning lower insolation at low latitudes than at the poles. On the other hand, the seasonal cycle would have been greatly amplified, resulting in hot biannual summers, which do not favor glaciation. The association of carbonates and glacial deposits is not explained by this model, nor is the middle Proterozoic glacial hiatus (Fig. 2); once low obliquities were established, high obliquities should not recur (Laskar et al., 1993). The model does have the merit of a simple falsifying test—high-latitude glaciation. Only moderately high (30°–40°S) latitude glaciations have been documented paleomagnetically (Torsvik et al., 1995).

DIRECTOR — *Institute for Environmental Education*

The Geological Society of America (GSA) recognizes that earth systems science is central to environmental issues, practices, policies, and problems in society today. Thus, GSA is soliciting applications for the position of Director for the Institute of Environmental Education (IEE). Through Institute programs, GSA offers an interface between the public, business and industry, government, and the geological community on matters of earth systems science and related public policy issues. The Institute fosters communication and application of geoscience information relevant to environmental issues, education and research related to earth systems problems and public policy, and programs to facilitate professional development in the area of environmental earth science.

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Another approach that avoids global glaciation, but which could explain rapid transitions from normal low-latitude to high-latitude conditions, is inertial-interchange true polar wander (IITPW). True polar wander refers to rotation of the entire solid shell (crust and mantle) of Earth relative to the spin axis, a special case of which involves interchange of the major and intermediate axes of Earth's nonhydrostatic moment of inertia tensor. The requisite condition arises if the geoid figure closely approximates a prolate ellipsoid: the prolate axis will stabilize in the equatorial plane to conserve angular momentum (Goldreich and Toomre, 1969), but if the other two axes are nearly equal, small changes in mass distribution may cause the globe to rotate 90° around the prolate axis in a few million years (Gold, 1955; Fisher, 1974). Consequently, continents located near the poles of the prolate axis will undergo 90° rotations, and continents located far from the axis will migrate through 90° of latitude at velocities far exceeding those due to plate tectonics. IITPW has been invoked in the interpretation of Cambrian paleomagnetic data (Kirschvink et al., 1997), and if the inferred prolate geoid figure was inherited from the former supercontinent Rodinia (1.05–0.72 Ga), then IITPW may have occurred several times in the late Neoproterozoic (Evans, 1998). This model attributes the carbonate-glacial association to rapid changes in paleolatitude; it does not explain low paleomagnetic inclinations obtained from the glacial deposits themselves (Park, 1997; Sohl, 1997). No changes in global climate are required in the model, but they would surely occur as ocean circulation patterns changed in response to migration of Earth's rotation axis. Continents moving in or out of the polar regions would experience short-term relative-sea-level falls or rises, respectively, because of their migration with respect to Earth's rotational bulge (Mound and Mitrovica, 1998). These sea-level changes would mimic those expected from glacio-eustasy.

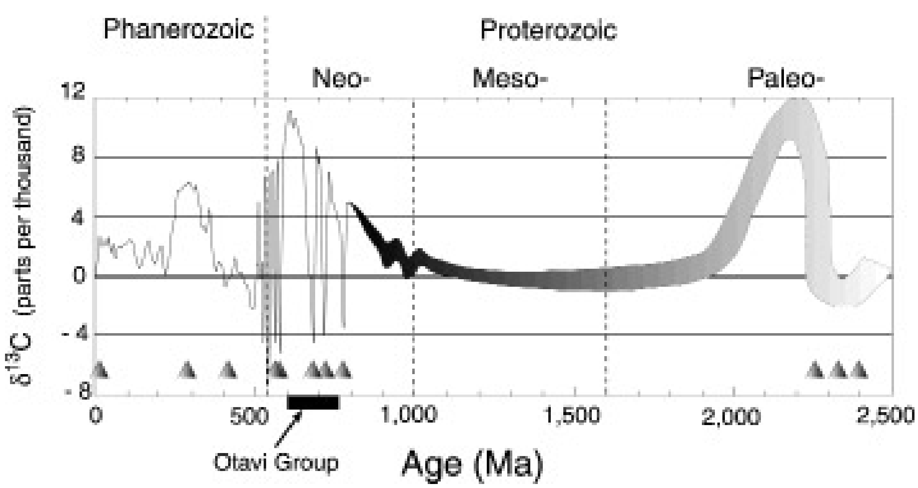

Figure 2. Secular variation in $\delta^{13}C$ (PDB) values of marine carbonates from 2.5 Ga to the present (compiled from Berner, 1989; Kaufman and Knoll, 1995; Kaufman et al., 1997, and references therein). Note enriched late Neoproterozoic isotopic values and high-amplitude negative excursions coincident with glaciations, indicated by triangles. Bar indicates inferred Otavi Group age span.

Global Glaciations *continued on p. 4*

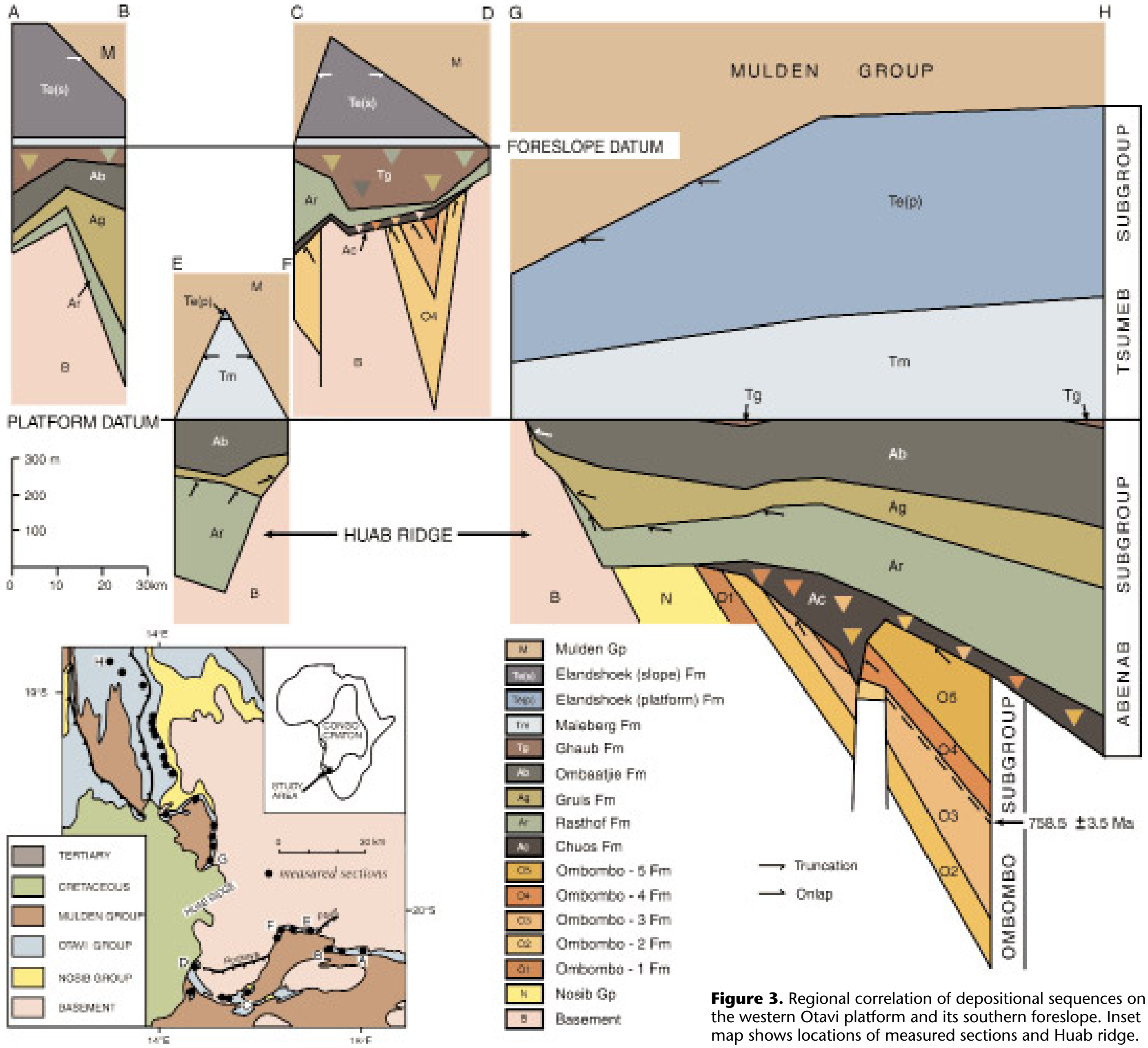

Figure 3. Regional correlation of depositional sequences on the western Otavi platform and its southern foreslope. Inset map shows locations of measured sections and Huab ridge.

Global Glaciations *continued from p. 3*

Rampino (1994) suggested that the purported glacial deposits are actually impact ejecta. His argument is that ballistic debris flows resulting from large impacts exhibit many features conventionally identified with glacial and glaciomarine deposits, including faceted and striated clasts and grooved bedrock pavements. Rampino (1994) did not discuss carbon-isotopic anomalies, but negative excursions do accompany impact-induced mass extinctions (Hsü and McKenzie, 1985; Zachos et al., 1989). Cessation of surface ocean productivity (Strangelove ocean) would cause rapid (<10^3 yr) loss of the ocean's isotopic gradient (~2‰ in the present ocean), meaning that $\delta^{13}C$ in the surface ocean would fall to whole-ocean values (Kump, 1991). Only if productivity ceased for hundreds of thousands of years would $\delta^{13}C$ approach the ocean input value of –5‰ (Kump, 1991). Barring a succession of large impacts, the isotopic excursions should strictly postdate the ballistic ejecta deposits, providing a stratigraphic test for the impact hypothesis.

The occurrence of iron-formation in several Neoproterozoic glacial deposits inspired the hypothesis that glaciation was preceded by deep ocean anoxia, favoring organic carbon burial. Invigorated thermohaline circulation during and after glaciation would result in upwelling of ferrous iron-, bicarbonate-, and CO_2-charged bottom waters, releasing CO_2 to the atmosphere and driving the precipitation of ferric oxide and isotopically depleted bicarbonate as limestone in oxic and highly oversaturated surface waters (Kaufman et al., 1991, 1997; Kaufman and Knoll, 1995; Grotzinger and Knoll, 1995). This hypothesis has been extended to account for the end-Permian mass extinction (Knoll et al., 1996), which has a carbon-isotopic signature somewhat comparable to the Neoproterozoic glacial events (Holser et al., 1989; Magaritz, 1989).

The Sun's luminosity was only 93%–94% of its present value in the late Neoproterozoic because main-sequence stars radiate more energy as their helium cores grow more massive (Gough, 1981). However, the absence of middle Proterozoic glacial deposits (Fig. 2) shows that this fact alone cannot explain late Neoproterozoic glaciations. CO_2 concentrations of 10^{-3} b (three times pre-industrial values) would have offset the reduced solar luminosity,

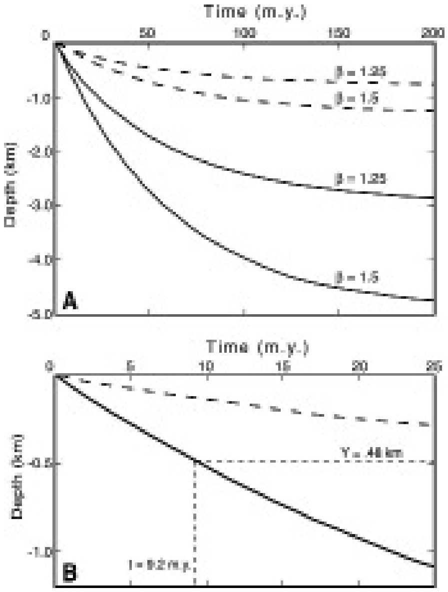

Figure 4. A: Thermal subsidence (dashed lines) and sediment accumulation (solid lines) curves generated by lithospheric stretching factors (ß) of 1.25 and 1.50. Sediment accumulation is calculated as thermal subsidence plus loading by carbonate sediment, filling available accommodation to sea level. Maximum thickness of ~2.8 km for Otavi Group after 160 m.y. implies ß ~1.25. B: Curves as above for first 25 m.y. of thermal subsidence generated by ß ~1.25. Thickness of the section (480 m) containing the negative carbon-isotopic excursion associated with Ghaub glaciation, beginning and ending with shallow-water deposits and corrected for glacial erosion, implies a duration of ~9.2 m.y.

but this dependence could have left Earth susceptible to severe chilling in event of CO_2 drawdown (Kasting, 1992). Coupled energy-balance models suggest that such scenarios are sensitive to the distribution of land masses but that CO_2 concentrations would have to fall to 10^{-4} b (0.3 times pre-industrial values) to drive tropical sea-surface temperatures to the freezing point even with reduced solar luminosity (Marshall et al., 1988; Crowley and Baum, 1993). Nevertheless, Kirschvink (1992) suggested that albedo feedback from extensive sea-ice formation on a globe with an equatorial ring of continents might lead to a "snowball Earth," in which the ocean is decoupled from the atmosphere by global pack ice, with profound implications for ocean chemistry and biological activity. For example, exchange of O_2 between the ocean and atmosphere would be inhibited, permitting ferrous iron generated at mid-ocean ridges or leached from bottom sediments to build up in solution, only to be precipitated as ferric iron-formation upon ventilation of the ocean when the ice pack receded (Kirschvink, 1992).

Global Glaciations *continued on p. 6*

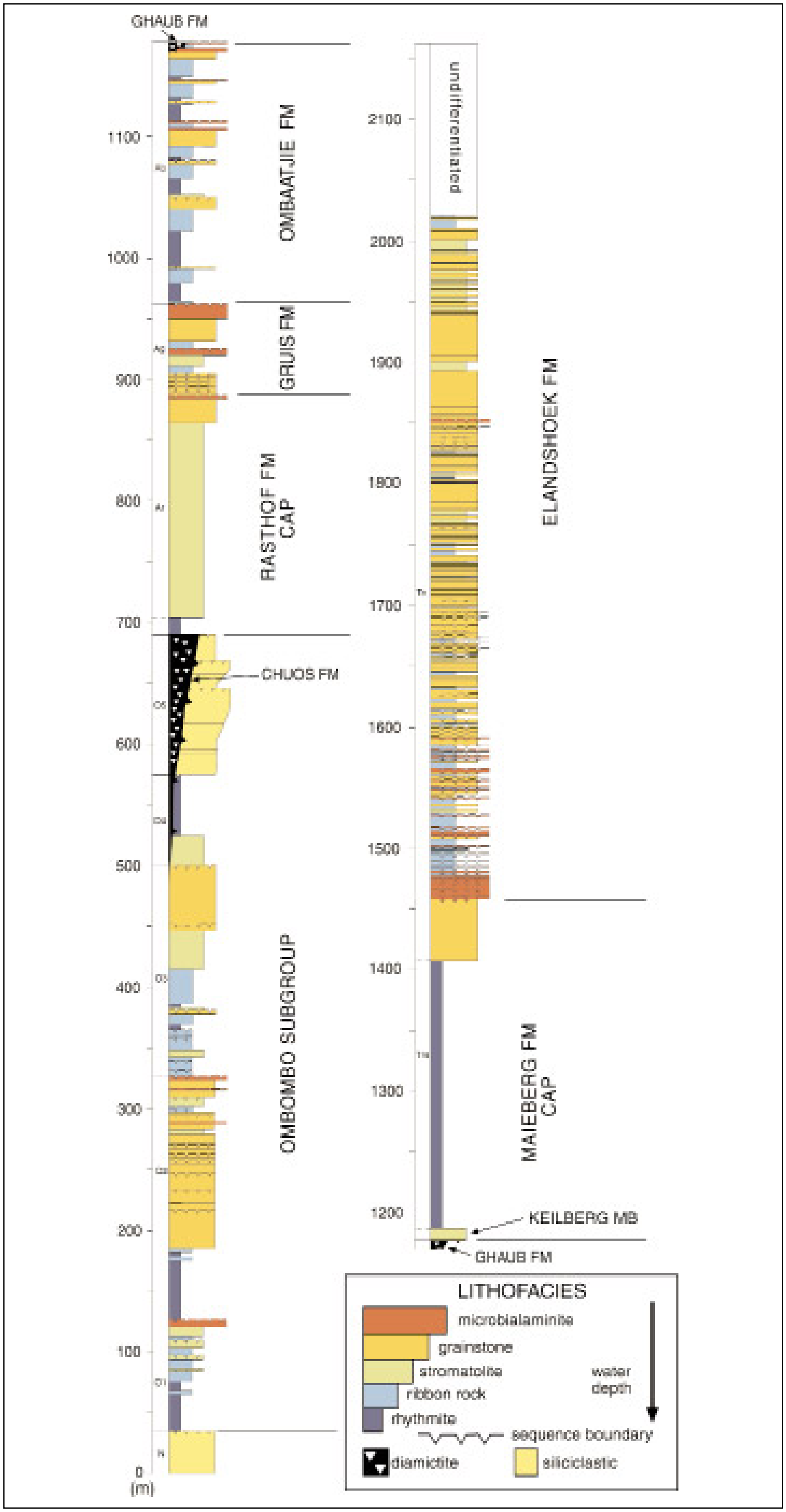

Figure 5. Representative stratigraphic section from the intra-shelf basin north of the Huab ridge (part G–H in Fig. 3). Top of left column continues at base of right column. Note anomalous thicknesses of Rasthof and Maieberg postglacial cap carbonates.

Global Glaciations *continued from p. 5*

OTAVI CARBONATE PLATFORM

In late Neoproterozoic time, the Congo craton was a low-lying platform the size of the conterminous United States. It was blanketed by carbonates and shales containing regionally mappable diamictite units of glacial origin (Hambrey and Harland, 1981). Two discrete glaciogenic intervals are contained in carbonates of the Otavi Group (Fig. 1A), which drape the southern promontory of the craton in northern Namibia (Fig. 3). We consider the Otavi Group to be entirely pre-Vendian in age (Fig. 2), on the basis of chemo- and biostratigraphic arguments. Carbon-isotopic compositions above +8‰ observed near the top of the Otavi Group (Kaufman et al., 1991) are unknown in the Vendian (Kaufman and Knoll, 1995), and Vendian fossils, abundant in the Nama Group carbonates of southern Namibia (Grotzinger et al., 1995), are absent from the Otavi Group. Paleomagnetic data from the eastern part of the Congo craton (Meert et al., 1995; Meert and Van der Voo, 1996) imply that the Otavi Group was at ~12°S paleolatitude at 743 ± 30 Ma and ~39°S at 547 ± 4 Ma (compare with age constraints in Fig. 1A).

The Otavi Group is exposed in fold belts along the southern and western borders of the cratonic promontory (Miller, 1997). The southern belt coincides with the edge of the Otavi platform, which is flanked by correlative slope and deep-sea fan deposits draped over extended Congo crust (Henry et al., 1990). A long-lived basement high, the Huab ridge (Porada et al., 1983), separates the platform margin from an intra-shelf basin to the north. The ridge was intermittently active in early and middle Otavi Group time, shedding clastic wedges bilaterally into the flanking carbonates. The western belt provides a transverse profile of the intra-shelf basin and the Huab ridge (Fig. 3), which along with the western part of the southern margin has been the focus of our field work. Another basement high occurs near the Namibia-Angola border, 300 km to the north of the Huab ridge, and the scale and structure of the intra-shelf basin and basement highs are remarkably similar to the present Namibian continental shelf (Light et al., 1993).

Regional subsidence patterns and overstepping of growth faults suggest that rifting of the western and southern margins of the Otavi platform ceased shortly before 758 Ma and shortly after 746 Ma, respectively (Fig. 1A, Hoffman et al., 1996). If carbonate sedimentation continued until the platform collided with the South American cratons at ~600 Ma (Stanistreet et al., 1991; Machado et al., 1996; Trompette, 1997), the Otavi Group represents ~160 m.y., by which time thermal subsidence would be largely complete (Fig. 4A). The maximum of 2.8 km of carbonate accumulated during thermal subsidence, after correction for sediment loading, amounts to ~0.73 km of tectonic subsidence. This amount of ultimate thermal subsidence would be induced by a uniform synrift stretching factor ß ~1.25 and would begin with tectonic subsidence rates of ~14 m/m.y., averaged over the first 10 m.y. (McKenzie, 1978). This corresponds, with sediment loading, to a carbonate accumulation rate of ~52 m/m.y. (Fig. 4B). We take this as a rough upper bound for the purpose of constraining the minimum duration of the isotopic anomalies.

GLACIAL DEPOSITS AND POSTGLACIAL CAP CARBONATES

The glacial deposits are characterized by diamictites, which are sheets of unstratified wackestone carrying outsize matrix-supported clasts of carbonate and basement rocks. Within both the Chuos and Ghaub glacial units (Fig. 3), separate diamictite sheets differ in composition, but clast and matrix compositions covary, indicating a common origin. Overall, basement debris is more abundant in the Chuos, and the Ghaub diamictites are normally dominated by debris from directly underlying carbonates. The Chuos diamictites are associated with fluvial outwash facies and fill paleovalleys with up to 180 m of local relief. Such incision is observed beneath the Ghaub diamictites only on the southern foreslope, where they are intercalated with subaqueous debris flows and topped by laminated dololutite choked with carbonate dropstones (Fig. 1, B and C). Both glacial intervals have highly complex and variable internal stratigraphies, but their external contacts are remarkably similar and consistent. On the platform, their basal contacts show intense brecciation of the underlying carbonates. Both of their upper contacts are knife-sharp and lack lag deposits or any evidence of hiatus. Where the glacial deposits are subaerial, the upper contact is a smooth flooding surface; where they are subaqueous, there is simply an abrupt cessation of ice-rafted debris.

The Rasthof and Maieberg cap carbonates (Fig. 5) directly overlie the Chuos and Ghaub glacial units, respectively, or their equivalent subglacial erosion surfaces (Fig. 3). They are single depositional sequences without internal exposure surfaces, whose average thickness of 200–300 m is an order of magnitude greater than that between successive exposure surfaces in other parts of the platformal Otavi Group. Average parasequence thickness is 20 m in the Ombombo Subgroup below the Chuos Formation and 8 m in the Gruis Formation above the Rasthof cap carbonate. It increases again to 30 m in the Ombaatjie Formation below the Ghaub glaciation, reflecting rifting at the southern margin of the platform, before declining to only 4 m in the Elandshoek Formation above the Maieberg cap carbonate. Thus, the cap carbonates require highly anomalous amounts of accommodation. From the onset of glaciation to the end of cap-carbonate deposition, the accumulated sediment must equal the sum of the tectonic subsidence, net glacial erosion/deposition, and the effect of sediment loading. Compaction is negligible in the Otavi Group carbonates and <20 m of net erosion occurred on the platform during the Ghaub glaciation. Given the average thickness of the Maieberg cap carbonate of 280 m (Fig. 3) and the maximum sediment accumulation rate of 52 m/m.y. calculated earlier, the minimum time required to create sufficient accommodation would be 5.4 m.y. Note that this is not the minimum time for cap carbonate deposition, which could be far less, but rather the total time for the glaciation as well as the cap carbonate. It is impossible to estimate the partitioning of time between the two because of transient glacio-eustatic and glacio-isostatic effects (Boulton, 1990). For example, postglacial sea-level rise can create much accommodation, but it will subsequently be eliminated by glacial rebound. Postglacial cap carbonates described elsewhere are relatively thin (Fairchild, 1993; Kennedy, 1996) but they may represent only the transgressive parts of postglacial depositional sequences. It is only from the perspective of sequence stratigraphy that the anomaly in postglacial accommodation becomes apparent, an aspect that escaped notice in the lithostratigraphic recognition of cap carbonates. Moreover, the anomaly stands out only when the cap carbonates are viewed in the sequence-stratigraphic context of the Otavi Group as a whole.

The two cap carbonates have distinctive and highly unusual lithologies (Fig. 6). The Rasthof is dark to medium gray, mostly dolomite and relatively carbonaceous (0.03–0.3 wt% C); the Maieberg is pale cream to pink, mostly limestone and extremely lean (0.001–0.02 wt% C). The complete Rasthof sequence in the intra-shelf basin consists essentially of three stratigraphic units (Fig. 5). The basal unit comprises finely and smoothly laminated micrite and varies from 5 to 60 m in thickness, dependent on the presence of centi meter-scale allodapic limestones (turbidites). The top of the flat-laminated unit is marked by profligate development of irregular domal stromatolites, the peculiar geometries of which suggest synaggradational, fault-propagation folds, verging in all directions. By implication, stromatolite development was a response to lateral growth expansion. Up-section, the stromatolite unit contains numerous coiled roll-ups (Fig. 6A), which formed while the sediment was cohesive (microbially bound?), but pliable (lightly mineralized). Also present are irregular synsedimentary collapse breccias, composed of microbialaminite blocks and void-filling thrombolite. The thick stromatolitic unit is devoid of desiccation structures and current bedforms. At its top, the lamination fades and the stromatolites pass cryptically into regressive pale gray grainstones, which coarsen upward to a sequence boundary marked by tepees and chert-breccias.

The basal transgressive unit of the Maieberg cap carbonate (Keilberg Member of Hoffmann and Prave, 1996) on the platform is an unusual stromatolitic dolomite (Fig. 6B), highly reminiscent of the postglacial Noonday dolomite (Sturtian?) in eastern California (Wright et al., 1978; Hegenberger, 1987). This pale dolomite unit consists of microbialaminite and long slender columnar stromatolites, between which are persistent synoptic depressions forming vertical sediment- and cement-filled "tubes." The stromatolite member thickens over the Huab ridge and develops into a mounded reef complex at the platform margin. Talus blocks at the base of the reef complex are infilled by meter-scale silica fans, pseudomorphic after aragonitic sea-floor cements. The stromatolite member is overlain transgressively by marly rhythmite, followed by a thick regressive sequence of pink limestone rhythmite, pale dolomite rhythmite, and dolomite grainstone that coarsens upward to an exposure surface made prominent by downward-penetrating boxwork chert. Directly above the sequence boundary are multitudinous meter-scale parasequences with ubiquitous tepee structures, representing the basal member of the kilometer-thick Elandshoek peritidal platform. The Keilberg stromatolite member is absent on the southern foreslope, where the basal Maieberg cap carbonate consists of pale dolomite rhythmite, sheeted with early isopachous carbonate cement (Fig. 1B). Carbon-isotopic curves indicate that the Maieberg cap carbonate thins dramatically from the platform onto the foreslope, and that most of the rhythmite and rhythmite-breccia section above the Ghaub diamictite is a foreslope facies of the Elandshoek platform (Fig. 3).

CARBON-ISOTOPIC RESULTS

The carbon-isotopic composition of Phanerozoic marine carbonates is complicated by the vital effects of skeletal organisms and pervasive bioturbation. Proterozoic carbonates are not plagued with these problems. The primary Otavi Group carbonates were pure lime muds, silts, sands, and microbial micrites, most of which underwent early fabric-retentive dolomitization, rendering them relatively impermeable. Elemental ratios sensitive to diagenesis indicate minimal alteration of most samples (for details of analytical procedures used in screening for diagenetic alteration, see Kaufman et al., 1991; Kaufman and Knoll, 1995). Even the brecciated and ferruginized samples deliberately collected at exposure surfaces rarely have anomalous carbon-isotopic values, indicating that soil waters were not significantly depleted by decomposition of organic carbon. Furthermore, the carbon-isotopic trends for closely spaced samples are stratigraphically coherent and regionally reproducible.

We have obtained $\delta^{13}C$ values for ~800 samples collected through the entire Otavi Group at different locations. These data (incorporated in Fig. 2) and their interpretation have been submitted for publication elsewhere. The thick, shallow-water carbonates of the Ombombo Subgroup are strongly and uniformly enriched in ^{13}C (>+5‰), consistent with preglacial Neoproterozoic carbonates worldwide (Kaufman et al., 1997). An influx of siliciclastics (from the Huab ridge) and erosional truncation at the top of the Ombombo Subgroup create problems in obtaining data for the youngest pre-Chuos sediments. The basal Rasthof carbonates are strongly depleted in ^{13}C, beginning near –4‰ and rising to ~0‰ near the top of the flat-laminated member. At the base of the overlying stromatolitic member, $\delta^{13}C$ values rise abruptly and ultimately stabilize near +5‰ for >150 m through the remainder of the Rasthof Formation. The shift from negative to positive values is widely correlated with the onset of deep-water stromatolite development in the intra-shelf basin.

Prior to the Ghaub glaciation, $\delta^{13}C$ values through most of the Ombaatjie Formation hovered between +5‰ and +9‰, exemplifying the familiar preglacial enrichment in ^{13}C. However, the ultimate Ombaatjie shallow-water parasequence, directly beneath remnants of Ghaub diamictite or the Maieberg cap carbonate, displays a monotonic downward trend from +5‰ at the base to –3‰ at the top, reaching –5‰ in some sections. This preglacial isotopic shift occurs in at least nine sections over a north-south distance of 150 km, and Kennedy et al. (1997) reported a somewhat smaller shift beneath the Ghaub diamictite well to the east of our sections. There is little change in $\delta^{13}C$ values across the glacial interval: the basal Maieberg cap carbonate begins near –3‰ and declines gradually up-section to a nadir of –6‰ about 20 m above the zone of inferred maximum flooding. While $\delta^{13}C$ values gradually rise above this level, they remain negative through the sequence boundary at the top of the Maieberg Formation. In fact, the crossover to positive $\delta^{13}C$ values occurs ~200 m above the base of the Elandshoek Formation, which is composed of repetitious peritidal parasequences with ubiquitous subaerial exposure surfaces. Thus, the overall negative isotopic excursion begins and ends in peritidal sediments and spans a total thickness of 500 m. On the basis of previously estimated maximum thermal subsidence rates and assuming <20 m of glacial erosion beneath the Maieberg cap carbonate on the platform, the minimum duration of the negative isotopic excursion was 9.2 m.y. (480 m ÷ 52 m per m.y.; Fig. 4B). Regional sequence stratigraphic mapping provides no evidence of growth faulting coincident with the isotopic excursion, which might have produced anomalous subsidence rates, hence less time, during the interval.

DISCUSSION AND CONCLUSIONS

Let us now return to the contending hypotheses. (1) The high-obliquity hypothesis (Williams, 1975, 1993) does not account for the intimate association of glacial deposits with carbonates including inorganic sea-floor aragonite precipitates requiring warm-water conditions, exemplified by the basal Maieberg reefal cement fans. (2) The inertial-interchange true polar wander hypothesis that certain regions migrated rapidly between low and high latitudes (Kirschvink et al., 1997) does not explain the temporal association of glacial deposits with large carbon-isotopic excursions. Nor do we find transitional mid-latitude facies between the diamictites and their respective cap carbonates, as predicted by this hypothesis. (3) The suggestion that the diamictites are mega-impact ejecta (Rampino, 1994), implying that the associated isotopic excursions signify impact-induced mass extinctions, is contradicted by the onset of the negative isotopic shift, which predates the Ghaub diamictite. Moreover, we do not rely on ambiguous criteria for recognizing glacial deposits such as striated and faceted clasts, which are difficult to observe in carbonate-dominated diamictites, but on stratigraphic relations and abundant dropstones, around which only the subjacent laminations are deformed and pierced. (4) The ocean-overturn hypothesis (Kaufman et al., 1991, 1997; Kaufman and Knoll, 1995; Grotzinger and Knoll, 1995; Knoll et al., 1996) predicts that negative isotopic excursions should be short-lived, limited by the residence time for carbon in the ocean, liberally estimated at 10^5 yr (Kump, 1991). The negative excursion associated with the Ghaub glaciation, requiring an estimated minimum duration of 9.2 m.y. for 125 m of net thermal subsidence, exceeds the predicted time limit by two orders of magnitude.

So what remains? Sherlock Holmes's dictum—that when all other hypotheses fail, the one that remains must be true—is not always appropriate in science because not all possible hypotheses are known. In this instance, however, we believe that one of the contending hypotheses, with more

Global Glaciations *continued on p. 8*

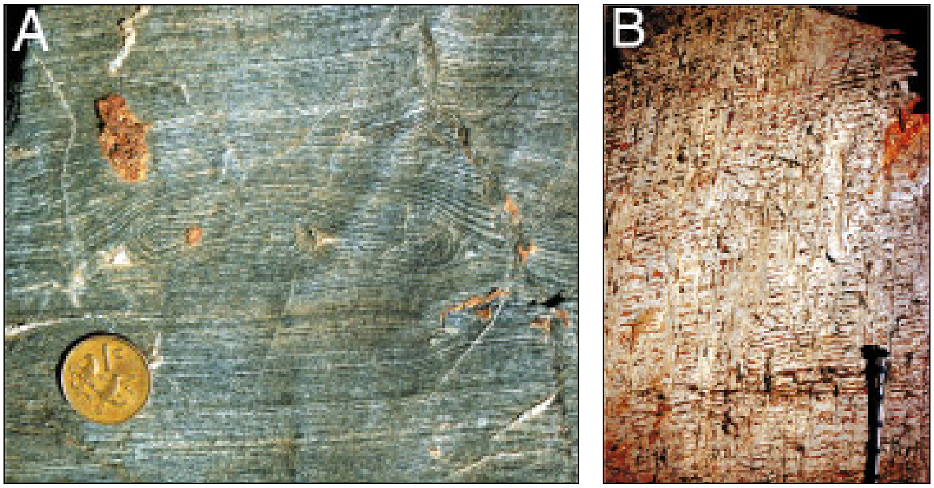

Figure 6. Unusual lithologies in postglacial cap carbonates. A: Microbial roll-ups in middle Rasthof cap carbonate (2-cm-diameter coin). B: Vertical "tubes" in basal Maieberg cap carbonate (10 cm scale divisions).

Global Glaciations *continued from p. 7*

elaboration than is possible here, provides a satisfactory explanation consistent with the data (Hoffman et al., 1998). Whether or not Agassiz's (1840) vision of panglacial catastrophes is valid for the Neoproterozoic, Namibia teaches us that Agassiz was correct when he said, "If you learn about Nature in books, when you go out of doors you cannot find Her."

ACKNOWLEDGMENTS

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Coastal Sediments '99 Conference Calls for Abstracts

Abstracts are due *May 11, 1998*, for the Coastal Sediments '99 conference to be held June 20–24, 1999, on Long Island, New York. Scales of Coastal Sediment Motion and Geomorphic Change is the theme of the conference; GSA is a co-sponsor.

The address for submittal of abstracts (five paper copies) is: William G. McDougal, Co-Chair, Coastal Sediments '99, Dept. of Civil Engineering, Oregon State University, Corvallis, OR 97331-2302. For further information: Nicholas C. Kraus, USAE Waterways Experiment Station, Coastal & Hydraulics Lab. (CEWES-CC), 3909 Halls Ferry Rd., Vicksburg, MS 39180-6199, or http://www.coastalsediments.org.

A GSA Committee May Need You

Steve Stow, *Chair, 1997 Committee on Committees*

Perhaps you feel that if you nominate someone for a GSA committee, your nomination goes into a black hole, or is lost among hundreds of other nominations submitted when the Society annually calls for members to serve on committees, as it does in this issue of *GSA Today.* And if you were to volunteer for a committee assignment, your offer wouldn't be taken seriously, would it?

The reality is that there is no black hole, and every nomination for committee service is considered carefully.

The reality is also that since 1990, the number of volunteers for committee service has dropped from 50 per year to an average of 30 and that the number of members nominated for appointment has varied annually from a low of 16 in 1996 to a high of 75 in 1993; the average is 39 per year. Since 1992, the number of appointees to GSA committees has been highly variable, from zero to more than 20. The 1997 Committee on Committees, relying heavily on nominations and volunteers, selected 12 of the 29 volunteers and 12 of the 34 nominees for service on GSA committees.

For many reasons, it is not possible—or even advisable—to use only names of volunteers and nominees in making committee assignments. Many factors, including experience, geoscience discipline, geography, prior GSA experience, and minority representation, go into the selection process. The Committee on Committees draws on names of individuals considered but not selected by the previous committee, as well as its own personal knowledge of qualified candidates, in getting a slate that is truly representative of the GSA membership and qualified to perform the functions of the varied committees. It is a full day's job (after a lot of preliminary work) to arrive at the final list of candidates to be presented to the GSA Council for approval, an indication of how carefully each volunteer and each nominee are considered.

If your name, volunteered or nominated, comes before the 1998 Committee on Committees and is not selected, don't lose hope—try again next year. The simple fact that someone wants to devote some of his or her time to helping GSA, or the fact that one member feels strongly about nominating another, goes a long way in elevating that person's chance of being selected.

Graduate Students Encouraged to Volunteer!
Graduate students are now eligible to serve on GSA Committees as full members. All graduate students are encouraged to volunteer or nominate others for committee service.

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Rock Stars

Norman L. Bowen: The Experimental Approach to Petrology

H. S. Yoder, Jr., *Geophysical Laboratory, Carnegie Institution of Washington, Washington, DC 20015, yoder@gl.ciw.edu*

The greatest petrologist of the 20th century is clearly Norman Levi Bowen (1887–1956). He promoted the solution of petrological field problems by the application of principles deduced from simple phase diagrams of the end members of common rock-forming minerals, thereby providing a quantitative approach to a field previously concerned only with observation and classification. Despite his quiet personality, subdued presentations, droll sense of humor, and even his small stature, he was a giant.

Work and Play

As a youth, Bowen helped his father in the family bakery, driving the delivery rig—an experience that resulted in his enduring distrust of horses. Winters were spent ice skating, and during the summer months he became a strong breast-stroke swimmer and took part in races. He sang in the choir of the local Anglican church and is alleged to have had a fine tenor voice.

The Field Experience

Public schools in Kingston, Ontario, had prepared him for college entrance examinations at Queen's University. Even though registered in the arts course with the intent of becoming a teacher, Bowen had the urge, as many young people do, to see new and alluring country and to earn some money. He joined an Ontario Bureau of Mines geological mapping party to Larder Lake under the leadership of R. W. Brock. Brock, who was an outstanding personality and eventually became Director of the Geological Survey of Canada, had so much confidence in Bowen's inherent abilities, in addition to his skills for surviving in the bush, that he left the young man to carry out the work alone! Travel in the bush was by canoe, and traversing in search of outcrops was done under a blanket of mosquitoes and black flies. Bowen could use an axe and tump line, make pace-and-compass surveys, and cook. In the course of his mapping, he became interested in the differentiation of diabase.

Courses Chosen

As a result of his field experiences, when he returned to Queen's University, Bowen registered in the School of Mining, taking mineralogy and geology. After two more field seasons around Lake Abitibi and Gowganda Lake, again paying attention to the diabases, he won a prize of $25 and the President's gold medal from the Canadian Mining Institute for the best paper submitted by a student: "Diabase and aplite of the cobalt-silver area." (See 1956 edition of Bowen [1928] for references to his published works.) Trained in the Canadian bush on the myriad of variables in natural geological processes, he had rapidly absorbed the principles of geology and chemistry. On graduation in 1909, he won a London Exhibition of 1851 Scholarship, which gave him the opportunity to continue on in graduate school.

Norman L. Bowen on his first job involving land surveying.

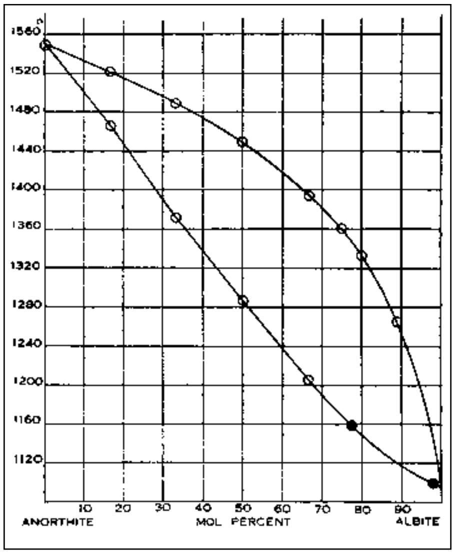
Charismatic Teachers

He was first attracted to Norway because of J. H. L. Vogt's (1903–1904) book, *Die Silikatschmelzlösungen* and by W. C. Brøgger, who had applied physicochemical principles developed in the investigation of slags to the problem of differentiation. Bowen was discouraged, however, from going to Norway because of the language barrier and because Brøgger was too busy with legislative duties. Instead, Bowen went to MIT to study under the sparkling and charismatic teacher Reginald A. Daly, who indoctrinated him with the idea that basaltic liquid was a primary magma and all others were derivative. He also introduced Bowen to some of the possible causes of differentiation, such as diffusion, fractional crystallization, crystal segregation, gaseous transfer, immiscibility (liquation), and assimilation. Probably Charles H. Warren imbued Bowen with the principles of physical chemistry as applied to mineralogical and petrological problems. It was clear that he had already focused on igneous differentiation and the principles of physical chemistry.

The Experimental Experience

In 1910, at the suggestion of T. A. Jaggar, then at MIT, Bowen applied to the Geophysical Laboratory at the Carnegie Institution of Washington to do an experimental study related to a geological field problem for partial fulfillment of the requirements of the Ph.D. As the laboratory's first predoctoral Fellow, he was assigned the "nephelite problem," a favorite topic of J. P. Iddings. At that time, most of the experimental techniques for high temperatures used today were all in their early stages of development. The controllers for the high-temperature furnaces were very large street-car-type banks of resistor coils; platinum-rhodium thermocouples had just been calibrated to 1755 °C by Day and Sosman (1911); the quenching method had just been invented by Shepherd, Rankin, and Wright (1909). Wright (1910) had perfected a new petrographic microscope for examining fine-grained synthetic preparations. Particularly important was the development of a calculation scheme for translating the chemical analyses of rocks, whether crystalline or glassy, into a set of end-member minerals, the CIPW normative system (Cross et al., 1902), that could be simplified for laboratory experimentation. In addition, the theory of solid solutions had been laid out by H. W. Bakhuis Roozeboom (1901). In short, Bowen arrived at a most opportune time to do the nepheline-anorthite system—all the tools and theory were in hand. The nepheline-anorthite diagram was determined with considerable efficiency with 17 different mixtures and 55 quenching experiments under the tutelage of E. S. Shepherd and F. E. Wright. That simple system, the first example found in silicates of solid solu-

The courtship of N. L. Bowen and Mary Lamont, a medical student in Boston.



The plagioclase phase diagram, with temperature in °C and the seven new synthetic and two natural anorthite-albite compositions studied, indicating the liquidus (upper curve) and solidus. The melting point of anorthite was already well established and used as a point for thermocouple calibration.

tion combined with polymorphism, generated in Bowen's mind a much larger picture. While writing his thesis he also managed to produce in 1912 a paper of lasting value, "The order of crystallization in igneous rocks." With this publication at age 25, Bowen had introduced the precursor to a major change in the approach to petrology.

Career Decision

In the summer of 1911 Bowen was in the field again with Reginald Daly, surveying the Shuswap terrane of British Columbia, famous for its crosscutting granites and wholesale injection. In spite of his absences from Boston, he managed to court Mary Lamont, and they were married on October 3, 1911. Upon graduation from MIT on June 4, 1912, he had offers from Jaggar, then at the Volcano Observatory in Hawaii, for a post in economic geology at Tucson, for a position at the Geological Survey of Canada, and for the job of assistant petrologist at the Geophysical Laboratory. After another field season in British Columbia, in charge of his own field party, he decided to join the Geophysical Laboratory staff, arriving September 1, 1912 (Yoder, 1992).

Critical Mineral Systems

Plagioclase is the most abundant mineral in Earth's crust, so Bowen next undertook a study of the two-component system albite-anorthite. That system, studied earlier by Day, Allen, and Iddings (1905), was the subject of the first official publication of the Geophysical Laboratory. They had been able to determine the melting temperature only from An_{100} to $An_{26.1}$ $Ab_{73.9}$. Kinetic problems prohibited their measuring the solidus temperature with the cooling-curve method, even though they recognized the system as one of the Roozeboom theoretically possible types, with continuous solid solution containing neither a maximum nor minimum. With the quenching method and run times of only 1/2–2 hours, Bowen was able to generate the entire plagioclase diagram, well documented with later studies. It provided the basis for his subsequent views on magma differentiation and crystal fractionation, both old ideas (Scrope, 1825; Becker, 1897) but lacking experimental demonstration.

A New Integrated Approach

Several alternatives for the processes leading to magma diversity had already been presented and explicitly summarized by Iddings (1892). But Bowen set out his prejudices forcefully and clearly in 1915 in two papers after studying only two more, yet most critical, phase diagrams illustrating the reaction principle. One paper, "The later stages of the evolution of igneous rocks," provided a flexible, broad theory based on quantitative experimental observations that he defended with rigorous argumentation. As a result of his incredible perceptiveness and intuition, Bowen had integrated all the new experimental methods, physicochemical theory, and field observations into a unified new approach to petrology. It was his clarity of presentation, documentation of principles with experimental demonstrations, and application to specific field problems that eventually made his 1928 book *The Evolution of the Igneous Rocks,* the handbook for petrologists worldwide. It was with some reluctance that field geologists eventually accepted Bowen's philosophy as leading to the most satisfactory interpretation of the facts as they were perceived by geologists: (1) recognition of a set of field observations that appear to be related; (2) simplification of these relations into a set of laboratory experiments analogous to the conditions believed to have existed in nature; (3) execution of those experiments in an unambiguous manner; (4) application of the principles derived from the experimental results to specific field occurrences; (5) reexamination of the field relations and testing the new principles with additional observations; and (6) reiteration of the above sequence until a satisfactory solution is achieved, recognizing that any new observation or inconsistency may initiate the process again.

Successful Philosophy

After half a century, it is clear that his philosophy had been successful even though new interpretations of the details were required (Yoder, 1979). Bowen's legacy, in addition to the many accurate and precise phase diagrams of the end members of common rock-forming minerals, is the construction of an experimental and theoretical basis for the interpretation and documentation of the diversity of igneous and metamorphic rocks.

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Walcott Biography To Be Published

GSA original Fellow and 13th president Charles Doolittle Walcott is the subject of a biography by Ellis L. Yochelson; it will be published in June. Yochelson's Rock Star profile of Walcott, a famous paleobiologist and biostratigrapher, was in the January 1996 issue of *GSA Today.* The book covers Walcott's life from birth in 1850 until 1907, when he resigned as third director of the U.S. Geological Survey to become secretary of the Smithsonian Institution.

The book is available from Kent State University Press, P.O. Box 5190, Kent, OH 44242 **(not available through GSA Publication Sales)**. *Charles Doolittle Walcott, Paleontologist* is available at the prepublication price of $40, including postage and handling, for a limited time (after July 31, 1998, the price will be $53). All orders must include payment and the title of the book; Ohio residents add 6.25% sales tax.

SAGE REMARKS

Edward E. "Dr. Ed" Geary, Director of Educational Programs

GSA Educational Programs: What Are We Doing and Where Does the Money Come From?

Last year I used this column (*GSA Today,* February 1997) to look back at the evolution of GSA's educational programs over the past five years. This year I want to use this opportunity to update you on the status of some of our current programs and let you know how we fund our education and outreach activities. Please read this article, let us know what you think of our efforts, and contact us if you would like to learn more about or become more involved in geoscience education activities.

What Are We Doing?

Programs

The **Partners for Education Program** (PEP) promotes and supports professional partnerships between geoscientists and K–12 educators both in formal and informal settings. In 1997, PEP was busy:

- Growing! PEP now includes 1,700 volunteers in all 50 states and more than 60 international associates; these Partners volunteer in formal classroom settings and in a wide variety of informal settings such as museums, parks, science fairs, special science events, and field trips, to help share the excitement of the geosciences.
- Expanding! Although we're growing by the day, at last count 470 PEP e-mail Partners and 97 PEP Experts are also signed up to help answer questions in their own specialties for each other, students, other educators, and the public.
- Reaching out! Through PEP, we are collaborating with a variety of local, regional, and national groups to reach a broader segment of the public. For example, 10 PEP members volunteered their expertise at the Geology Merit Badge booth at the 1997 Boy Scout Jamboree. We are also expanding our outreach through programs such as Rooted in Rock (in collaboration with the National Park Service) and GeoArt (in collaboration with local governmental agencies) both described in the Informal Education section below.
- Supporting! Our second annual Project WET (Water Education for Teachers) workshop at the 1997 GSA Annual Meeting in Salt Lake City drew a lively crowd of scientists, classroom educators, informal science educators, and graduate students, all eager to refine their professional partnering skills. We offered support to scientist-teacher workshops hosted by PEP members. We also offer membership incentives such as low-cost U.S. Geological Survey maps and a listing of all state science supervisors and how to reach them. We are collecting an anthology of PEP members' favorite "educational geoscience places."
- Communicating! Our quarterly PEP News keeps PEP members up to date on geoscience educational resources, activities, opportunities, and each other's experiences. We update and distribute our national PEP Membership Directory each spring.
- Appreciating! We are happy to award year-end certificates to express our thanks to our wonderful PEP members.

The **Geological Education Through Intelligent Tutors** (GET-IT) project is now in its third year. GSA, in collaboration with Cambrian Systems Incorporated, is currently beta testing an interactive, multi-media, geoscience CD-ROM for middle school students. The CD-ROM introduces students to scientific investigations of Earth through visits to a virtual Geoscience Museum. The focus of student investigations is energy transfer in the Earth system. Students visiting the museum can conduct rock-melting experiments, learn about pressure, temperature, and volume relationships, study historic volcanic eruptions and make predictions about future eruptions, analyze hurricane storm tracks, and a variety of other activities. When the students finish a series of investigations and experiments, Throbby the Brain and Professor Exactamundo, two high-energy characters, reinforce the key learning concepts of each lesson through a set of short, engaging animations. Students use real data in carrying out their GET-IT investigations, and at the same time they develop their mathematics and writing skills.

In 1997, GSA, in collaboration with Cypress College and the Space Science Institute, conducted two summer workshops, each two weeks long, for the **Earth and Space Science Technological Education Project** (ESSTEP). This four-year project brings together teams of undergraduate and secondary faculty with professional societies, businesses, and government agencies in a partnership to provide faculty in grades 8 through 14 with (1) hands-on experience in state-of-the-art data acquisition, manipulation, and presentation technologies for the earth and space sciences; (2) innovative strategies for using technology in classrooms and laboratories; (3) internship opportunities in earth and space science technology fields; and (4) improved access to a wide variety of technology-based education resources. Over 40 geoscience, geography, biology, mathematics, astronomy, and technology faculty participated in the 1997 workshops. Faculty and staff continue to work together during the 1997–1998 school year, on project goals via Tapped In, an on-line professional development tool that supports both synchronous and asynchronous forms of communication. The first-year project participants will come back to Boulder in 1998 to share their initial classroom ESSTEP experiences, advance their technological knowledge and skills, and develop strategies to share their ESSTEP experiences and materials with others. The next two ESSTEP workshops, for 40 new faculty, will be held July 6–18 in Cypress, California and July 27–August 8, 1998, in Boulder, Colorado. ESSTEP and GET-IT are supported in part by grants from the National Science Foundation.

Meetings and Workshops

The K–16 Education Program at the 1997 **GSA Annual Meeting in Salt Lake City** was outstanding in both the variety of offerings and the quality of presentations. Workshops were offered on the solar system, marine geology, the fossil record, Project WET, mapping and spatial analysis, grant writing, and effective teaching. Educational symposia and theme sessions ranged from "Engaging the National Science Education Standards" to "Earth System Science Laboratories for Introductory Undergraduate Courses" to "Earth Science Education for Pre-Service Teachers." The third Rock and Mineral Raffle and the fifth Earth Science Share-a-Thon, co-sponsored by the National Earth Science Teachers Association (NESTA), attracted many curious scientists, students, and teachers. Several workshops and field trips for K–16 educators and scientists were also held at GSA's 1997 Section meetings. In 1997, we also conducted "standards-based" workshops on plate tectonics and ESSTEP at the Western Regional Meeting of the National Science Teachers Association.

Informal Science Education Programs

A major advancement for the **Colorado Rock Park Project** in 1997 was the selection of a location for the two-acre outdoor exhibit. After consideration of approximately 15 different sites, we have chosen a site in Fort Collins, a city within the Denver–Front Range metropolitan area, approximately 50 miles north of Denver. The site is easily accessible and will be part of a new outdoor Environmental Learning Center. The Fort Collins site will also include a new visitor center with classrooms, nature trails, interpretive programs, and tourist information. This chosen location also brings dynamic partners into the Rock Park project: the city of Fort Collins, Colorado State University, Colorado State Parks, and the

Fort Collins Convention and Visitors Bureau. As part of developing the Rock Park from a concept to a more detailed plan, GSA has fostered many new collaborations with industry, state government offices, and other Colorado educational institutions. Project development, sample collection, and fund-raising will be the focus of the Rock Park activities in 1998.

Rooted in Rock is a proposed five-year initiative to increase geologic and earth systems interpretation in the national parks. Rooted in Rock will serve visitors with: (1) current, accurate geologic information informed by relevant research; (2) geologic information and interpretation directly tied to the features and processes observable in the park; (3) interpretation that connects geology with other natural and human systems; and (4) interactions with park staff who are well informed on the park's geology and how it relates to the park's other natural and human systems. A funding proposal for Rooted in Rock was submitted, in cooperation with the Geologic Resource Division of the National Park Service, to the National Science Foundation in November 1997. We are also pursuing other options for funding the program.

GeoArt will help people examine geologic information and concepts through art. The program builds on common ground between art and geology, such as the strong use of observation and interpretation in both fields, and the importance of frameworks such as pattern, scale, and change in both fields. Participants will produce their own artwork while they learn about local geologic features and processes. A materials grant of $200 from the Boulder County (Colorado) Commissioners funded two GeoArt training workshops in March 1998, for interpretive staff and volunteers for parks and open-space properties in GSA's headquarters community. The workshop participants will choose from several opportunities to present their own GeoArt sessions for the public soon after their training in order to gain experience and comfort with GeoArt techniques. Future plans include models for disseminating GeoArt into other communities and into informal and formal educational settings such as youth groups, adult learning, and K–12 classrooms.

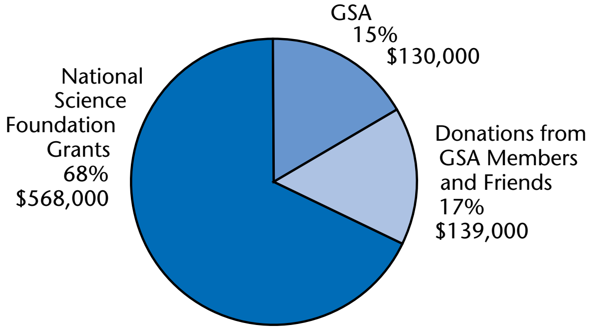
Collaborative Efforts

SAGE has been and continues to be very active in collaborative efforts with other organizations. In 1997 SAGE collaborations included:

- Representation on the Program for the Advancement of Geoscience Education (PAGE), American Geological Institute (AGI), and Project Learn II Advisory Committees.
- Continued participation in Professional Career Pathways in the Geosciences, a careers project coordinated by AGI and supported by the Alfred P. Sloan Foundation.
- Working with CONNECT, the Colorado statewide systemic initiative in mathematics and science.
- Participation in the Second International Conference on Geoscience Education, cosponsored by the Coalition for Earth Science Education (CESE).
- Financial support of the National Association of Geoscience Teachers Outstanding Earth Science Teachers Award.
- Working with national environmental education programs such as Project WET, Project WILD, and Project Learning Tree to promote K–12 geoscience education partnering between geoscientists and educators.
- Collaborating with groups such as the American Association of Petroleum Geologists, the Big Horn Basin Foundation, the Alabama Geological Survey, and many more to support PEP members' efforts in a wide array of settings, from classrooms to scouting groups to paleontology workshops for teachers to a multistate excursion integrating geology, botany, and cultural history for Puerto Rican university and K–12 educators, and much more.
- Strengthening our collaboration with the National Park Service and initiating programs that will bring improved and expanded geologic interpretation to national park visitors.
- Strengthening communications and cooperation with the American Indian Science and Engineering Society, also headquartered in Boulder.
- Preliminary planning with the Mineralogical Society of America, the Geochemical Society, and the USGS to develop Web-based learning modules for high school students and teachers.
- Meeting with AGI, AGU, NAGT, and NESTA representatives to discuss concerns and issues in geoscience education outreach.
- Advising the USGS on development of teacher-support materials for their Dynamic Planet Map project.

How GSA Educational Programs Are Funded

1997 Total = $837,000



Information Dissemination

During 1997 GSA Educational Programs handled 1,350 requests for information from students, teachers, scientists, and organizations on topics ranging from earthquakes, crystals, and National Science Education Standards, to careers in the geosciences, internship opportunities, and awards. In 1997, we continued to offer education and career information request forms that can be accessed and submitted electronically via the GSA World Wide Web site.

1997 Educational Programs Staff

All of these activities would not have been possible without the support of our wonderful staff. Special thanks to Beth Baker, Beth Ann Brown, Holly Devaul, Vicki Harsh (now at U.S. West in Denver), Liz Knapp, Gwenevere McNally, Barb Mieras, and Van Schoales (now headmaster at Jarrow Montessori school in Boulder).

Where Does The Money Come From?

Funding for our education and outreach activities comes from a variety of sources (see pie chart). These sources include government agencies such as the National Science Foundation, corporate and private foundations, members, and GSA's operating budget. As you can see, in 1997, our total educational program budget was $837,000. Of this total, 68% of our funding came from the National Science Foundation, 17% came from corporate and private foundations and member gifts, and 15% came from GSA's operating budget.

It is worth noting that GSA now spends less of its operating budget on educational programs than it did in 1992, the first full year of educational program activities. At the same time, the overall scope of our educational activities has grown dramatically. Our education budget is more than five times what it was in 1992 and our staff has tripled in size. Our reliance on outside funding gives us both a sense of pride and concern. We are proud that the vast majority of our programs and staff are funded by non-GSA sources. We feel that we are making good use of GSA's contributions to education activities and making your dollars go farther. However, owing to our reliance on outside funding for many of our programs, the future of some programs, such as PEP, are uncertain as outside funding sources disappear.

In 1998 we will be integrating our Educational (SAGE) and Institute for Environmental Education (IEE) program departments to provide a more seamless set of outreach programs for students, teachers, GSA members, policy makers, and the public. We will also be assessing the value of individual projects and activities, discussing issues of long-term program sustainability, and aligning our program goals and objectives with the new GSA strategic plan, currently under development. ■

LETTERS

CO_2 Source or Sink

In reference to the report from David J. Verardo, "Forests as Carbon Sinks" (*GSA Today,* v. 8, no. 2, February 1998), it is heartening to see a GSA congressional fellow getting geology into this important topic. I would point out, however, that while the process of CO_2 fixation by photosynthesis is a no-brainer, *net* carbon storage (sink/source for the atmosphere) is the *balance* of photosynthesis/production and decomposition/burning. In a recent paper in *Science* (Goulden et al., v. 279, p. 214, January 9, 1998), a diverse team of scientists discovered an unexpected conundrum: even a boreal forest with vast amounts of biomass and soil carbon can become a CO_2 source in some years and a CO_2 sink in other years. The underlying cause for the C imbalance in this system was oxidative decomposition; the soil carbon flux was found to completely offset plant production in years that proved favorable to decomposition. Although the permafrost was likely a key player in the CO_2 release in this study, many forests suffer the same fate: all but the youngest of landforms (Harden et al., *Science,* v. 258, p. 1921) have enough soil carbon to contribute significant amounts of CO_2 from decomposition. Although the coarse wood growing in trees is a temporary C sink, the wood entering the soil becomes a C source within decades of tree death. Additionally, all forests and their carbon reserves are vulnerable to fire—anywhere from 20% to 80% of biomass is lost to stand-killing fires; therefore depending on recurrence times and moisture-dependent fire losses, the apparent C sink term is reduced considerably over any reasonable spatial scale. To further complicate the picture, the fire and decomposition terms are inexorably tied to the very climatic trends that we strive to mitigate.

Under what conditions would we expect a long-lived (≥100 year) sink of CO_2? (1) Retardation of decomposition: submergence, freezing, burial, and high lignin contents work well; (2) landscapes where plant production is greater than decomposition, a situation that occurs on newly created landscapes such as fresh deposits or recent landslides. Of course, the fate of the eroded carbon must also be considered for an accurate portrayal of the net C balance. Under condition 1, the creation of wetlands would foster carbon sequestration, but possibly at low production rates unless fertilized. Under condition 2, forests will work as temporary C sinks, but longer-term solutions reside in soil conditions less favorable (wet, cold) to healthy forests.

Thus, the conundrum continues for terrestrial ecology: what are the interactions and trade-offs between plant production, N and CO_2 fertilization, decomposition, and fire, and how do the interactions change under changing land management and climate? These questions are *unresolved* in the scientific community, and the solutions are likely to be as complex as the systems.

Jennifer Harden
U.S. Geological Survey
Menlo Park, CA 94025

G. K. Gilbert

The accolade for Rock Star G. K. Gilbert by Bourgeois (*GSA Today*, February 1998, p. 16–17) expressed beautifully what an exceptional thinker and doer Gilbert was....

Gilbert's 1896 publication on the underground water of the Arkansas Valley in eastern Colorado devoted equal space to stratigraphy and underground water. Although plagued by too little information, he courageously put lines on a map showing depth to water, saying "I confess that I have drawn this map with great reluctance" (Agnew in E. Yochelson, *The Scientific Ideas of G. K. Gilbert*, GSA Special Paper 183, p. 81–91). He recommended experimental borings, as his report was a practical one that was intended for local residents (nongeologists).

... Gilbert was a true Rock Star—a century before we rediscovered the value of making our geologic reports speak to nongeologists as well as to the choir.

Allen F. Agnew
Corvallis, OR 97330

Mapping

As the director of a state geological survey I am pleased to see the support for detailed geologic mapping expressed by independent geologists such as John Trammell (*GSA Today*, February 1998, p. 14) in his comment on the letter by Rowley, Dixon, and Stevens (*GSA Today*, October 1997, p. 17–19) which describes the National Cooperative Geologic Mapping Program. From his comments, I surmise that Trammell would be more supportive of this program if some of the funds were used to support contract geologists such as himself to conduct geologic mapping.

Since its inception, the Maine Geological Survey has received approximately $139,000 in support through the program for geologic mapping in Maine. Of that amount, about $99,000 (over 70%) has gone to contract mappers (consultants, college professors, and students). Many other state geological surveys can produce similar statistics. Those of us involved in the program recognize that the monumental task of geologically mapping the nation in detail cannot be accomplished solely with the capabilities of government agencies. We greatly value and rely on the expertise of independent geologists in accomplishing the goals of the program.

The National Cooperative Geologic Mapping Program has accomplished much since it was first passed by the Congress in 1992 and unanimously reauthorized in 1997. But to accomplish the task of mapping the nation, the program requires full funding. The products of the program can stand on their own merits, but without political action from both the geological and map-user communities there is only a small chance that full funding will be achieved. I urge you to contact your congressional representatives and urge them to fully fund the National Cooperative Geologic Mapping Program.

Robert G. Marvinney
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Ediacara Biota

"The Ediacara Biota" [*GSA Today*, February 1998, p. 1–6] was an outstanding article! It covers a subject quite outside my field (petroleum), but one in which I have always been interested. Guy Narbonne's review was understandable, comprehensive, well illustrated, and greatly appreciated. Articles like that have me looking forward to my issues of *GSA Today*.

Duncan Goldthwaite
Metairie, LA 70006-1032

Tribute to John Mann

As one of Southern California's most senior hydrogeologists, Dr. John Mann [see *GSA Today,* January 1998, p. 1; April 1998, p. 11] brought a valuable perspective to the students he taught, the clients he served, and the issues at hand. His teaching skills were often helpful when complex groundwater conditions needed to be understood—such as comparing ground-water flow velocity to the speed of a snail (we all have seen the "tortuosity" of snail tracks). Only with the rich experience Dr. Mann had gained could one be able to give appropriate assessments of ground-water availablility during reconnaissance level investigations. He had a healthy respect for good data and thorough analytical procedures, while not relying too much on simulations where unspoken assumptions control conclusions. His "safe yield" treatise, prepared over twenty years ago, is still an excellent reference.

John was a pleasure to work with. I enjoyed engaging in dialogue on critical resource issues as well as comparing notes on our travel experiences. His and Carol's travels yielded many beautiful Christmas cards.

We will miss him. His work will stand the test of time.

Timothy S. Cleath
Cleath & Associates
San Luis Obispo, California ■

Death on the High Seas

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

It isn't always about science policy.

In the pre-dawn hours of November 24, 1995, in storm-tossed seas northeast of New Zealand's North Island, a Korean freighter rammed and sank a U.S.-registered 47-foot cutter-rigged sloop. The vessel sank in less than 60 seconds. Aboard the yacht were an American couple and their two young children. Forty-two hours later, the sloop's inflatable raft washed ashore carrying a lone, badly injured survivor.

This story began in 1994 when the couple, along with their nine-year-old son and seven-year-old daughter, went on an extended break from their careers to sail throughout the Pacific. At 1200 hours local time on November 16, 1995, the yacht left Nuku'alofa, Tonga, on a passage to the Bay of Islands, New Zealand. She was part of a flotilla of eight sailing vessels that were headed south to avoid the approaching typhoon season. The passage would take eight days. The forecast on November 23 called for deteriorating weather with gusty winds and squalls. With the mainsail doused and the staysail rigged, the sloop sailed well, making six knots and barely rolling. There were scattered showers, visibility between five and seven miles, and no moon.

At 0200, the wife relieved her husband on watch. About 15 minutes later, a large shape loomed out of the rain and, in a series of bone-jarring hits, sealed the vessel's fate. Within seconds, the vessel's cabin filled with water. The wife, who had been knocked to the deck, was trying to regain her footing when her husband and daughter emerged from the cabin below. Those on deck abandoned the stricken vessel for the inflated raft trailing astern on a 15-foot sea-painter line. The wife and daughter climbed aboard first; the father tried to rescue his son below deck but flooding seas forced him back to the raft. The sloop slipped beneath the waves and left the three in stunned silence. Their anguish was interrupted moments later when a wave capsized their life raft. The family managed to right the raft only to have it overturned again by another wave. This occurred repeatedly, so they decided to leave the raft inverted and hold fast to the painter. At one point during this desperate struggle, a large vessel's navigational lights were recognized moving away from their position.

The three survivors held on for their lives. Hours passed. Though the water was 68° F, the relative warmth merely slowed the weakening effects of hypothermia. The morning of November 24 saw a gray dawn with winds blowing at 40 knots and seas running 14 feet. At about 1100 hours, a large wave rolled the raft and the family lost hold of the painter. The wife quickly regained her grip but her daughter and husband drifted away. They tried to regain the raft but were unable. Both drowned within her sight.

At 2000 hours on November 25, after 42 hours at sea, the life raft and its sole passenger washed ashore on rocks near Cape Brett. While scrambling onto the rocks, the woman slipped and fractured two vertebrae. Paralyzed from the waist down, she crawled onto the beach. Several hours later she was rescued when search aircraft, alerted by overdue notices from other vessels in the flotilla, spotted the raft. Her suffering was not over, though. Now, bureaucracy would torment her.

When the sole survivor of the shipwrecked family sought economic recovery from the owners of the Korean vessel, she was stymied because of an arcane U.S. law called the Death on the High Seas Act (DOHSA). The original law was enacted in 1920 to allow recovery for the wrongful death of seafarers occurring outside the three-mile territorial waters of the United States. The right to recover is limited to the decedent's wife, husband, parent, child, or dependent relative against a vessel, person, or corporation. This right is further limited to monetary damages such as economic losses suffered as a result of the death, loss of services, loss of inheritance, and funeral expenses. Recovery for pain and suffering, mental anguish, or punitive damages is not allowed. The U.S. Senate is now considering legislation (i.e., S.943) to amend DOHSA; this was prompted not by shipwrecks, but by the 1996 crash of TWA Flight 800 off the coast of Long Island, New York.

The application of DOHSA to aviation disasters began with a court case in 1972 involving the crash of a corporate jet into the waters of Lake Erie; the jet had struck a flock of gulls upon takeoff. In that case, the court declined to apply DOHSA because it ruled that the flight was essentially land-based, even though the crash occurred in navigable waters. In a footnote to the decision, however, the court stated that a wrongful death action stemming from an aviation disaster, occurring beyond a maritime league (e.g., three miles) from the shore of any state, could be prosecuted under the provisions of DOHSA. Subsequent cases involving aviation accidents have ruled DOHSA applicable.

The bill before the U.S. Senate specifies that remedies provided under DOHSA that are applicable to aviation accidents occurring on or after January 1, 1995, shall not supersede common laws or state law remedies. The bill would retroactively amend DOHSA to remove the arbitrary distinction between remedies available for aviation disasters occurring within three miles of the coast (currently subject to state tort law) and those occurring outside the three mile limit (currently subject to DOHSA). As introduced, however, S.943 would create another arbitrary distinction in the treatment of wrongful death actions between aviation and maritime disaster claims. In the bizarre, though not incredible, instance of an aviation disaster occurring on the high seas (i.e., beyond three miles of the coast) that also causes loss of life onboard a recreational vessel, the relatives of those traveling on the plane would be subject to state tort and able to secure nonpecuniary damages, while those onboard the recreational vessel would be restricted to DOHSA. Discussions in the Senate Commerce, Science, and Transportation Committee may remove these arbitrary distinctions and create a more inclusive law that allows recovery of damages for victims of accidents that occur at sea. Although money does not bring back the dead, it does help survivors endure. To date, the surviving woman's case has not come to trial, and she remains emotionally and physically disabled by her experiences and injuries.

This case provides a working example of the intricacies of public policy formulation. What is a solution for one group is a problem for another. More often than not, public policy, like science, changes at the edges, incrementally. Only occasionally does a comprehensive shift occur in core values or conventional wisdom as a result of a single event or discovery. If you believe that the goal of government is to protect and improve the life of its citizens, then stark case histories provide the basis for action. Creating public policy is not a clean, linear process. As Theodore Roosevelt remarked, "From the very beginning, our people have combined practical capacity for affairs with power of devotion to an ideal. The lack of either quality would have rendered the other of small value." Winning or losing on the policy front is often due less to persuasive argument than to the sheer breadth of competing interests across the social landscape. ■

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.*

Penrose Conference, January 18–24, 1999

Subduction to Strike-slip Transitions on Plate Boundaries

A Geological Society of America Penrose Conference, "Subduction to Strike-slip Transitions on Plate Boundaries," will be held January 18–24, 1999, in Puerto Plata, Dominican Republic. This location is within the active subduction to strike-slip transition area of the North America–Caribbean plate-boundary zone, so the conference will include a field trip along the primary strike-slip fault (Septentrional fault zone) within the plate-boundary zone. Shoreline features record recent activity of the offshore subduction boundary that included a magnitude 8.1 earthquake in 1946.

The meeting will assemble a multidisciplinary group of the world's leading experts from the United States, the Caribbean, New Zealand, Latin America, Europe, and other areas. The purpose is to foster discussion of new ideas and develop associations between ideas drawn from different disciplines in earth science. Talks and discussions will focus on a better characterization of the tectonic controls and deformational effects of subduction to strike-slip transition areas. Experts in geology, seismology, paleoseismology, geodesy, modeling of geological and geophysical data, and deep seismic imaging will discuss deformation at all levels in lithosphere and mantle of subduction to strike-slip transition areas. This information will provide insights into the seismogenic mechanisms for the large and commonly destructive earthquakes that affect these areas.

Paritcpants will focus on the manifestation of both tectonic styles in tectonically active areas including the Dominican Republic, Trinidad and eastern Venezuela, Panama and Costa Rica, the Scotia Sea, northern California, eastern Alaska, the western Aleutian arc and Kamchatka, Japan, Taiwan, the Marianas trench, New Guinea and Irian Jaya, New Zealand and the Macquarie Ridge, Indonesia, Thailand, Pakistan, and the Alpine-Mediterranean area. Experts on other transition areas or on non–site-specific modeling work are welcome as participants.

Discussion topics by keynote speakers and participants will include the following: (1) How is plate motion partitioned between outboard subduction systems and inboard strike-slip systems, and how do these features interact to produce the observed patterns of diffuse seismicity and active faulting? Is there any evidence for linked seismic events in the two systems? (2) Why are strike-slip to subduction transition areas characterized by deep trenches that are the sites of some of the world's largest gravity minima? (3) How does the behavior of subducted slabs in subduction to strike-slip transition areas affect upper crustal deformation in the transition region? What is the role of slab rupture at depth, interaction of two opposed slabs at depth, extension of subducted slabs, and completely detached slabs like the ones present in the mantle beneath the Dominican Republic? (4) What is the sedimentary and structural record of subduction to strike-slip transition along ancient plate boundaries? Is there a systematic and predictable progression of structures that indicates that such a transition has occurred? What clues from these ancient events can be used to better understand active boundaries? (5) What are the seismic and tsunami hazards associated with subduction to strike-slip transition areas? Can answers to tectonically related questions 1–4 above be used to better understand and perhaps reduce these hazards?

The conference is limited to 65 participants. We encourage interested graduate students to apply; some partial student subsidies will be available. The registration fee, which covers lodging, meals, field trips, and all other conference costs except personal incidentals, is not known at this time. Participants will be responsible for transportation to and from the conference. Further information on travel will be provided in the letter of invitation.

Co-conveners are: ***Paul Mann,*** Institute for Geophysics, University of Texas at Austin, 4412 Spicewood Springs Rd., Austin, TX 78759, paulm@utig.ig.utexas.edu, (512) 471-0452, fax 512-471-8844; ***Nancy Grindlay,*** Dept. of Earth Sciences, University of North Carolina, 601 South College Road, Wilmington, NC 28403-3297, grindlayn@uncwil.edu, (910) 962-3736, fax 910-962-7077; ***James F. Dolan,*** Dept. of Earth Sciences, University of Southern California, Los Angeles, CA 90089-0740, dolan@earth.usc.edu, (213) 740-8599, fax 213-740-0011.

Application deadline is **August 1, 1998.** Invitations will be mailed to participants by September 1, 1998. Potential participants should send a letter of application to Paul Mann (address above), including a brief statement of interests, the relevance of the applicant's recent work to the themes of the conference, and a proposed title of the presentation (oral or poster; poster preferred). ■

Penrose Conference, March 25–31, 1999

Mid-Cretaceous to Recent Plate-Boundary Processes in the Southwest Pacific

The southwest Pacific region provides a natural laboratory for the study of plate boundary processes, and many different concepts in relation to plate tectonics and orogeny have originated as the result of studies there. Yet in many respects the evolution of the southwest Pacific has remained a source of enigma and controversy. In the past decade there have been many advances in our understanding of plate boundary processes in the area including (1) discovery of active metamorphic core complexes in the Woodlark Basin, as the result of lithospheric extension during the transition from continental rifting to sea-floor spreading; (2) recent geophysical studies that outline the crustal and upper mantle structure of the central South Island of New Zealand—an ideal area for studying mountain-building processes at a transpressional plate boundary; (3) recent work in the Ross Sea, in the South Tasman Sea, and along the West Antarctic margin that permits more accurate reconstructions of Australia-Pacific plate motion since late Eocene time; (4) the discovery of active metallogenic systems that define important links between the active tectonic environments and ore deposition; and (5) the interaction between back-arc spreading and subduction as revealed by seismic tomography.

To discuss the implication of these results and related studies on the tectonic evolution of the region, as well as future research directions, a Geological Society of America Penrose Conference on "Mid-Cretaceous to Recent Plate-Boundary Processes in the Southwest Pacific" will be held March 25–31, 1999, at the Wilderness Lodge near Arthur's Pass, South Island, New Zealand. That location provides easy access to the active Australian-Pacific transpressional plate boundary, where we will examine, during two field trips, the effects of mountain building and active deformation processes.

Penrose Conference *continued on p. 17*

STUDENT NEWS AND VIEWS

Brian Exton, University of Texas at Austin

Student News and Views provides GSA membership with commentary on matters relating to undergraduate and graduate students in the geosciences. The Correspondent for Student News and Views welcomes comments and suggestions, sent to stumatts@geosociety.org.

To Seniors: *Titanic* Advice on Grad School and Life

So you are about to graduate! Let me be one of the first to congratulate you and wish you the best success in whatever you do next. If my guess is correct, you are probably headed in one of two directions—back to school for an advanced degree, or head-first into the sea of humanity. Unfortunately, the cap and gown you are wearing weigh about as much as the *Titanic*, so you're easily being pulled under. Your diploma, on the other hand, keeps you safely afloat. Hey, that piece of paper is worth something after all! Thanks to the last four years of training, your chances of survival look good.

Before long, however, the water gets a bit chilly. Many of you realize that for a career in geology, indeed for most of the sciences, a graduate degree is standard-issue survival gear. Graduate school, if we continue the analogy, is a lifeboat with room for only a few, rowing away at light speed. Those of you who sacrifice your worldly possessions to get on board know that you'll spend a good portion of your life working to get it all back. As you struggle into the boat and collapse in triumph, the rest of your classmates disappear into the roiling cauldron of life. Safe at last. But when you look around, many of the lucky souls in your boat are near exhaustion, and in some cases even attempting to jump overboard! Suddenly you're not so sure of your decision any more.

By now you should recognize yourself as someone floating along with the masses, or taking your chances in a dinghy. Not much of a choice, eh? But there is help out there if you know where to look. Along floats a book. Then a second, and a third. No, these are not geology texts. These books are survival guides from the first-class graduate student library on the promenade deck! O miracle of miracles!

For most of you, your small fortunes went down with the ship, but the first book can help you resuscitate your finances. *The Guerilla Guide to Mastering Student Loan Debt*, by Anne Stockwell (HarperCollins, $14) is an indispensable guide to the ins and outs of financing your education and, once completed, repaying your student loans. The author financed much of her own education, and combines personal experience with expert advice from attorneys, collection agencies, legislators, loan officers, and others. Unlike the hard-line positions you may get from your school or lender, this book recognizes the fact that educational finance is *big business* in America ($100 billion in student loans since 1990), and maintains that as a consumer of this product, you have certain rights in addition to your obligations. The title of the book itself should give you some hint of the captivating style in which it was written. You may also want to visit the author's home page (http://home.earthlink.net/~joegoode), which has links to a variety of related resources.

If you happen to have made it to the safety of a lifeboat, there's no sense in just drifting aimlessly in the dark. *Getting What You Came For: The Smart Student's Guide to Earning a Master's or a Ph.D.*, by Robert L. Peters (Noonday Press, $12), is a comprehensive guide not just to entering and surviving graduate school, but to *excelling* in it. Every aspect of the process, including the more mundane tasks such as selecting your thesis committee, are described in great detail. Although the book is written for a more general audience, Peters's Ph.D. was in fish behavior (he was adrift for a while, too), so his examples are very relevant. Take my word, reading this book can save you *months* of floundering through departmental politics.

For those of you beginning to send out an SOS (or CV), *To Boldly Go: A Practical Career Guide for Scientists*, by Peter S. Fiske, provides excellent suggestions on how best to compose your message. This book is published by the American Geophysical Union, and as such is geared particularly to geoscientists. There is a companion Web site (http://www.agu.org/careerguide) with ordering information. My undergraduate advisor sent a copy to me recently, knowing that in a few years I will begin a systematic search for employment (you can't avoid the whirlpool forever, although some of us are trying desperately). Networking, job searching, and current resources on the Internet are discussed, but the most helpful aspect of this guide is the half dozen case studies that provide sample strategies for different opportunities.

The three books that were saved for you today are priceless gems of wisdom. You should make a heroic effort to read at least one of them, depending on the situation in which you find yourself now. Follow their examples, and your chances of rescue, or in other words *employment*, will increase exponentially. Good luck, and bon voyage! ■

Penrose Conference *continued from p. 16*

The main themes of the conference are: plate reconstructions in the southwest Pacific: the record from marine magnetic anomalies; subduction-related mantle flow in the southwest Pacific: insights from seismic tomography; magmatic processes: subduction initiation, polarity reversals, and the interaction between subduction and backarc spreading; mountain building and destruction along the Indo-Australian-Pacific plate boundary; the transition from continental extension to seafloor spreading; and metallogeny: ore deposits in active tectonic environments.

Participation in the conference is limited to 60 people, and those attending will be selected to include a broad representation of disciplines. We encourage graduate students whose thesis research is relevant to the conference to apply; limited conference funds will be available to support some graduate students. The registration fee, which will cover lodging, meals, field trips, and transportation during the meeting, is not expected to exceed US$750. Participants will be responsible for transportation to and from the conference venue.

The application deadline is October 1, 1998. Letters of application should include a brief statement of research interests, the relevance of the applicant's recent work to the themes of the meeting, and the subject of any proposed presentation. Co-conveners are ***Suzanne Baldwin***, Dept. of Geosciences, University of Arizona, UA P.O. Box 210077, Tucson, AZ 85721, (520) 621-9688, fax 520-621-2672, baldwin@geo.arizona.edu; ***Gordon Lister***, Australian Crustal Research Centre, Dept. of Earth Sciences, Monash University, Clayton, VIC 3168, Australia; 61-3-9905-5761, fax 61-3-9905-5062, gordon@earth.monash.edu.au. Potential participants should send a letter of application to Suzanne Baldwin. Formal invitations and additional information regarding travel arrangements will be mailed to participants in early December 1998. ■

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.

The TIMSS Is Now To Begin To Improve U.S. Math and Science Education

"Earlier this month our country received a wake-up call. Our high school seniors ranked near the bottom in math and science achievement when compared with their peers around the world.… This must be a call to action for all of us."

—President Bill Clinton, March 16, 1998

"How can we expect our students to test well in math and science internationally when we do not even ask them to take challenging courses and rigorous tests throughout their middle and high school careers?"

—Education Secretary William Riley

In mid-March, President Clinton convened leaders from education, government, business, and the scientific community to discuss an appropriate national response to recent findings that showed U.S. twelfth graders lagged well below the international average in science and math. These findings come from the Third International Math and Science Study (TIMSS), released in late February by the Department of Education's (DOE) National Center for Education Statistics (NCES). The study was sponsored by the International Association for the Evaluation of Educational Achievement, a Netherlands-based organization of ministries of education and research institutions in its member countries. Each country participating in TIMSS paid for its own national data collection. U.S. participation in TIMSS was supported by more than $30 million from the NCES and the National Science Foundation.

The study included participants from all over the world. DOE asserts, "Never before has an international comparative survey of education been conducted on such a scale." Nine- and thirteen-year-olds, students in their last year of secondary school, teachers, and the administrators of their schools were all included in the TIMSS evaluations. According to DOE, "TIMSS is the world's largest, most comprehensive, and most rigorous international education comparison ever." The study began in 1995, when researchers started testing the mathematics and science knowledge of more than half a million students in 41 countries. In the United States, students from the fourth, eighth, and twelfth grades were included. TIMSS is described by DOE as being a fair evaluation and far more comprehensive than any previous study. The TIMSS testing procedure was regulated to ensure that the participating students in each country were representative of its population.

The study has several parts, including a curriculum analysis component, a study of the curriculum presented in textbooks, and curriculum guides from each of the 41 countries. This analysis was conducted by hundreds of individuals from around the world who collected detailed analytic content data from over 1,600 mathematics and science textbooks and official curriculum guides. The curriculum analysis component was designed to uncover international trends in implementing present and future mathematics and science education. It was also designed to be linked to data on instructional practices and student achievement.

With respect to the U.S. twelfth graders, four different areas of performance—mathematics general knowledge, science general knowledge, physics, and advanced mathematics—were tested. These U.S. students were compared to students at the end of their secondary school education in the other countries. In 21 countries, students were tested for general knowledge in mathematics and science. In addition, in 16 countries, advanced students were tested in physics and advanced mathematics.

Among the countries included in the study were Australia, Austria, Canada, Cyprus, Denmark, France, Germany, Hungary, Iceland, Italy, Japan, New Zealand, the Netherlands, Norway, South Africa, Slovenia, Switzerland, Sweden, the Russian Federation, and the United States. Most Asian countries chose not to participate. U.S. twelfth graders outperformed students from only two of the 21 participating countries in math and science, Cyprus and South Africa. Otherwise, U.S. students' science scores were not significantly different from those of students from seven other countries, including Italy, Germany, France, and the Russian Federation. U.S. math scores were similar to those of four other countries, including Italy and the Russian Federation.

TIMSS also examined how advanced U.S. twelfth-grade students taking math, those studying precalculus and calculus, and those in science studying physics, performed in relation to advanced students in other nations. On the advanced math assessment, U.S. students were outperformed by those in 11 countries, were similar to those in four countries, and did not outperform any participating countries. On the physics assessment, U.S. students were outperformed by those in 14 countries, were the same as those in one country, and outperformed no one.

In all three areas of advanced math and in all five content areas of physics, U.S. advanced math and physics students' performance was among the lowest of the TIMSS nations. On the assessment of math general knowledge, the U.S. score was 461. Hungary, Germany, Slovenia, Austria, Canada, Australia, New Zealand, France, Norway, Iceland, Switzerland, Denmark, Sweden, and the Netherlands had significantly higher average scores than the U.S. scores. The highest score was 560 in the Netherlands. On the assessment of science general knowledge, the U.S. average score was 480. Denmark, Slovenia, Austria, Switzerland, Australia, New Zealand, Canada, Norway, Iceland, Netherlands, and Sweden had significantly higher average scores than the United States. The highest score was 559 in Sweden. The U.S. students who took the Advanced Mathematics TIMSS had already taken or were currently enrolled in precalculus, calculus, or advanced-placement calculus. They represented 14% of young people their age. Those who took the physics assessment had previously taken or were currently enrolled in physics. They also represented 14% of the U.S. youngsters their age. The United States was one of three countries that did not have a significant gender gap in math general knowledge among twelfth graders. While there was a gender gap in U.S. science general knowledge, as there was in every other TIMSS nation, the U.S. gender gap was one of the smallest.

An example of the type of question asked for the advanced physics assessment is "A car moving at a constant speed with a siren sounding comes towards you and

Washington Report *continued on p. 19*

Plate Tectonics and Crustal Evolution (fourth edition). *By Kent C. Condie. Butterworth Heinemann, Oxford, UK, 1997, $49.95 (paperback).*

The crucial part of any science is the telling of what is known and why it is important, and we do this in three different ways. First and foremost, we write peer-reviewed journal articles. This is where new knowledge is reported, but journal articles are designed for specialists. Second, we write introductory geology texts, but because these present the vast panorama of geologic knowledge to audiences with scientific backgrounds that range from limited to negligible, only basic principles, a lot of nomenclature and pretty pictures, and a few scientific highlights can be presented. It is the third way—the book that presents a broad and up-to-date overview of the earth sciences to the "geoliterate"—that links the specialist's understanding and the neophyte's curiosity. These are the books that fire student imaginations, provide new material for science educators, and help scientists answer questions that lie beyond their expertise. Such books are essential for the continued vigor of our science, but are under-rewarded from both scientific and commercial perspectives. We owe a debt of thanks to those hearty souls—such as Kent Condie—who take on the task of writing books like *Plate Tectonics and Crustal Evolution.* And our debt should be doubled for reasonably priced books such as this one.

The fourth edition of Condie's book reflects a 20-year commitment to the title, and the energy and effort spent on it are impressive. It has been extensively rewritten—more than 75% according to the Preface—and the fourth edition looks and feels completely different from the third (1989) edition. Amazingly, the present volume is much shorter (7 chapters and 282 pages) than the third edition (11 chapters and 476 pages). A comprehensive table of contents and well-designed index make it easy to navigate the book. The list of more than 700 references is very up-to-date; I flipped many times to the back to check an unfamiliar—and invariably recent—reference. There are few typographical errors, a good indication of care.

The book has several disappointing aspects, however. Its purpose and intended audience are not identified in the Preface. The title is misleading—this is really not a book about plate tectonics. The first chapter gives an overview of modern plate boundaries and associated crustal environments, but at a level that is about what would be found in a good introductory geology text. There is a discussion of "cycloid plate motions" that confuses more than it illuminates, and it is unclear why the short section on "stress distribution within plates" was included. The second part of the title—*Crustal Evolution*—is covered more extensively in chapters 2, 3, and part of 5, but still inadequately, because many of the most important topics in crustal evolution are covered too briefly. Such topics include subduction zones, continental collision, and the hypothesis of delamination. Too many important recent advances are omitted—for example, the existence of volcanic and nonvolcanic passive margins, the critical taper model of accretionary prisms, extensional collapse of orogens, and the fact that many ophiolites are produced in forearcs at the time subduction begins. The less-than-exhaustive treatment of important topics may be the unavoidable result of broadening and shortening the book. The strongest chapter in the book is chapter 4, "The Earth's mantle and core." This is a valuable and balanced synopsis of how Earth's sublithospheric interior operates, including the distribution of isotopic components in the mantle, mantle mineralogy and the significance of upper mantle seismic discontinuities, how the geomagnetic dynamo operates, and how the core may have formed. An entire chapter (6), "The atmospheres, oceans, climates, and life" is added to the fourth edition, and although it is understandable that hard-rock geologists want to connect with the global change community, chapter 6 doesn't add much to the book. This is particularly true because this chapter contains a mistake—the assertion that metazoan life began at 1.7 Ga, not in the late Neoproterozoic as most of the scientific community now accepts. Chapter 6 reinforces the idea that the fourth edition of *Plate Tectonics and Crustal Evolution* perhaps

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then passes by. Describe how the frequency of the sound you hear changes." Thirty-seven percent of the international participants answered this question correctly. Only 12% of advanced U.S. students were able to provide the correct answer. Education Secretary William Riley stated, "This is unacceptable, and it absolutely confirms what the president and I have been saying, that academic standards must be raised dramatically across America. The standards of many state assessments in math are far lower than national and international standards of excellence; too many science and math teachers are teaching out-of-field; and far too few high school seniors have taken physics, trigonometry, calculus and advanced placement courses."

The results of the fourth- and eighth-grade TIMSS assessments were released in 1996 and 1997, respectively. They showed that the achievement of U.S. fourth-grade students is quite high, performing above the international average in both mathematics and science. U.S. fourth graders were outperformed in science only by Korea. By eighth grade, U.S. students' relative standing declined, to only slightly above the international average in science and below the international average in mathematics. One explanation given for the poor performance in eighth grade mathematics is that while most students in grades four to eight in other nations are studying the beginning concepts of algebra, geometry, and other topics, U.S. students continue to be taught primarily arithmetic.

"We need to have higher expectations for our students ..., even among college bound high school seniors, 51 percent have not even taken four years of science. This research also shows that our high school curriculum and instruction has less rigor and depth than other nations and less focus on building understanding of major concepts," Riley noted. So we shouldn't be surprised that by the twelfth grade, our students have fallen even farther behind their counterparts abroad. "We need to raise our expectations of our students if we want to be internationally competitive. Our twelfth graders' low international ranking isn't the only cause for alarm here. If we're to continue to be global competitors in the new knowledge economy, we'll need a steady and competent pool of employees. Right now, the low performance of those in the pipeline for those future jobs has troubling implications for our future."

Riley also noted that 28% of high-school math teachers and 18% of high-school science teachers neither majored nor minored in these subjects. He challenged states and communities to ensure that students are taught by teachers who are prepared to teach advanced math and science. In the physical sciences, where student performance lags the most, almost half of American students are taught by teachers without a major or minor in that field.

Copies of the report are available from the National Library of Education, (202) 219-1692. The report also will be available from the U.S. Government Printing Office. Additional information can be found on the TIMSS home page, (http://nces.ed.gov/timss/index.html). ■

GSAF UPDATE

Valerie G. Brown, Director of Development, GSA Foundation

GSA's Fund-Raising Program: Continuing to Thrive (Part 2)

Last month we described the generosity of corporate donors to GSA's program activities.

This month we honor the foundations whose gifts are supporting GSA's education and outreach initiatives. To date, foundations have contributed $539,165 of the revenue received during the Second Century campaign.

In this category, as with corporations, we have two superstars—**the Boettcher Foundation, and El Pomar Foundation**—that together have given nearly half of the total received from foundations. In fact, these outstanding gifts were literally paired with each other.

Flashback to 1994: The new addition to the headquarters building had just been completed, and GSA had approved the launch of several innovative technological education programs under the SAGE (Scientific Awareness through Geoscience Education) heading. The common element in these undertakings was the need for significant upgrades and additions to the Society's electronic capabilities.

In response to the need, the Boettcher Foundation pledged a major challenge grant of $132,000. Boettcher's commitment reflected not only its long-standing dedication to furthering education in Colorado but also the roots of its founding fortune in Colorado's mining enterprises. The grant required that an equivalent amount be raised from other sources. GSA presented the challenge to El Pomar Foundation, a creation of the Penrose family. In 1934, the bequest of R. A. F. Penrose, Jr. ensured GSA's welfare in a new phase of organization growth. In 1994, the present custodians of the Penrose heritage agreed to meet the Boettcher challenge, thereby securing GSA's next phase of growth and influence.

These two gifts have funded acquisition of sophisticated electronic equipment that has noticeably improved GSA's communications and publications capabilities and permitted implementation of SAGE programs now applauded for their successful contributions to science education.

Accounting for the remaining half of receipts in this category are several other foundations whose generosity to GSA is equally meaningful and equally worthy of our gratitude. So join us in thanking one that wishes to remain anonymous and:

ARCO Foundation, Inc.
Bullitt Foundation
Frank A. Campini Foundation
Ecological Society of America Foundation
Gates Foundation
Howard and Jean Lipman Foundation
Ruth and Vernon Taylor Foundation

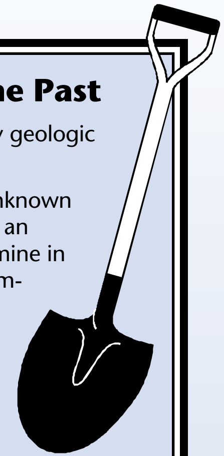
Although it is each foundation's responsibility to give, it is each foundation's *election* to give to GSA. We are truly grateful! ■

Digging Up the Past

Most memorable early geologic experience:

Being shot at by an unknown assailant while visiting an abandoned open-pit mine in Connecticut in the company of John Rodgers, Bob Gates, Jim Clarke, John Lucke, and Bob Sneider.

—John J. Prucha



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tries to cover too much and consequently lacks focus.

In summary, the book's synopses of important geologic themes and the reference list will be valued by advanced graduate students, professors, and other scientists, but the text must be refocused before it can become optimally suited for a course in plate tectonics and crustal evolution intended for advanced undergraduate and beginning graduate students and among earth science educators.

Robert J. Stern
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Late Glacial and Postglacial Environmental Changes. *Edited by I. Peter Martini. Oxford University Press, New York, 1997, 343 p. $65.*

This multi-authored volume contains 19 chapters organized into five parts that center around three major ice ages: the Quaternary, late Paleozoic, and late Precambrian. The fifth part attempts to compare the Quaternary and late Paleozoic events in terms of weathering and associated organic deposits. Most of the 23 contributing authors are internationally recognized experts in their respective fields; hence, the treatments are up-to-date with the literature, and the reader can depend upon a reasonably accurate representation of the essential debates in each discipline.

Clearly, in bringing these authors' contributions together, Martini is attempting to provide a comparison of the environmental changes brought about during and following glacial episodes in the Phanerozoic. With this goal in mind, I was satisfied with some chapters and disappointed with others. The problem in some chapters is that the authors present the chronostratigraphic resolution typically associated with that time period and fail to address the fact that Quaternary environmental changes were large but often associated with subtle changes in the stratigraphic record (for instance, isotopic stages and Heinrich layers in deep-sea sediments). Only a few of the authors presented views on ancient glaciations that kept pace with Quaternary-style events, notably the reliable work of Visser and Lopez-Gammundi on the Karoo and Parana basins, respectively. The representation of the Australian record was a disappointment; it did not even reference some of the excellent glacial marine stratigraphic work recently completed in parts of the Sydney and Tasmania basins.

A major omission of the volume, to which one author admits, is the lack of Antarctic Cenozoic glacial record and detail on Quaternary events in the Southern Hemisphere. Most of the Antarctic record lies on the continental margins and speaks directly as to what is likely to be preserved in ancient sequences (especially the late Precambrian rift-associated intervals, well presented by Young), and how.

The deep-marine record of Quaternary events is well presented in the chapter by Andrews, and terrestrial correlatives are evenly treated by Clarke, Baker, and Lundqvist. The late Paleozoic chapters focus upon intracratonic basins, which lack a record comparable to that of the late Quaternary deep sea, where the majority of our paleoclimate record is archived. Thus, there is a natural disjunct, due to preservation, when one attempts to compare the two major Phanerozoic ice ages. The notable exceptions to this are the fine chapters on Quaternary peat vs. Paleozoic coal deposits. It is this type of comparison that really begins to shed light on the vagaries of Permian and Quaternary climate oscillations.

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Donors to the Foundation, February 1998

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As someone who teaches a nontraditional glacial geology course that treats ancient and Quaternary events as well as the marine record, I find that the book is a useful volume of supplementary reading. Others may find it somewhat less useful for typical undergraduate courses, although it is a very good graduate and research reference and should be in all geology libraries.

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Clinton, NY 13323

Cool-Water Carbonates. *Edited by Noel P. James and Jonathan A. D. Clarke. SEPM (Society for Sedimentary Geology Special Publication 56), Tulsa, Oklahoma, 1997, 440 p., $111.*

There is a vast literature on the sedimentary geology of carbonate sediments and rocks deposited in tropical settings. Although there are important carbonate accumulations on the modern seafloor formed in seawater colder than 20 °C, and there are many carbonate rocks in t he geologic record that bear evidence of being deposited in cool-water environments, until recently scant attention has been paid to this facies. This compendium of papers is an attempt to rectify the situation.

Cool-Water Carbonates is a collected series of papers dealing with carbonate sediments and rocks deposited on shelves and offshore banks in waters colder than 20 °C. The contributions come mainly from a workshop, organized by Clarke and sponsored by the Australian Sedimentology Research Group of the Geological Society of Australia, held in Geelong, Victoria, in January 1995. This SEPM Special Publication joins a long line of outstanding volumes in this series in the field of sedimentary geology. The volume includes 24 papers that deal with a range of topics and case studies involving the deposition and diagenesis of modern cool-water carbonates and those from the rock record interpreted as being deposited in cool-water environments of banks, shelves, and platforms. After a very readable and informative paper by Noel James summarizing the sedimentary geology of the cool-water depositional realm, the book is divided into three sections. The first section deals with the modern depositional milieu, with emphasis on the "down-under" settings of Australia and New Zealand, and the second and third emphasize Tertiary and Mesozoic-Paleozoic environments, respectively. Papers in the latter two sections deal with the sedimentology, geochemistry, and paleobiology of interpreted cool-water carbonates mainly of Tertiary, Permian, Mississippian, and Late Ordovician age. These periods of time seem to have recurring examples of cool-water carbonates. The question, of course, is why?

Of the exciting new developments in carbonate sedimentology and geochemistry in recent years, not the least is the recognition that significant deposits of sedimentary carbonates can be formed in seawaters other than tropical. *Cool-Water Carbonates* is an excellent summary of the present status of understanding and current research involving this facies. It is a volume for research scientists and students alike interested in sedimentary carbonates in general and in particular in these facies, which may represent a far larger proportion of the sedimentary carbonate mass than heretofore recognized.

Fred T. Mackenzie
University of Hawaii
Honolulu, HI 968220 ■

NOMINATION FOR GSA COMMITTEES FOR 1999

(One form per candidate, please. Additional forms may be copied.)

(Please print)

Name of candidate ______________________________

Address ______________________________

____

Phone ( ) ______________________________

COMMITTEE(S) BEING ☐ VOLUNTEERED or ☐ NOMINATED FOR (please check):

Committee(s):

Comment on special qualifications:

☐ GSA Fellow Section affiliation:

☐ GSA Member Division affiliation(s):

Brief summary of education:

Brief summary of work experience (include scientific discipline, principal employer—e.g., mining industry, academic, USGS, etc.):

If you are VOLUNTEERING to serve GSA, please give the names of 2 references (please print):

Name:______________________________

Phone: ( ) ______________________________

Name: ______________________________

Phone: ( ) ______________________________

If you are NOMINATING SOMEONE other than yourself to serve GSA, please give your name, address, and phone number (please print):

Name: ______________________________

Address: ______________________________

____

Phone: ( ) ______________________________

DEADLINE: Please return this form to GSA Headquarters, Attn: Executive Director, P.O. Box 9140, Boulder, CO 80301-9140, **by Friday, July 10, 1998.** *Form must be complete to be considered.*

Call For GSA Committee Service—1999

The GSA Committee on Committees wants your help. The committee is looking for potential candidates to serve on committees of the Society or as GSA representatives to other organizations. You can help by volunteering yourself or suggesting the names of others you think should be considered for any of the openings and submitting your nomination on the form on page 22. Younger members are especially encouraged to become involved in Society activities.

Listed are the number of vacancies along with a brief summary of what each committee does and what qualifications are desirable. If you volunteer or make recommendations, please give serious consideration to the special qualifications for serving on a particular committee. *Please be sure that your candidates are Members or Fellows of the Society and that they meet fully the requested qualifications.*

Volunteering or Making a Recommendation

All nominations received at headquarters by **Friday, July 10, 1998,** on the official one-page form will be forwarded to the Committee on Committees. *Council requires that the form be complete.* Information requested on the form will assist the committee members with their recommendations for the 1999 committee vacancies. Please use one form per candidate (additional forms may be copied). The committee will present at least two nominations for each open position to the Council at its October 27, 1998, meeting in Toronto, Ontario. Appointees will then be contacted and asked to serve, thus completing the process of bringing new expertise into Society affairs.

Committee on Committees

The 1998 committee consists of the following people: Chair **Marcus E. Milling**, American Geological Institute, 4220 King St., Alexandria, VA 22302-1502, (703) 379-2480; **Laurie Brown**, Department of Geosciences, University of Massachusetts, 233 Morrill Science Center, Amherst, MA 01803, (413) 545-0245; **Karl W. Flessa**, Geoscience Department, University of Arizona, 1840 E. 4th St., Tucson, AZ 85721, (520) 621-7336; **Don O. Hermes**, Department of Geology, University of Rhode Island, 315 Green Hall, 8 Ranger Road, Suite 2, Kingston, RI 02881, (401) 874-2192; **Eric W. Mountjoy**, Department of Earth and Planetary Science, McGill University at Montreal, Province of Quebec, H3A 2A7, Canada, (524) 398-4894; **Frederick L. Schwab**, Department of Geology, Washington & Lee University, Lexington, VA 24450, (540) 463-8870.

Committee Vacancies

Annual Program (5 vacancies)

Develops a plan for increasing the quality of the annual meeting in terms of service, education, and outreach. Evaluates the technical and scientific programs of the annual meeting.

Committee members should have previous program experience or experience at organizing an annual meeting, or be actively involved in applying geology knowledge to benefit society and awareness of critical issues.

Continuing Education (2 vacancies)

Directs, advises, and monitors the Society's continuing education program, reviews and approves proposals, recommends and implements guideline changes, and monitors the scientific quality of courses offered.

Committee members should be familiar with continuing education programs or have adult education teaching experience.

Day Medal (3 vacancies)

Selects candidates for the Arthur L. Day Medal.

Committee members should have knowledge of those who have made "distinct contributions to geologic knowledge through the application of physics and chemistry to the solution of geologic problems."

Education (3 vacancies—2 at large; 1 middle school teacher)

Stimulates interest in the importance and acquisition of basic knowledge in the earth sciences at all levels of education.

Committee members work with other interested scientific organizations and science teachers' groups to develop precollege earth-science education objectives and initiatives. The committee also promotes the importance of earth-science education to the general public.

Geology and Public Policy (3 vacancies)

Translates knowledge of the earth sciences into forms most useful for public discussion and decision making.

Committee members should have experience in public-policy issues involving the science of geology. They should also be able to develop, disseminate, and translate information from the geologic sciences into useful forms for the general public and for the Society membership; they should be familiar with appropriate techniques for the dissemination of information.

Honorary Fellows (2 vacancies)

Selects candidates for Honorary Fellows, usually non–North Americans.

Committee members should have knowledge of geologists throughout the world who have distinguished themselves through their contributions to the science.

Membership (1 vacancy)

Evaluates membership benefits and develops recommendations that address the changing needs of the membership and attracts new members.

Committee members must be able to attend one meeting a year. Previous experience in benefit, recruitment, and retention programs is desired.

Minorities and Women in the Geosciences (3 vacancies)

Stimulates recruitment and promotes positive career development of minorities and women in the geoscience professions.

Committee members should be familiar with minority and female education and employment issues and have expertise and leadership experience in such areas as human resources and education. Membership shall include representation of minorities and women and representatives from government, industry, and academia.

Committee Service *continued on p. 24*

The GSA Council acknowledges the many member-volunteers who, over the years, have stimulated growth and change through their involvement in the affairs of the Society.

Each year GSA asks for volunteers to serve on committees, and many highly qualified candidates express their willingness to serve. Not everyone can be appointed to the limited number of vacancies; however, members are reminded that there are also opportunities to serve in the activities and initiatives of the sections and divisions. Annually, the Council asks sections and divisions to convey the names of potential candidates for committee service to the Committee on Committees.

1998–1999 Section Officers and Past Chairs

CORDILLERAN SECTION

Gregory A. Davis	Chair
Margaret E. Rusmore	Vice-Chair
Bruce A. Blackerby	Secretary
Alison B. Till	Past Chair

ROCKY MOUNTAIN SECTION

Scott S. Hughes	Chair
Glenn D. Thackray	Vice-Chair
Kenneth E. Kolm	Secretary
Larry T. Middleton	Past Chair
Ronald C. Blakey	Past Vice-Chair

NORTH-CENTRAL SECTION

Dennis Kolata	Chair
Ardith K. Hansel	Vice-Chair
Robert F. Diffendal, Jr.	Secretary
William I. Ausich	Past Chair
Walter C. Sweet	Past Vice-Chair

SOUTH-CENTRAL SECTION

M. Charles Gilbert	Chair
Calvin Barnes	Vice-Chair
Rena M. Bonem	Secretary-Treasurer
Elizabeth Y. Anthony	Past Chair

NORTHEASTERN SECTION

Allan Ludman	Chair
Robert D. Jacobi	Vice-Chair
Kenneth N. Weaver	Secretary-Treasurer
Jon C. Boothroyd	Past Chair

SOUTHEASTERN SECTION

R. Heather MacDonald	Chair
Samuel E. Swanson	Vice-Chair
Harold H. Stowell	Secretary-Treasurer
Ernest A. Mancini	Past Chair
Larry D. Woodfork	Past Vice-Chair

GSA ON THE WEB

Visit the GSA Web Site at **http://www.geosociety.org.** ***From our home page you can link to many information resources. Here are some highlights:***

As of **April 10**, the **electronic abstract submittal form** is LIVE, and ready for your submittals. Go to the GSA Home Page, and under the "Annual Meetings & Penrose Conferences" click on the link "Submit an abstract for the 1998 Annual Meeting in Toronto." You may choose to review instructions, or if you are already knowledgable about our system, you may wish to jump right to the abstract form. When your abstract is complete, you will be directed to our secured credit card page. Again this year, there is a nonrefundable fee of $15 for each abstract submittal. If you need paper abstract forms, please contact ncarlson@geosociety.org.

Jim Clark Retires

GSA Publications Production and Marketing Manager James R. (Jim) Clark has retired after more than 18 years on the headquarters staff of the Society. During that time, he oversaw the production, manufacture, distribution, and marketing of 684 issues of GSA periodicals, about 88 issues of *Abstracts with Programs*, and 328 of GSA's nonperiodicals: Memoirs, Special Papers, Maps and Charts, etc.

In addition, he organized and managed the marketing, production, manufacture, and distribution of the Decade of North American Geology (DNAG) publications: 30 volumes, 157 plates, seven major maps, and 21 transects—nearly 16,000 pages in all; he was also responsible for marketing eight additional volumes produced in Canada.

Clark conceived the idea for the best-selling volume, *The Art of Geology* (Special Paper 225) as a GSA Centennial specialty book for nongeologists, and coordinated its production. He instituted *GSA Journals on Compact Disc*, now a semi-annual release with nearly 600 subscribers. He designed and initiated several Web-based systems including the GSA Bookstore on the Web and its attendant purchasing system; the GSA Data Repository on the Web, and the GSA Electronic Retrospective Index on both CD-ROM and the Web.

He also managed the receipt and processing of all abstracts for section and annual meetings, and the production of the GSA *Abstracts with Programs*. He designed the familiar GSA abstract forms and was co-designer and co-creator of GSA's Web-based electronic abstract-submittal system, now in its third year of use for annual meetings.

Clark moved GSA's publications through many technological changes, into the current desk-top publishing. He coordinated the computerization of many publications functions, personally designing many GSA data sets and their supporting systems.

Committee Service *continued from p. 23*

Nominations **(2 vacancies; one to be a member from Canada or Mexico)**

Recommends to the Council nominees for the positions of GSA officers and councilors.

Committee members should be familiar with a broad range of well-known and highly respected geological scientists.

Penrose Conferences **(1 vacancy)**

Reviews and approves Penrose Conference proposals, recommends and implements guidelines for the success of the conferences.

Committee members must either be past conveners or have attended two or more Penrose Conferences.

Penrose Medal **(2 vacancies)**

Selects candidates for the Penrose Medal.

Committee members should be familiar with outstanding achievements in the geological community that are worthy of consideration for the honor. Emphasis is placed on "eminent research in pure geology, which marks a major advance in the science of geology."

Research Grants **(0 vacancies)**

Evaluates research grant applications and selects grant recipients.

Committee members must be able to attend the spring meeting and should have experience in directing research projects and in evaluating research grant applications.

Young Scientist Award (Donath Medal) **(2 vacancies)**

Selects candidates for the Donath Medal.

Committee to have members covering a broad range of disciplines, i.e., geophysics, economic geology, stratigraphy. Committee members should have knowledge of young scientists with "outstanding achievement(s) in contributing to geologic knowledge through original research which marks a major advance in the earth sciences."

GSA Representative to the North American Commission on Stratigraphic Nomenclature **(1 vacancy)**

Must be familiar with and have expertise in stratigraphic nomenclature. ■

May *BULLETIN* and *GEOLOGY* Contents

The Geological Society of America
BULLETIN
Volume 110, Number 5, May 1998

CONTENTS

GEOLOGY

VOLUME 26
NO. 5
P. 385–480
MAY 1998

Call for Applications and Nominations for *GSA BULLETIN* Editor

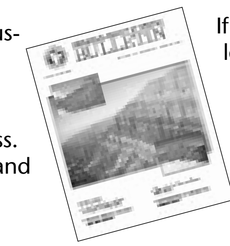
The term of one of the current editors of the *GSA Bulletin* will end December 31, 1998, and a new editor will begin a four-year term at that time. Thus, GSA is soliciting applications and nominations for the position of editor of the *Bulletin.* A phased transition should begin in the fall of 1998.

This is not a salaried position, but GSA pays the expenses for secretarial assistance, mail, and telephone at the editors' locations and for travel to GSA headquarters. GSA headquarters staff conducts copy-editing and production activities.

EDITOR DUTIES

Working as a team, the two *Bulletin* editors:

1. Strive to maintain the *Bulletin* as one of the premier journals in the geological sciences.
2. Select and maintain an appropriate board of Associate Editors.
3. Maintain expeditious manuscript flow.
4. Make decisions regarding acceptability of manuscripts in concert with recommendations of reviewers and Associate Editors.
5. Advise authors about necessary revisions.
6. Organize the content and select the cover illustration for each issue of the *Bulletin.*
7. Keep the Committee on Publications and the GSA headquarters staff informed about the flow of manuscripts and other *Bulletin* business.
8. Respond promptly to inquiries from authors and prospective authors.



EDITOR QUALITIES

1. Broad background and active research in the geological sciences, with particular emphasis on regional geology (including geomorphology, geophysics, geochemistry).
2. Good organizational skills.
3. Capability to coordinate working schedules with a co-editor.
4. Willingness to invest about one day per week on *Bulletin*-related activities.
5. Enthusiasm and imagination for promoting innovations and improvements in the *Bulletin.*
6. Broad knowledge of geological research activities of scientists both nationally and internationally.
7. Effective communication skills.
8. Objectivity.
9. Scientific maturity.
10. Patience, courtesy, tact, and firmness in working with authors and Associate Editors.

If you are interested in applying, submit a resume and a brief letter describing relevant qualifications, experience, and objectives. If you are nominating someone, include a letter of nomination and the nominee's written permission and resume. Send nominations and applications to Donald M. Davidson, Jr., Executive Director, Geological Society of America, P.O. Box 9140, Boulder, Colorado 80301, by July 15, 1998.

1998 Committees and Representatives

Executive Committee
Victor R. Baker—President and Chair; Gail M. Ashley—Vice-President; George A. Thompson—Past President; David E. Dunn—Treasurer; John E. Costa—Council Member-at-Large

Annual Program Committee
Sharon Mosher—Chair, 1996–1998; G. Randy Keller, 1995–1998; Orrin H. Pilkey, Jr., 1995–1998; John M. Bartley, 1996–1998; Jonathan G. Price, 1996–1998; Denis M. Shaw, 1997–1999; *Ex officio:* Sue S. Beggs—Meetings Director; Donald M. Davidson, Jr.—Executive Director; John D. Humphrey

Audit Committee
Charles G. Groat—Chair, 1996–1998; Morris W. Leighton, 1997–1999; Gail A. Mahood, 1997–1999; Melvin J. Hill, 1998–2000; Joaquin S. Ruiz, 1998–2000; *Ex officio:* David E. Dunn—Treasurer

Committee on the Budget
David E. Dunn—Chair and Treasurer; Samuel S. Adams, 1996–2000; Arden L. Albee, 1998–2002; *Ex officio:* Donald M. Davidson, Jr.—Executive Director; Dennis G. Kyhos—Chief Financial Officer

Committee on Committees
Marcus E. Milling—Chair; Laurie Brown; Karl W. Flessa; Don O. Hermes; Eric W. Mountjoy; Frederick L. Schwab

Committee on Continuing Education
Carolyn G. Olson—Chair, 1996–1998; Jean M. Bahr, 1996–1998; Odin D. Christensen, 1997–1999; Grant R. Woodwell, 1997–1999; Charles G. Groat, 1998–2000; David S. McCormick, 1998–2000

Committee on the Arthur L. Day Medal Award
J. Leslie Smith—Chair, 1998; Richard G. Gordon, 1996–1998; Robert Kerrich, 1996–1998; Kip V. Hodges, 1997–1999; Julie D. Morris, 1998–2000; E. Calvin Alexander, Jr., 1998–2000; Jon P. Davidson, 1998–2000

Committee on Education
David W. Mogk—Chair, 1996–1998; Debbie M. Hill, 1996–1998; Kenneth L. Verosub, 1996–1998; R. Heather MacDonald, 1997–1999; Madge Evans, 1997–1999; Maureen Allen, 1998–2000; Section representatives: Elizabeth Ambos (Cordilleran); Cathleen L. May (Rocky Mountain); Sherman P. Lundy (North-Central); Frances (Betsy) E. Julian (South-Central); Daniel P. Murray (North-eastern); John E. Callahan (Southeastern); *Ex officio:* Gail M. Ashley—Vice-President; Conferee: Edward E. Geary—Director of Educational Programs

Committee on External Awards
Warren B. Hamilton—Chair; J. Leslie Smith; Division Representatives: James R. Staub (Coal Geology); William C. Haneberg (Engineering Geology); George A. Thompson (Geophysics); (vacant—Geoscience Education); William R. Brice (History of Geology); Leslie D. McFadden (Quaternary Geology and Geomorphology)

Committee on Geology and Public Policy
Monica E. Gowan—Chair, 1996–1998; Peter F. Folger—Chair Designee, 1997–1999; J. David Applegate, 1996–1998; Robert H. Rutford, 1996–1998; Lee C. Gerhard, 1997–1999; James M. Robertson, 1997–1999; James E. Evans, 1998–2000; Virgil A. Frizzell, Jr., 1998–2000; Sally J. Sutton, 1998–2000; Past Congressional Science Fellows: Jill S. Schneiderman, 1996–1998; Peter F. Folger, 1997–1999; Tamara J. Nameroff, 1998–2000; *Ex officio:*

1998 Committees *continued on p. 27*

1998 Committees *continued from p. 26*

(Section representatives): Robert H. Fakundiny (Northeastern); Thomas J. Evans (North-Central); Jerome V. DeGraff (Cordilleran); Cathleen L. May (Rocky Mountain); John D. Kiefer (Southeastern); (vacant—South-Central); Conferee—ad hoc Committee on Critical Issues: Allison R. (Pete) Palmer; *Ex officio:* Paul K. Doss—Past Chair; Elizabeth S. Knapp—(Acting) IEE Program Manager; Council/Committee Liaison: George A. Thompson—Past President

Committee on Honorary Fellows
Parke D. Snavely III—Chair, 1997–1999; Gerhard H. Eisbacher, 1996–1998; Miriam Kastner, 1996–1998; Brian J. Skinner, 1997–1999; Michael A. Dungan, 1998–2000; Donald R. Lowe, 1998–2000; *Ex officio:* Ian W. D. Dalziel—International Secretary

Committee on Investments
Carel Otte—Chair, 1996–1998; R. Thayer Tutt, Jr., 1996–1998; F. Michael Wahl., 1996–1998; John E. Costa, 1998–2000; Melvin J. Hill, 1998–2000; *Ex officio:* David E. Dunn—Treasurer; Brian J. Skinner—GSA Foundation designee

Committee on Membership
William D. Carlson—Chair, 1997–1999; Richard W. Ojakangas, 1996–1998; George H. Davis, 1997–1999; Reinhard A. Wobus, 1997–1999; Bruce A. Bouley, 1998–2000; Kenneth L. Pierce, 1998–2000

Committee on Minorities and Women in the Geosciences
Mary E. Dowse—Chair, 1998–2000; Kathleen E. Johnson, 1996–1998; Lauret E. Savoy, 1996–1998; Barbara L. Sherriff, 1996–1998; Rosaly Lopes-Gautier, 1997–1999; Joseph C. Cepeda, 1998–2000; James B. Finley, 1998–2000; Lisa A. Rossbacher, 1998–2000; Conferees: Joanne Bourgeois—Council/Committee Liaison; Edward E. Geary—Director of Educational Programs

Committee on Nominations
Peter W. Lipman—Chair, 1997–1998; Darrell S. Cowan, 1997–1998; G. Randy Keller, 1997–1998; John W. Hess, Jr., 1998–1999; Lisa M. Pratt, 1998–1999; Derald G. Smith, 1998–1999

Committee on Penrose Conferences
J. Douglas Walker—Chair, 1996–1998; Joann M. Stock, 1997–1999; Thomas W. Gardner, 1998–2000; Naomi M. Oreskes, 1998–2000; Fred M. Phillips, 1998–2000

Committee on the Penrose Medal Award
Warren B. Hamilton—Chair, 1998; Steven M. Stanley, 1996–1998; Phillip C. England, 1997–1999; John E. Suppe, 1997–1999; Leonard F. Konikow, 1998–2000; Mary J. Kraus, 1998–2000

Committee on Publications
Joanne Bourgeois—Chair, 1996–1998; B. Clark Burchfiel, 1997–1999; Allison R. (Pete) Palmer, 1998–2000; Kevin T. Biddle, 1997–1999; Abhijit Basu, Editor, Books; John W. Geissman, Editor, *Bulletin;* Lee R. Kump, Editor, *Geology;* John M. Sharp, Jr., Co-Editor, *Environmental and Engineering Geoscience;* Conferee: Donald M. Davidson, Jr.—Executive Director

Committee on Research Grants
James N. Connelly—Chair, 1997–1999; Duncan M. FitzGerald, 1997–1999; Paul M. Myrow, 1997–1999; Thomas L. Patton, 1997–1999; Allen F. Glazner, 1998–2000; Brian G. Katz, 1998–2000; Jim E. O'Connor, 1998–2000; NSF Conferee: Thomas O. Wright

***Treatise on Invertebrate Paleontology* Advisory Committee**
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Ad Hoc Committee on Critical Issues
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Ad Hoc Committee on Ethics
David A. Stephenson—Chair; Donald M. Davidson, Jr.; Fletcher G. Driscoll; Richard I. Grauch; Thomas L. Holzer

Ad Hoc Committee on the GSA Strategic Plan
Victor R. Baker—GSA President; Gail M. Ashley; Sue S. Beggs; Joanne Bourgeois; Valerie G. Brown; Bruce Clark; Donald M. Davidson, Jr.; George H. Davis; Edward E. Geary; Dennis Kyhos; Eldridge M. Moores; Sharon M. Mosher; Daniel Sarewitz; David A. Stephenson; George A. Thompson; Susan Ward

GSA Member of the American Geological Institute (AGI) Member Society Council
George A. Thompson, 1996–1998

GSA Member of the AGI Education Advisory Committee
Edward E. Geary—GSA Director of Educational Programs

GSA Member of the AGI Government Affairs Program Advisory Committee
Virgil A. Frizzell, Jr., 1998–2000

GSA Representatives to the American Association for the Advancement of Science (AAAS)
Section E—Geology and Geography: Maryellen Cameron, February 19, 1997–Feb 22, 2000; Section W—Atmospheric and Hydrospheric Sciences: John G. Weihaupt, July 1, 1988–February 22, 2000

GSA Representatives to the AAAS Consortium of Affiliates for International Programs (CAIP)
Ian W. D. Dalziel—International Secretary; Donald M. Davidson, Jr.—GSA Staff Liaison

GSA Representatives to the North American Commission on Stratigraphic Nomenclature (NACSN)
W. Burleigh Harris, 1995–1998; Ernest A. Mancini, 1996–1999; David T. King, Jr., 1997–2000; Ardith K. Hansel—Representative Elect, 1998–2001 (term begins during the NACSN 1998 fall meeting in Toronto)

GSA Representative to the *Treatise* Editorial Advisory and Technical Advisory Boards of the Paleontological Institute
John Pojeta, Jr.—Chair, *Treatise on Invertebrate Paleontology* Advisory Committee

GSA Representatives to the Joint ASCE-GSA-AEG Committee on Engineering Geology (American Society of Civil Engineers, Association of Engineering Geologists)
Donald C. Helm, 1997–1999; Bruce R. Rogers, 1997–1999

GSA Representative to the U.S. National Committee on Scientific Hydrology
David A. Stephenson, 1990–; John M. Sharp, Jr. (alternate)

GSA and AASG Selection Committee for the John C. Frye Memorial Award in Environmental Geology (Association of American State Geologists)
Frank E. Kottlowski—Chair, AASG representative; Richard C. Berg (tentative), GSA representative, 1998–2000; Larry D. Fellows, AASG representative ■

1998

October 26–29
Metro Toronto Convention Centre
Sheraton Centre Toronto Hotel

www.geosociety.org/meetings/98

Abstracts due: ***July 13***

ASSEMBLY OF A CONTINENT

Call for Papers and First Announcement in the April issue of GSA Today.
Registration and Housing information will be in the June issue.

GENERAL CHAIRS

Jeffrey J. Fawcett, *University of Toronto*
Peter von Bitter, *Royal Ontario Museum*

TECHNICAL PROGRAM CHAIRS

Denis M. Shaw, *McMaster University*
Andrew Miall, *University of Toronto*

FIELD TRIP CHAIRS

Pierre Robin, Henry Halls
University of Toronto

Both technical program and field trip deadlines have passed.

Travel to Toronto

- Visit the GSA Toronto Web site for links to travel information: www/geosociety.org/meetings/98, then e-mail us if you have any questions: meetings@geosociety.org.

Federal and State Employees

- Put in your request NOW for foreign travel. Be sure the GSA Annual Meeting in Toronto is on the “approved” travel list.

U.S. Visa Holders

- Get in touch with your consulate NOW. 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 native-born Americans and/or U.S. citizens, it’s really easy! Canadian Immigration only requires either a passport or a birth certificate, supported by photo I.D.
- 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. This is also easy!

See you in Toronto!

Have Enough Abstracts Forms for the 1998 GSA Annual Meeting?

IF NOT ... REQUEST THEM NOW.

(303) 447-2020, ext. 161 • e-mail: ncarlson@geosociety.org.

FOR ELECTRONIC SUBMISSION Information is available under the Meetings heading on the GSA home page at http://www.geosociety.org.

REMEMBER Deadline for receipt at GSA is ***July 13***.

GSA SECTION MEETING

1998

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.

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
Department of Geological Sciences
University of Colorado
Campus Box 399
Boulder, CO 80309-0399
(303) 492-6172
fax 303-492-2606
alan.lester@colorado.edu

Bruce Trudgill
Department of Geological Sciences
University of Colorado
Campus Box 399
Boulder, CO 80309-0399
(303) 492-2126
fax 303-492-2606
bruce@lolita.colorado.edu

FUTURE MEETINGS

2000 Reno, Nevada
November 13–16

2001 Boston, Massachusetts
November 5–8

2002 Denver, Colorado
October 28–31

For information on any GSA Meeting call the GSA Meetings Department.

1-800-472-1988 or
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CALL FOR
CONTINUING EDUCATION COURSE PROPOSALS
Due December 1, 1998

The GSA Committee on Continuing Education invites those interested in proposing a GSA-sponsored or cosponsored course or workshop to contact GSA headquarters for proposal guidelines. Continuing Education courses may be conducted in conjunction with all GSA annual or section meetings. We are particularly interested in receiving proposals for the 1999 Denver Annual Meeting or the 2000 Reno Annual Meeting.

Proposals must be received by December 1, 1998. Selection of courses for 1999 will be made by February 1, 1999. For those planning ahead, we will also consider courses for 2000 at that time.

For proposal guidelines or information, contact:
Edna Collis, Continuing Education Coordinator, GSA headquarters, 1-800-472-1988, ext. 134, ecollis@geosociety.org

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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.

1999 Penrose Conferences

January
January 18-24, **Strike-slip to Subduction Transitions on Plate Boundaries: Tectonic Setting, Plate Kinematics and Seismic Hazards**, Puerto Plata, Dominican Republic. Information: Paul Mann, Institute of Geophysics, University of Texas, Bldg 600, 4412 Spicewood Springs Road, Austin, TX 78759-8500, (512) 471-0452, fax 512-471-8844, paulm@utig.ig.utexas.edu.

March
March 25-31, **Mid-Cretaceous to Recent Plate Boundary Processes in the Southwest Pacific**, Arthur's Pass, South Island of New Zealand. Information: Suzanne L. Baldwin, Department of Geosciences, University of Arizona, Tucson, AZ 85721, (520) 621-9688, fax 520-621-2672, baldwin@geo.arizona.edu.

June
June 18-24, **Terrane Accretion along the Western Cordilleran Margin: Constraints on Timing and Displacement**, Winthrop, Washington. Information: J. Brian Mahoney, Department of Geology, University of Wisconsin, Eau Claire, WI 54702-4004, (715) 836-4952, fax 715-836-2380, mahonej@uwec.edu.

August
August 17-22, **The Marine Eocene-Oligocene Transition**, Olympia, Washington. Information: Donald R. Prothero, Department of Geology, Occidental College, 1600 Campus Road, Los Angeles, CA 90041, (213) 259-2557, fax 213-259-2704, prothero@oxy.edu.

1998 Meetings

June
June 25–26, **Western United States Earthquake Insurance Summit,** Sacramento, California. Information: Western States Seismic Policy Council, 121 Second St., 4th Floor, San Francisco, CA 94105, (415) 974-6435, fax 415-974-1747, summit@wsspc.org, www.wsspc.org/summit.

September
September 3–6, 1998, **Earth Stress and Industry–The World Stress Map and Beyond (Euroconference),** Heidelberg, Germany. Information: WSM Euroconference Office, Geophysical Institute, University of Karlsruhe, Hertzstraße 16, 76187 Karlsruhe, Germany, fax: 49 721 71173, wsm@gpiwap1.physik.uni-karlsruhe.de.

September 9–14, **Association of Earth Science Editors–European Association of Science Editors–Council of Biology Editors–GeoInfo VI,** Washington, D.C. Information: Barbara Haner, Science & Engineering Library, 4697 Geology Bldg., University of California, Los Angeles, CA 90095, (310) 825-1055, bhaner@library.ucla.edu, or http://earth.agu.org/editorinfo98.

1999 Meetings

January
January 24–27, **Conference on Tailings and Mine Waste,** Fort Collins, Colorado. Information: Linda Hinshaw, Dept. of Civil Engineering, Colorado State University, Fort Collins, CO 80523-1372, (970) 491-6081, fax 970-491-3584 or 7727, lhinshaw@engr.colostate.edu. *(Abstracts deadline: June 12, 1998.)*

March
March 1–3, **13th International Conference and Workshops on Applied Remote Sensing,** Vancouver, British Columbia. Information: ERIM Geologic Conferences, Box 134008, Ann Arbor, MI 48114-4008, (734) 994-1200, ext. 3234, fax 734-994-5123, wallman@erim-int.com, http://www.erim-int.com/CONF/conf.html. *(Abstracts deadline: July 13, 1998.)*

April
April 26–28, **Thrust Tectonics 99,** Egham, Surrey, UK. Information: K. R. McClay, Royal Holloway University of London, Egham, Surrey TW20 0EX, UK, phone 44-1784-443618, fax 44-1784-438925.

May
May 26–28, **Geological Association of Canada–Mineralogical Association of Canada Joint Annual Meeting,** Sudbury, Ontario. Information: P. Copper, Dept. of Earth Sciences, Laurentian University, Sudbury, Ontario P3E 2C6, Canada, (705) 675-1151, ext. 2267, fax 705-675-4898, gacmac99@nickel.laurentian.ca.

June
June 6–9, **37th U.S. Rock Mechanics Symposium,** Vail, Colorado. Information: ExpoMasters, 7632 E. Costilla Ave., Englewood, CO 80112, (303) 771-2000, fax 303-843-6212, mcramer@expomasters.com.

June 21–24, **International Gemological Symposium,** San Diego, California. Information: Dona Dirlam, Gemological Institute of America, 5345 Armada Dr., Carlsbad, CA 92008, (760) 603-4154, fax 760-603-4256, ddirlam@gia.edu. *(Abstract (poster) deadline: October 1, 1998.)*

July
July 11–16, **Meteoritical Society 62nd Annual Meeting,** Johannesburg, South Africa. Information: W. U. Reimold, Dept. of Geology, University of the Witwatersrand, Private Bag 3, P.O. Wits 2050, Johannesburg, South Africa, phone 27 11 716 2946, fax 27 11 339 1697, 065wur@cosmos.wits.ac.za.

Send notices of meetings of general interest, in format above, to Editor, *GSA Today,* P.O. Box 9140, Boulder, CO 80301, E-mail: editing@geosociety.org.

Friends of Paleobiogeography To Meet

Friends of Paleobiogeography, formed in 1996, works on (1) developing a consensus on the principles of paleobiogeographic classification and nomenclature of paleobiogeographic units (biochores) that are congruent with neobiogeography, and (2) applying those principles to published biochores by compiling all named units on a single set of maps and analyzing synonymies and homonymies.

The group, led by Gerd E. G. Westermann, McMaster University, plans to meet at major national and international conferences, including the 1998 GSA Annual Meeting in Toronto, Ontario, in October.

For more information, contact Westermann at School of Geography and Geology, McMaster University, Hamilton, Ontario L8S 4M1, Canada, opperman@mcmaster.ca.

Things To Do in Denver …

Internationally known computer expert Betty Gibbs, publisher of *Earth Science Computer Applications* (formerly *Computers & Mining*) will coordinate a display in the 1998 mining and minerals exhibit at the Festival of Mountain and Plain–A Taste of Colorado in downtown Denver over Labor Day weekend this year. The Computer Science Learning Center will involve hands-on hardware with software on exploration, mining, reclamations, etc.

Volunteers are needed to help Gibbs set up the display and describe modern exploration, mining, processing, and reclamation technologies to exhibit attendees (estimated to be 40,000 people).

If you are willing to help with this high-impact public education project, please contact Betty Gibbs (bgibbs@csn.org, http://www.csn.net/~bgibbs/erthsci/) or Guy Johnson, exhibit coordiantor for the Colorado Mining Exhibit Foundation at (303) 969-0365, fax 303-716-0503, GPJ222@aol.com.

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Positions Open

GEOMORPHOLOGY POSITION
UNIVERSITY OF ARIZONA

The Department of Geosciences at the University of Arizona 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 collaboration 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 process will begin July 1, 1998 and 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: Professor Joaquin Ruiz, Chairman, Department of Geosciences, The University of Arizona, Tucson, AZ 85721, PH: (520) 621-6024, FAX: 520-621-2672; chair@geo.arizona.edu.

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

HYDROGEOLOGIST

Kansas Geological Survey, Univ. 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.

RESEARCH GEOLOGIST
IDAHO GEOLOGICAL SURVEY

The Idaho Geological Survey (IGS) invites applications for a Research Geologist. The IGS is the lead agency in the state for the collection, interpretation, and dissemination of all geologic and mineral information for Idaho. As a Special Program of the university of Idaho, the IGS researches the state's geology and its mineral resources and provides geologically related services to the public. The position requires a scientist who is capable of undertaking research into the basic geologic framework of the state, with an emphasis on publishing studies useful to the state's citizens.

Qualified candidates will demonstrate an ability for outstanding field research and geologic mapping, indicate a background and interest to obtain externally funded programs, and exhibit excellent written and oral communication skills. Qualified candidates also will demonstrate an interest in and an ability to interact with industry, local, state, and federal agencies, educational institutions, the general public, and professional collegues. The successful applicant will conduct research and perform service with little direct supervision, and will participate in the pursuit of funding for IGS programs.

A Ph.D. in geology is required. Candidates with experience and expertise in field geology and geologic mapping are preferred. Experience investigating the geology and ore deposits of Idaho is desirable. Applicants experienced in using computers for word processing, graphics, data manipulation, and in using the Internet are preferred. Interested persons should send a letter of application, curriculum vitae, separate statements of research interests and philosophy of geological service to the public, and the names, addresses, telephone numbers, and e-mail addresses of three references to: Kurt Othberg, Search Committee, Idaho Geological Survey, University of Idaho, Moscow, ID 83844-3014. Search will be closed when a sufficient number of qualified applicants have been identified, but not earlier than April 30, 1998. The IGS and the University of Idaho are equal opportunity/affirmative action employers. Applications from women and minority groups are strongly encouraged.

THE UNIVERSITY OF NEW BRUNSWICK
ECONOMIC GEOLOGIST

Applications are invited for the CHAIR IN ECONOMIC GEOLOGY to be appointed at the Assistant Professor level. The position is at this time supported for a 4 year term. As a priority position within the Department and Faculty of Science, it is intended to establish the Chair as a tenure-track position at the earliest possible date. Responsibilities will include undergraduate and graduate teaching covering resource exploration, evaluation and development. The Department of Geology supports Geology, Environmental Geochemistry and Geological Engineering programs, to which all faculty contribute. The Department is particularly seeking a candidate who can integrate into and complement existing research interests. Candidates must have a Ph.D. at the time of appointment, with a strong background in some aspect of mineral deposits geology (e.g. mineral exploration science, stable isotopes, ore genesis). The successful candidate is expected to develop a research focus on mineral deposits and other economic/resource geology topics through an externally-funded research program.

The Department of Geology is involved in rejuvenation of its faculty and anticipates significant opportunities for the successful candidate. Research facilities include microprobe, analytical SEM & TEM, XRD, high-temperature geochemistry lab, AA/graphite furnace/ICP and GIS lab. Given suitable candidates, the position is available as of July 1, 1998. It is intended to fill the position by January 1, 1999. In accordance with Canadian immigration requirements, this advertisement is directed to Canadian citizens and permanent residents. Applicants are asked to provide a curriculum vitae, a statement of teaching and research plans, and arrange for three letters of recommendation to be sent directly to: Dr. Joseph C. White, Chair, Department of Geology, University of New Brunswick, 2 Balley Drive, Fredericton, NB E3B 5A3 CANADA.

The University of New Brunswick is committed to the principle of Employment Equity.

SYSTEMS PERFORMANCE
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The U.S. Nuclear Regulatory Commission is currently seeking a Systems Performance Analyst for our Rockville, MD location. Responsibilities include evaluating, integrating and applying geostatistical methods in system performance assessments of radioactive waste disposal facilities; applying the results of these assessments to the evaluation of evolving statutory requirements, environmental standards, environmental impacts, and regulatory criteria relevant to NRC's waste management and decommissioning programs; and developing technical positions and review plans for implementation of performance assessment.

Requires BS/BA or equivalent combination of education, training, and experience; and at least 1 year experience at next lower grade level.

Additional information and application materials should be obtained by calling the NRC Personnel Smartline at (800) 952-9678. Refer to Vacancy Announcement R9848017. Please send your resume or Federal application (OF-612) and statement addressing rating factors and salary history, no later than 05/11/98 to: U.S. Nuclear Regulatory Commission, Office of Human Resources, Attn: Tammy Simmons (Dept. A-98104), Mail Stop: T2-D32, Washington, DC 20555. EOE, M/F/D/V. U.S. citizenship required.

HARVARD UNIVERSITY
DEPARTMENT OF EARTH & PLANETARY SCIENCES
JUNIOR FACULTY POSITION

The Department of Earth and Planetary Sciences at Harvard University seeks to fill a tenure-track position at the assistant or untenured associate professor level. We are interested in candidates who investigate the processes and evolution of the Earth and planets through studies of the physical and chemical properties of rocks, minerals and melts. The incumbent will be expected to develop a strong research program and to teach at the undergraduate and graduate levels. Applicants should send a statement of research and teaching interests, curriculum vitae and the names of three referees to Prof. Roberta Rudnick, Chair, Petrology Search Committee, Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, MA 02138. Applications should be received by September 15, 1998. We particularly encourage applications from women and minorities. For more information about the department you may visit our web stie at: www.eps.harvard.edu

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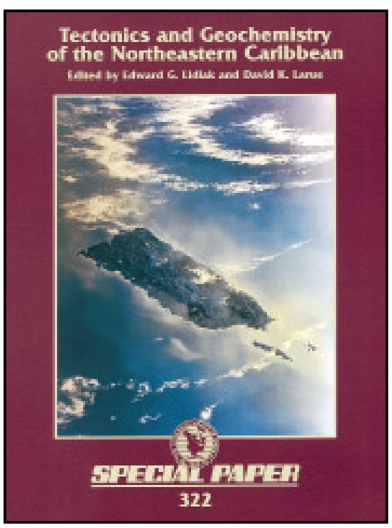
1998 ANNUAL MEETING AND EXPOSITION — **October 26–29, 1998**

Tectonics AND Geochemistry OF THE Northeastern Caribbean

edited by
Edward G. Lidiak and
David K. Larue, 1998



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.

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