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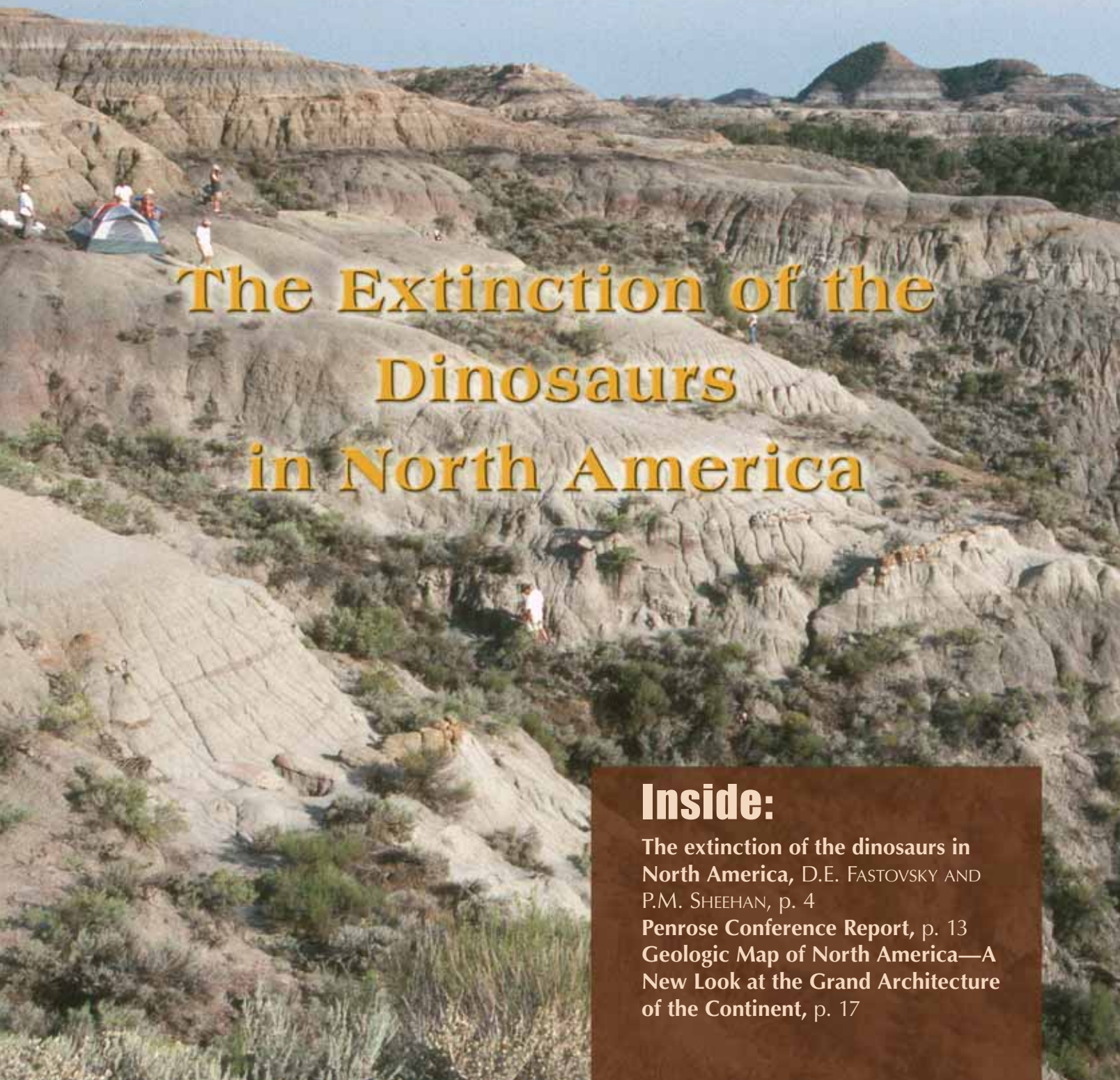

The Extinction of the Dinosaurs in North America

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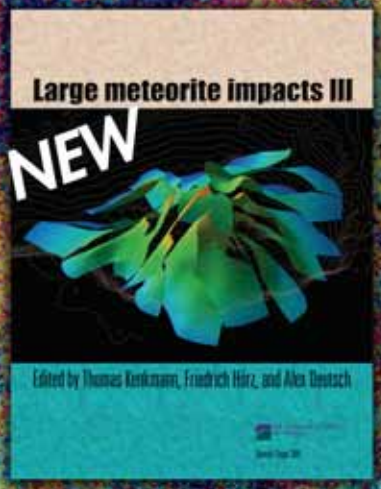

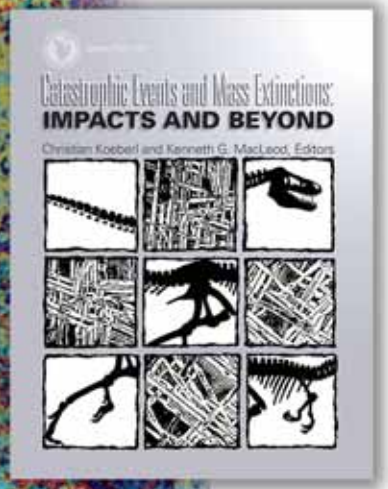

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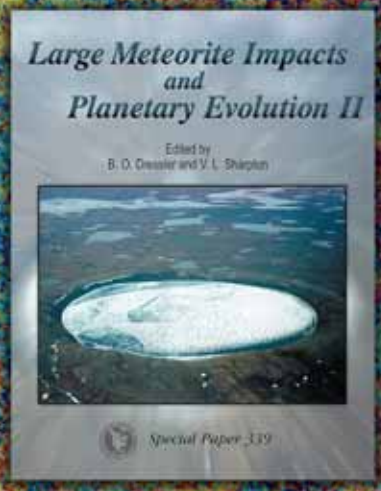

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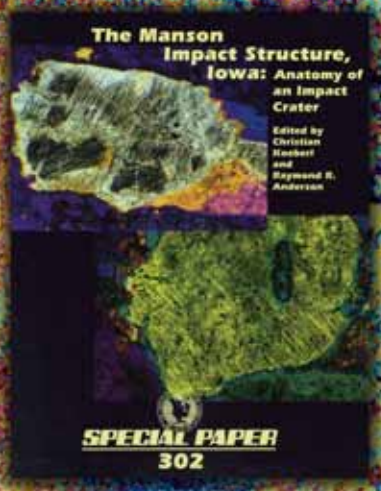

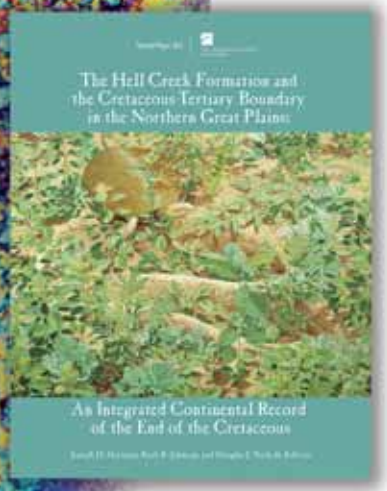

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Space radar image of the Yucatan Impact Crater site by the California Institute of Technology. Used with permission from NASA.

GSA TODAY

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Cover: The Cretaceous–Tertiary (K-T) boundary (next to tent) at the Sand Creek Overlook, Makoshika State Park, Montana, USA. Here the K-T boundary coincides with the lithologic boundary between the Fort Union Formation and the underlying Hell Creek Formation permitting identification of both boundaries in the field. Photo by Joanne Peterson, Milwankee Public Museum. See "The extinction of the dinosaurs in North America" by D.E. Fastovsky and P.M. Sheehan, p. 4–10.

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The Extinction of the Dinosaurs in North America

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ABSTRACT

Rightly or wrongly, dinosaurs are poster children for the Cretaceous-Tertiary (K-T) extinction. The rate and cause of their extinction, however, has been contentious, at least in part because of their rarity. Nonetheless, significant data have accumulated to indicate that the dinosaur extinction, in North America at least, was geologically instantaneous. The evidence comes from field studies in geologically disparate settings involving the reconstruction of dinosaur stratigraphic ranges as well as community structure in the Late Cretaceous, and from quantitative studies of the post-Cretaceous evolution of mammals.

The hypothesis of extinction by asteroid impact is concordant with what is known of the rate of the dinosaur extinction, as well as the patterns of selective vertebrate survivorship across the K-T boundary. The precise nature of the kill mechanism(s), however, remains under discussion.

INTRODUCTION

The question of what happened to the dinosaurs at the Cretaceous-Tertiary (K-T) boundary has come to exemplify the K-T extinction. Did they die out instantly, or were they gradually going extinct over millions of years? As has been noted by Clemens et al. (1981), identifying the patterns of the dinosaur extinction is a question quite separate from, but a prerequisite to, identifying the cause(s) of the extinction itself. In the last 25 years, much has been learned about the patterns of the dinosaur extinction. Ultimately, what we know about extinction patterns constrains causal mechanisms, a point forcibly made by Bakker (1986). Here, we review a variety of different studies, all of which ultimately converge on the conclusion that the extinction of the dinosaurs in North America was geologically instantaneous. From this conclusion and data pertaining to the post-Cretaceous recovery, we consider potential causes of the extinction.

For many years it has been said that dinosaurs were waning in number and diversity over the last 10 m.y. of the Cretaceous (the Campanian-Maastrichtian interval). A typical statement of this viewpoint can be found in Dodson (1996) who notes, "[Among dinosaurs] I see a pattern of dwindling. Ten million years before the end [the K-T boundary] there were two subfamilies of ceratopsids. …At the end, only the chasmosaurines were left. Ten million years before the end, there were two families of hadrosaurs. …At the end, only the hadrosaurines were left. Ten million years before the end, there were two families of armoured dinosaurs. …At the end, only the ankylosaurids were left" (p. 280).

This apparent drop in diversity looks to us to be comparable to other Late Cretaceous fluctuations in the imperfect dinosaur record. Considered in the context of all dinosaur diversity fluctuations throughout the Late Cretaceous, this drop in diversity over the last 10 m.y. does not appear remarkable, either for North America or globally (Fastovsky et al., 2004). Consequently, we focus here on the final two m.y. of the dinosaur record as key to the rate and mechanism of their extinction.

It would be ideal to be able to resolve the precise duration of the North American dinosaur extinction, no matter what its length. At a temporal distance of 65 m.y. and beset by a fragmentary terrestrial record, however, we can only characterize events as geologically instantaneous, by which we mean encompassing timescales of tens of thousands of years (or less). Nonetheless, this allows us to distinguish between processes and events that occurred on such timescales (or less) and those that occurred on longer ones.

Global databases for dinosaurs exist (e.g., Weishampel et al., 2004), and fluxes in dinosaur diversity have been reconstructed from them (e.g., Dodson, 1990; Fastovsky et al., 2004); yet, the North American record remains uniquely suited to understanding the rate of the dinosaur extinction. This is because only in North America are there dinosaur-bearing exposures with a high level of stratigraphic resolution that preserve a terrestrial K-T boundary *and* that have been studied quantitatively.

SEDIMENTARY ENVIRONMENTS THAT PRESERVE THE LATE HISTORY OF THE DINOSAURS

In the latest Cretaceous of the North American Western Interior, dinosaurs such as *Triceratops*, *Tyrannosaurus*, and *Edmontosaurus* (and a host of lesser luminaries) roamed upland and coastal plain settings (Lehman, 1987) that formed during the Laramide phase of the Rocky Mountain uplift (Peterson, 1986). Dinosaur-bearing units that have been the subjects of studies sufficiently detailed to resolve the nature of the extinction are preserved in the structurally complicated Hanna Basin, an intermontane basin in southern Wyoming (Eberle and Lillegraven, 1998; Lillegraven et al., 2004), and undeformed sediments of the Williston Basin, an intracratonic basin extending through eastern Montana and western North and South Dakota (Peterson, 1986) (Fig. 1).

In the Hanna Basin, the K-T boundary is found within the Ferris Formation,

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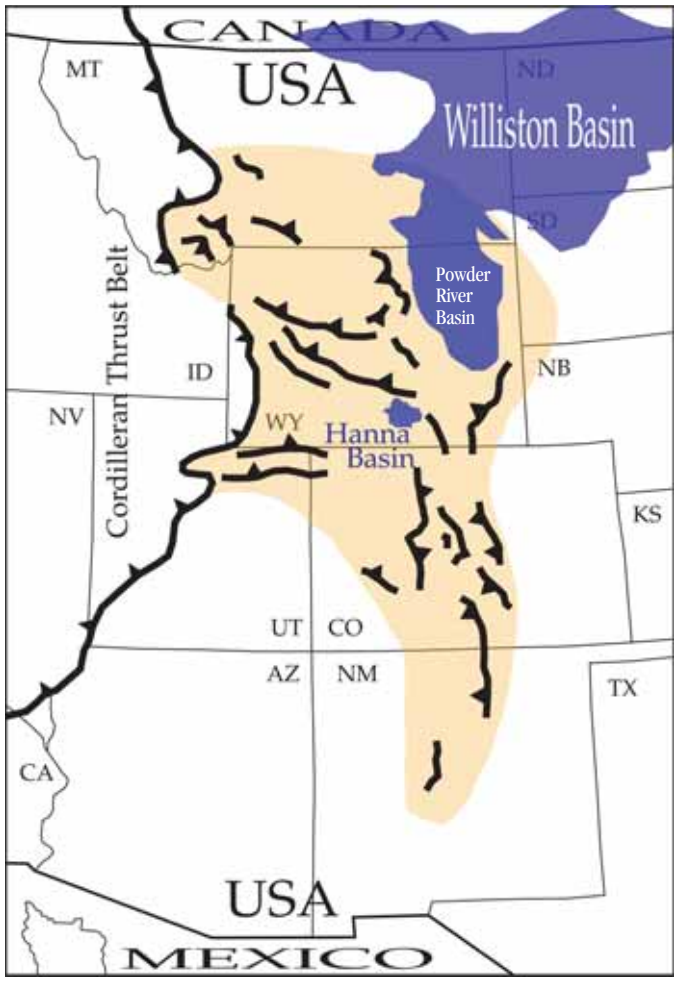

Figure 1. The Western Interior of North America, showing in blue the Cretaceous-Tertiary Hanna, Williston, and contiguous Powder River (not discussed here) basins. Area shown in tan exhibits Laramide deformation; Laramide-age thrust faults shown as barbed lines. Redrawn from Hamilton (1988) and Lillegraven and Eberle (1999).

a 1.2-km-thick sequence of sandstones and mudstones interpreted to represent fluvial deposition. A well-developed braided river system bisects the Cretaceous part of the formation, giving way (~300 m below the K-T boundary) to a meandering fluvial system with lacustrine subenvironments (Eberle and Lillegraven, 1998; Wroblewski, 2003, 2004). In the Williston Basin, the latest Cretaceous is represented by the Hell Creek Formation, a unit that consists of ~100 m of mudstones interbedded with sandstones, interpreted as the remnants of ancient, meandering, aggradational fluvial systems (Fastovsky, 1987; Murphy et al., 2002).

Like some great cosmic joke designed to frustrate paleontologists, the K-T boundary is rarely found in a thick sequence of strata unambiguously representing continuous deposition in a single paleoenvironmental setting. In the Hanna Basin, the K-T boundary probably occurs adjacent to or within a disconformity-bounded, 8-m-thick, complexly channeled sandstone, the so-called "zone of uncertainty" of Lillegraven and Eberle (1999). By contrast, in the Williston Basin, the boundary interval is characterized by a facies change in which the interbedded mudstones and sandstones of the Hell Creek Formation generally give way to extensive laminated siltstones and coal deposits of the basal part of the Fort Union Formation (Fastovsky, 1987; Lofgren, 1995). The lithostratigraphic contact between the Hell Creek and Fort Union Formations is not precisely isosynchronous, but varies by as much as 3 m above or below the palynologically identified K-T boundary (see Fastovsky, 1987; Johnson, 1992; Lund et al., 2002; Nichols and Johnson, 2002; Pearson et al., 2002). The low density of dinosaur preservation (an estimated 0.000056 dinosaurs/m^2 of exposure; White et al., 1998) means that in practice, the facies change is commonly (but certainly not always) associated with the dinosaur extinction.

RECONSTRUCTING FLUXES IN DINOSAUR DIVERSITY AT THE K-T BOUNDARY

Over the past 15 years, three studies, by three different research groups using different approaches, have produced stratigraphically refined, quantitative data bearing upon the rate of the Late Cretaceous dinosaur extinction in western North America.

Hanna Basin

Dinosaur distributions in the Hanna Basin were studied by determining, with maximum refinement, the stratigraphic ranges of taxa preserved in the Ferris Formation. Stratigraphic relations were established using a combination of palynostratigraphy and North American Land Mammal "Ages" (Cifelli et al., 2004; Lofgren et al., 2004; see also Grimaldi et al., 2000). Seventy-six vertebrate-bearing localities contributed to the results of the study (Fig. 2). Regarding the pattern of dinosaur extinction, Lillegraven and Eberle (1999, p. 702) concluded "there exists little evidence for progressive reductions in taxonomic diversity of the local dinosaurian fauna… Indeed, our collections show that, exclusive of the rare forms, most species of dinosaurs from the Ferris Formation are represented up [to] … the eight meter thick zone of complexly channeled sandstone that is uncertain in age. …The late history of local dinosaurs seemed to have a sudden termination. That is, high taxonomic diversity persisted late into the [latest Cretaceous]…"

The authors thus identified a geologically instantaneous extinction, but, given the issues of temporal resolution described above, noted that their study could not distinguish between events that took place on 1000 to 10,000 year timescales and those that are much shorter.

Williston Basin

Sheehan et al. (1991) divided the Hell Creek into three sequential stratigraphic windows to test whether community-level changes among dinosaur assemblages were compatible with long-term extinction scenarios. A methodologically controlled census of dinosaur remains through the thickness of the formation produced a minimum number of 556 in situ, precisely located individuals within the Hell Creek Formation. Using rarefaction to compare the communities among the three windows, Sheehan et al. (1991) found that the number, rank order, and relative proportions of families were unchanged, indicating stable communities through the formation, and concluded that "there is no statistically meaningful drop in the ecological diversity of dinosaurs through

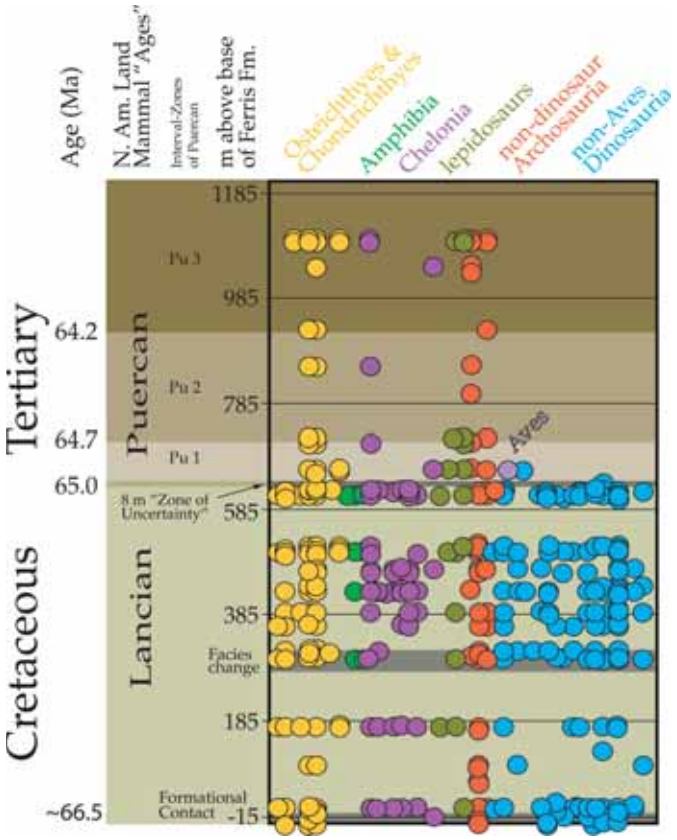

Figure 2. Stratigraphic range chart showing the distribution of non-mammalian fossil vertebrate specimens in the Ferris Formation in the Hanna Basin (data from Lillegraven and Eberle, 1999). Dinosaurs essentially disappear at the base of the 8-m-thick, largely unfossiliferous, "zone of uncertainty" (see text). Three exceptions to this are an isolated tooth found within the "zone of uncertainty" and two water-worn specimens, interpreted by Lillegraven and Eberle (1999) as Cretaceous material reworked in earliest Tertiary time. Formation thickness and key lithological changes, biostratigraphic zonations (North American Land Mammal "Ages" and "Interval Zones"), and geochronology (Ma) are shown on left. Dates are ±0.1 m.y. (interpolated from Lofgren et al., 2004; basal date from Grimaldi et al., 2000).

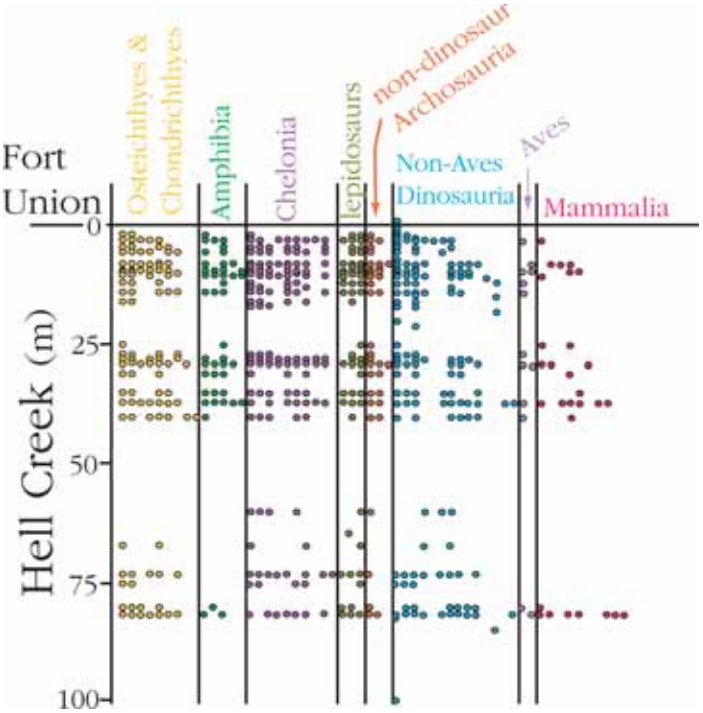

Figure 3. Composite stratigraphic range chart showing the distribution of identifiable fossil vertebrate specimens in the Hell Creek Formation, which records the last 1.4 m.y. of the Cretaceous in the Williston Basin. In the case of dinosaurs, no decrease in diversity could be found. A single non-avian dinosaur in the basal part of the Fort Union Formation demonstrates the diachroneity of the lithostratigraphic contact between the Hell Creek and Fort Union, reaffirming that in places, the basal Fort Union is Cretaceous in age. Redrawn from Pearson et al. (2002).

the Hell Creek. [O]ur data are compatible with abrupt extinction scenarios" (p. 838). The Sheehan et al. (1991) study was criticized for its use of rarefaction by Hurlbert and Archibald (1995), who noted that the technique was "only weakly related to ... variables such as absolute numbers of dinosaur taxa, population densities, or extinction rates" (p. 881). Sheehan et al. (1996) countered that the critique was misdirected because these variables were not the ones under consideration. They noted that absence of a taxonomic decline was established without rarefaction (number and rank order of taxa were unchanged) and affirmed that the statistical treatment was only an effort to search for a community-level reorganization such as might indicate a deteriorating ecosystem.

Approaching the question from a biostratigraphic perspective, Pearson et al. (2002) undertook a 10-year effort to determine the stratigraphic distribution of taxa in the Hell Creek (Fig. 3). At each of the 82 sites distributed among 20 localities that they studied, they identified the K-T boundary via pollen and then surveyed the vertebrate faunas found in each locality. Their database included 2233 dinosaur specimens distributed among 14 taxa and located to precise stratigraphic horizon. The results showed no obvious change in diversity through the Hell Creek, an inference that they statistically tested via rarefaction. They concluded, "there is no evidence for a decreasing trend [in diversity] through the formation … these results are not compatible with gradual extinction at the end of the Cretaceous" (p. 164–165).

All published, quantitative, stratigraphically refined, field-based studies involving dinosaurs are sending the same clear signal of geologically instantaneous extinction.

THE RECOVERY

One may also approach this problem from a quite different perspective: A catastrophic perturbation to the ecosystem, as has been proposed, ought to leave some kind of mark in the fossil record, reflected in the subsequent recovery of the ecosystem. And indeed, it has been common knowledge almost since dinosaurs were first identified as Mesozoic beasts that the terrestrial K-T boundary is characterized by a stunning ecosystemic turnover marked by the extinction of dinosaurs and the radiation of mammals. The nature of these early mammals has also long been well known: they were small, presumably omnivorous, generalists (e.g., Lillegraven et al., 1979; Maas and Krause, 1994). While their connection to more recent mammals is becoming manifest (e.g., Archibald et al., 2001; Archibald, 2002, 2003), and while modern clades of placental mammals may have roots prior to the K-T boundary,

there is little comparison to be made between the *appearance* of modern mammalian clades during Late Cretaceous time and the *radiation* that followed the K-T boundary.

Like the dinosaur extinction, mammalian evolution in the early Tertiary of North America has been evaluated quantitatively (Maas and Krause, 1994; Alroy, 1999; Archibald and Deutschman, 2001). All agree that earliest Tertiary mammals underwent high rates of speciation leading to a steep increase in rates of diversification during the first 5 m.y. of the Tertiary (Fig. 4). Indeed, seventeen of the eighteen orders of extant placental mammals did not exist before the K-T boundary (Archibald, 2002).

A range of evolutionary specializations took place during the early Tertiary, as mammals invaded ecospace abandoned by dinosaurs. As noted by Alroy (1998), "... the data are compatible with the idea that the extinction of large terrestrial vertebrates such as dinosaurs at the K-T boundary opened up the larger end of the body size spectrum for occupation by mammals" (p. 733).

Just how quickly did the post–K-T mammalian radiation proceed? Eberle and Lillegraven (1998) record increasing body sizes among primitive eutherian mammals (condylarths) within 400,000 yr of the K-T boundary in the Hanna Basin. Still, Maas and Krause (1994) report that it took mammals 3–5 m.y. to develop the broad range of body sizes and diversity of ecologic specializations that have characterized all successive, stable, mammalian faunas throughout the Cenozoic (e.g., Janis et al., 1998). An even longer estimate was provided by Kirchner and Weil (2000), who suggested that the recovery took as long as 10 m.y.

Rates of evolution were evidently fueled by multiple waves of immigration (Weil and Clemens, 1998; Lillegraven and Eberle, 1999; Clemens, 2002). Clemens (2002) summarizes this viewpoint: "Recovery of the terrestrial vertebrate fauna [in eastern Montana] was not simply the product of an explosive evolutionary radiation of a few surviving stocks. Immigration from other areas played a major role in reconstitution of mammalian diversity" (p. 240).

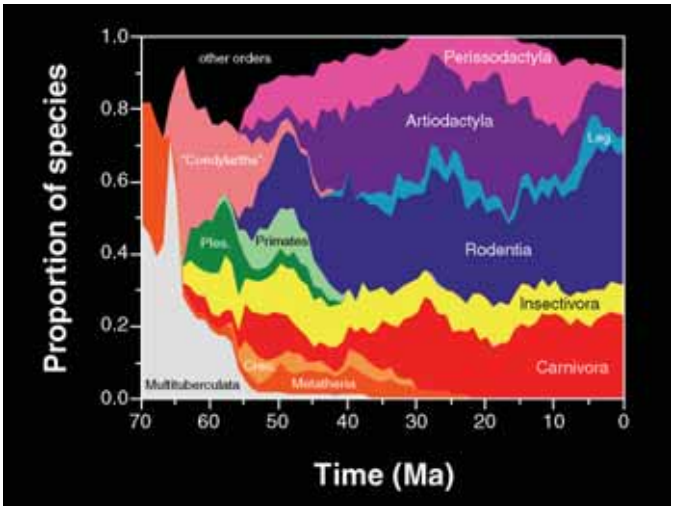

Figure 4. Cenozoic mammalian ordinal diversity plotted as a function of time. Note the sharp rises in the diversity of condylarths at 65 Ma and the secondary evolutionary bursts of Plesiadapiformes ("Ples.") and insectivores at 62–63 Ma. By 55 Ma, all of these orders of mammals started to become far less dominant as the larger, more diversified perissodactyls, artiodactyls, carnivorans, and rodents became important parts of successive global mammalian faunas. (From Alroy, 1999; also at http://www.nceas.ucsb.edu/~alroy/mammalorders.gif).

Interestingly, all accounts suggest that the timing of the post–K-T radiation of mammals lags somewhat behind that observed by d'Hondt et al. (1996, 1998) for planktonic foraminifera after the K-T boundary. However, these estimates of mammalian recovery intervals are in the range of those for other organisms following other mass extinction events (Jablonski, 1991).

The record of earliest Tertiary mammals, with its high rates of speciation and diversification and generally delayed onset of broad morphological specializations and size disparities, appears very much like the kinds of faunas and floras that typically develop after ecological traumas: the so-called "disaster species" (Brenchley and Harper, 1998). Indeed, evolutionary patterns in the earliest Tertiary are generally termed a *recovery* (but see Lillegraven and Eberle, 1999), signaling that there was something from which to recover.

CAUSES: SO WHAT KILLED THE DINOSAURS?

We have spent much of this article reviewing aspects of the pattern (in this case, the rate) of the North American dinosaur extinction. Causal factors are necessarily much more difficult to identify, because while events can potentially be shown to be coincident, the demonstration of causality is far more problematical. Indeed, the extinction of the dinosaurs has a notorious, ongoing history of insouciant proposals unfettered by data (see Fastovsky and Weishampel, 2005).

Our interest, however, is in published models that are grounded in data and that are potentially testable. In this category, Archibald and Bryant (1990) and Archibald (1996, 1997), basing their interpretations upon patterns of vertebrate survivorship, proposed marine regression with associated habitat fragmentation as the ultimate cause of the K-T extinctions. In this model, multiplication and lengthening of river systems due to a marine regression led to a diminution and fragmentation of coastal plain habitats, in turn causing range reductions and eventual extinction. A variation on this model was proposed by Dingus and Rowe (1997), who suggested that the regression in combination with latest Cretaceous igneous activity *and* the asteroid impact caused the extinction of the dinosaurs.

The conclusion that the extinction of the dinosaurs was geologically instantaneous precludes longer-term causes (e.g., events on million to ten-million-year timescales). So, although survivorship patterns may be in accord with habitat fragmentation–based models, habitat fragmentation as the driving force for the dinosaur extinction is problematical, because it is linked in this case to a marine regression that occurred over a million or more years. Moreover, recent stratigraphic work summarized in Johnson et al. (2002) suggests that the Hell Creek was deposited rather quickly (over ~1.4 m.y.; Hicks et al., 1999, 2002) in a transgressive setting (the final transgression of the North American Western Interior Sea). This interpretation is concordant with a previously inferred rise in the water table (Fastovsky and McSweeney, 1987). The transgressive geological setting is antithetical to the proposed

fluvial lengthening associated with the habitat fragmentation scenario and suggests that it was not likely a factor in the North American dinosaur extinction.

Death by Asteroid

The current "alternative hypothesis" for the cause of the extinction of the dinosaurs is, of course, an asteroid impact with Earth. Schultz and d'Hondt (1996), using the morphology of the crater as an indicator of the angle and direction of the impact, proposed that the Western Interior of North America would bear the brunt of impact effects. In all scenarios, wholesale extinctions on extremely short timescales are presumed to be a consequence of such an event. While the extinction cannot be shown to have occurred within hours, days, or weeks, extinction timescales can be constrained to a few tens of thousands of years *or less*. For this reason, what is known of the rate of the dinosaur extinction in North America is concordant with the predicted effects of an asteroid.

In this brave new world of an asteroid blight, how did some organisms survive and others became extinct? A number of workers (e.g., Weil, 1994; Archibald and Bryant, 1990; Archibald, 1996, 1997; Dingus and Rowe, 1997) have argued that the patterns of survivorship are not concordant with the expected effects of an asteroid impact. Such effects include global wildfires (Wolbach et al., 1988; Ivany and Salawich, 1993), acid rain (Prinn and Fegley, 1987; Zahnle, 1990; Retallack, 2004), and atmospheric dust (Alvarez et al., 1980).[1]

On the other hand, Sheehan and Hansen (1986) first proposed, for both marine and terrestrial faunas, that buffering against the effects of the K-T extinction might accrue from detritus feeding because animals in detritus-based food chains appear to have fared better than those dependent upon primary production. Sheehan and Fastovsky (1992) and Archibald (1993, 1996), using data from eastern Montana first presented in Archibald and Bryant (1990), demonstrated that in the terrestrial realm, aquatic organisms fared better than their fully terrestrial counterparts. Sheehan and Fastovsky (1992) proposed that aquatic organisms were generally more likely than exclusively terrestrial organisms to be in detritus-based food chains (see also Retallack, 2004) and that among terrestrial animals, those able to feed in detritus-based food chains (e.g., mammals) were more likely to survive than animals in food chains dependent on primary production (e.g., dinosaurs). In Sheehan and Fastovsky's (1992) scenario, as in the original Alvarez et al. (1980) scenario, sunlight was blocked for an extended period of time, causing a collapse in primary production and holding out the hope of survivorship to only those who could live exclusively from detritus.

These ideas were recently revisited by Robertson et al. (2004), who quantified a previously proposed infrared thermal pulse from a global rain of hot spherules (splashed from the K-T impact), reassessed the patterns of biotic survivorship, and suggested that the short-term (hours-long), global pulse of intense infrared radiation was the primary killing agent. It would have caused severe thermal stress and ignited global wildfires that incinerated anything that could not shelter itself: "sheltering underground, within natural cavities, or in water was the fundamental means to survival during the first few hours of the Cenozoic. Shelter was by itself not enough to guarantee survival, but lack of shelter would have been lethal" (Robertson et al., 2004, p. 760). This model differs from its antecedents because a heat pulse (and subsequent wildfires) rather than the cessation of photosynthesis, was the primarily killing agent, and thermal sheltering, rather than detritus feeding, allowed survival.

We sincerely doubt that we have reported the last word on the cause of the extinction of the dinosaurs. This is in part because, as we have seen, the number of studies reconstructing the pattern of the extinction is sparse and the temporal resolution of the data is limited. Moreover, in the case of the asteroid impact, although the enormous energy released by the impact made disastrous environmental consequences inevitable, a generally accepted model for all the environmental changes associated with the K-T impact has not yet emerged. Indeed, each of the potential effects of an asteroid impact has been the subject of considerable discussion. Among the putative effects to have undergone reconsideration are global wild fires (Belcher et al., 2003), acid rain (d'Hondt et al., 1994; Maruoka and Koeberl, 2003), and darkness, which may have been caused by aerosols rather than dust (Pope, 2002). Nonetheless, the extinction of the dinosaurs has been characterized by a rich intellectual debate as new methods of extracting highly refined stratigraphic data from sections are pioneered, as new interpretations of global events are entertained, and as an understanding of catastrophic events in earth history (e.g., Powell, 1998) is forged.

CONCLUSIONS

In the 25 years since Alvarez et al. (1980) first proposed that an impact was responsible for the K-T extinctions, stratigraphic and paleoecologic evidence have come together to present a reasonably cohesive picture of a quick demise of the dinosaurs. Evidence from the rates of dinosaur extinction suggests that the extinction was geologically instantaneous; this conclusion in combination with the nature of the post-Cretaceous biologic recovery suggests that the extinction occurred on an extremely short, irresolvable timescale. While the exact killing mechanisms may or may not yet have been identified, all the data—including the rate of extinction, the nature of the recovery, and the patterns of survivorship—are concordant with the hypothesis of extinction by asteroid impact.

[1]To review the most pervasively cited example: Since amphibians are particularly sensitive to pH conditions, and they passed through the boundary largely unscathed, the asteroid impact could not have had a significant involvement in the extinction, because one of its predicted side affects—acid rain—would surely have affected amphibian survivorship (Weil, 1994; Archibald, 1996, 1997). In fact, a significant body of work suggests that the survival of amphibians is good evidence that deadly acid rain was not a major effect of the impact (see also d'Hondt et al., 1994; Maruoka and Koeberl, 2003; Retallack, 2004).

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Comment and Reply
Dilational fault slip and pit chain formation on Mars, David A. Ferrill et al., GSA Today, v. 14, no. 10, p. 4–12.

Comment

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I am greatly intrigued by the cover article in the October issue of *GSA Today* by Ferrill et al. (2004) that describes grabens and pit craters in the Alba Patera region of Mars. The thrust of the article is that north-trending grabens and pit craters on north-northeast–striking structures are the result of east-west dilation (extension). Block diagrams show the pit craters forming along graben-bounding faults; loose surficial material flowed into open space along the dilated graben faults. However, the images of the area (particularly the cover illustration) show clearly that the pit craters formed along the transverse, north-northeast–striking structures, not along the graben-bounding faults.

The question arises, therefore: What *is* the mechanism of pit crater formation? I suggest that the transverse structures are strike-slip faults. Although the article states that the faults in the Alba Patera show "no consistent evidence of strike-slip displacement" (p. 6) (and I agree that the graben fault traces show no clear indication of such), the orientations of the graben faults nevertheless have the relation of gash fractures along left-lateral strike-slip faults defined by the aligned pit craters, and lateral movement on such a structure could result in dilation of segments that are not aligned perfectly with the direction of slip.

Grabens are common structures associated with major strike-slip faults, as along the Alpine fault in New Zealand, the San Andreas in California, and the Great Basin of Nevada. Such an association on Mars would not be a surprise. I have interpreted development of grabens in western Nevada to be related to lateral movement on strike-slip faults (Shawe, 1965). Whatever the case, I think that the origin of the pit craters on Mars is more complex than the October 2004 *GSA Today* cover article infers.

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Reply

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We appreciate Daniel Shawe's interest in our article (Ferrill et al., 2004). We agree that normal faults commonly form in association with strike-slip deformation (e.g., Ramsay and Huber, 1987). In addition, certain geometric features commonly associated with strike-slip deformation, such as en echelon fault arrangement, can form in normal fault stress regimes without strike-slip displacement (Ferrill et al., 1999).

As Shawe noted, the fault pattern in the cover illustration and Figure 3 of Ferrill et al. (2004) shows that pit chains are common along northeast-striking faults and crosscut north-striking faults. Faults that host pit chains have significant vertical components of displacement (e.g., 100–600 m throw, shown in Fig. 1A and in the cover illustration of Ferrill et al., 2004). Where drainage channels are cut by faults, they lack evidence of strike-slip deformation. These observations support our normal fault interpretation for the Alba Patera fault system. Rather than calling on strike-slip deformation, we interpret this fault pattern to reflect evolution of a regional stress field responding to a combination of volcano inflation and deflation and regional extension. This does not negate the possibility that these normal faults could be part of a larger scale strike-slip system. However, in a comprehensive review Schultz (1989) found only small scale strike-slip faults in the Coprates region southeast of the Valles Marineris. The paucity of evidence for strike-slip faulting on Mars, compared with Earth, may be attributable to the apparent lack of large-scale horizontal plate motion and the corresponding geometric requirement for transform plate-boundary displacement. Although we do not see evidence for strike-slip faulting at Alba Patera on Mars, there is active pit crater formation on extensional stepovers within strike-slip systems in southwest Iceland. Pit formation associated with dilational faults in the uppermost crust is expected, regardless of the dilational fault origin.

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GeoTrip: Eastern Australia—Students Only!

June 16–June 27, 2005.
Registration deadline: May 1, 2005.

GeoClass: Geology of Golden, Colorado, and the Surrounding Area

June 17–20, 2005.
Registration deadline: May 1, 2005.

GeoHostel: Geologic Excursions in South-Central Montana

July 9–14, 2005. Registration deadline: June 1, 2005.

To learn more about these trips and how to sign up, see the February issue of *GSA Today*. For complete details on GeoVentures™ or for full itineraries, contact Edna Collis, program officer, 1-800-472-1988, ext. 1034, fax 303-357-1072, ecollis@geosociety.org, or go to geoventures@geosociety.org.

Call for Nominations:

Fourteenth Biggs Award

for Excellence in Earth Science Teaching for Beginning Professors

The Biggs Award was established by GSA to reward and encourage teaching excellence in beginning professors of earth science at the college level.

Eligibility

Earth science instructors and faculty from all academic institutions engaged in undergraduate education who have been teaching full-time for 10 years or fewer. (Part-time teaching is not counted in the 10 years.)

Award Amount

An award of $750 is made possible as a result of support from the Donald and Carolyn Biggs Fund (maintained by the GSA Foundation), the GSA Geoscience Education Division, and GSA's Education and Outreach Programs. In addition, this award also includes up to $500 in travel funds to attend the award presentation at the GSA annual meeting.

Deadline and Nomination Information

Nomination forms for the 2005 Biggs Earth Science Teaching Award are posted at www.geosociety.org/aboutus/awards/biggs.htm. Or, contact Diane Lorenz, (303) 357-1028, awards@geosociety.org. Nominations must be received by **May 1, 2005.**

Mail nomination packets to:

Diane Lorenz
Program Officer, Grants, Awards, and Recognition
Geological Society of America
3300 Penrose Place, P.O. Box 9140
Boulder, CO 80301-9140, USA

2004 BIGGS AWARD

Gregory S. Hancock of William and Mary College receives the 2004 Biggs Award from Heather Macdonald, presented at the National Association of Geoscience Teachers/GSA Geoscience Education Division Luncheon and Awards Reception in Denver, November 2004.

PENROSE CONFERENCE REPORT

Secular Variation in Tectonics and Allied Fields

October 22–28, 2004

Conveners:

***Dwight Bradley**, U.S. Geological Survey, 4200 University Drive, Anchorage, Alaska 99508, USA,* and ***John Dewey**, Geology Department, University of California, One Shields Avenue, Davis, California 95616, USA*

A Penrose Conference on secular variation in tectonics and allied fields was held in St. George, Utah, in October 2004. It was jointly sponsored by the Geological Society of America and the U.S. Geological Survey, and was attended by forty people from ten countries. In keeping with the complexity of the earth system, and with the links between tectonics and most other fields, the conference was intentionally broad in scope. The focus was on long time scales, ranging from the entire span of earth history down to a few hundred million years.

The first three days were devoted to talks, posters, and discussions on secular analysis—the tracking of variables as a function of geologic age. Presentations on a wide range of topics were tailored for non-specialists. The keynote speakers were Kevin Burke on tectonics through time and Jan Veizer on evolution of the sedimentary system. We went on to hear about the mantle lithosphere, mantle dynamics, large igneous provinces, ophiolites, supercontinents, continental margins, accretionary orogens, greenstone belts, orogenic gold deposits, orogenic deformation styles, the plate mosaic, Archean continental crust, metamorphic conditions, continental margin magmatism, cyclicity in fossil diversity, tectonics and life, true and apparent polar wander, redox in the oceans, sediment-hosted ores, paleosols, seawater strontium, quartzite-rhyolite association, metallogeny of snowball episodes, and what drives climate.

Earth history has involved a combination of long-term, irreversible changes, catastrophic events, and cycles. As Kevin Burke put it, most processes affecting the lithosphere are cyclical, but some cyclical interactions have led to extraordinary secular changes. The conference served as a reminder of the value of an encyclopedic approach to earth history and earth system evolution. Any viable scenario must account for (1) the exponential decline in global radiogenic heat production; (2) the absence of rocks older than 4.0 Ga; (3) the existence of detrital zircons as old as 4.4 Ga; (4) the scarcity of komatiites younger than Paleoproterozoic; (5) the decrease in thickness of the thermal continental lithosphere from Archean to present; (6) peaks in the abundance of juvenile continental crust at 2500–2600 and 1800–1900 Ma; (7) peaks in the abundance of orogen gold deposits at 2500–2600 and 100–200 Ma but a complete absence in the Mesoproterozoic; (8) the abundance of massif anorthosites during the Mesoproterozoic; (9) the lack of blueschists before the Neoproterozoic; (10) the long-term increase and shorter-term fluctuations in seawater $^{87}Sr/^{86}Sr$; (11) sulfur-isotopic evidence for an oxidizing atmosphere beginning sometime between 2450 and 2090 Ma; (12) the abundance of banded iron ores between ca. 2000 and 2500 Ma; (13) peaks in the abundance of Mississippi Valley type lead-zinc deposits ca. 300 and 100 Ma; and (14) the unchanged state of mantle redox conditions since the Early Archean. Another fifty items could be added to such a list. An encouraging revelation was the diversity of big problems that may be tractable by secular analysis, despite the patchiness of the early rock record. The utility of ore deposits in the study of earth history made itself clear: Each deposit type requires its own unique alignment of controlling variables to form. Probably the biggest controversy to be aired was the long-standing but still anecdotal debate about the Archean tectonic regime: plate tectonics versus something else. Are we mesmerized by modern Earth? Secular analysis has not been widely applied in structural geology, but perhaps such an approach can be devised for the Archean problem.

A two-day field trip followed. We were led through the Phanerozoic stratigraphy of the Colorado Plateau by Ron Blakey of Northern Arizona University. There is no better place to be reminded of the vastness of geologic time. Ron began with a synthesis of the paleogeographic evolution of the Colorado Plateau, beautifully illustrated by maps that can be seen at the Northern Arizona University Web site, http://jan.ucc.nau.edu/~rcb7/. Highlights of the trip included stops in Jurassic eolian sandstones of Zion Canyon and in Permian sandstones at Toroweap Point in the western Grand Canyon, just upstream of Volcan's Throne, where the Canyon was once dammed by lava flows.

Conference participants included Walter Alvarez, Irina Artemieva, Ron Blakey, Wouter Bleeker, Dwight Bradley, Mike Brown, Kevin Burke, Kent Condie, John Dewey, Yildirim Dilek, Poul Emsbo, Richard Ernst, Rich Goldfarb, David Huston, Karl Karlstrom, Tim Kusky, Lisa Lamb, Dave Leach, David des Marais, Steve Marshak, Shigenori Maruyama, Joe Meert, Walter Mooney, Rich Muller, Steve Piercey, Tim Raub, Greg Retallack, Doug Reusch, Laurence Robb, Robert Rohde, Alexey Shulgin, Tom Skulski, Phil Thurston, Erkan Toraman, Jan Veizer, Gary Vermeij, Brian Windley, and Mike Zientek. Four graduate students were among the group. It was remarkable how many Red Sox fans happened to be in the same place in late October 2004.

A post-conference volume on *Secular Variation through Earth History* (edited by Dwight Bradley) will follow. It will contain 20–25 chapters and, pending approval, will be published as a Geological Society of America Special Paper. Contributions will be welcomed from those who were unable to attend the conference. Watch for the announcement in a future *GSA Today*.

Greetings from Capitol Hill!

2004–2005 Congressional Science Fellow Report

Sarah K. Noble, *2004–2005 GSA–U.S. Geological Survey Congressional Science Fellow*

It has certainly been an exciting fall, politically speaking, and I feel very fortunate to have the opportunity to witness it from the heart of the political world. It is truly amazing how politics permeates everything in this town. Every conversation, no matter what topic you start with, seems to eventually come around to politics.

I am happily settling in to life in this big city. I arrived in D.C. last September and began an intensive three-week orientation with 120 strangers, many of whom have now become close friends and an invaluable support system. Through lectures, field trips, and interactive workshops, all the fellows were given something of a crash course on the U.S. government and the role that science and scientists play in it.

This year's class of fellows is the largest yet in the 30-year history of the program. Thirty-five of us are working with Congress; the rest are scattered throughout the federal government in places like the State Department, Department of Homeland Security, National Institutes of Health, National Science Foundation, and other agencies. We are an incredibly diverse group that includes geologists, chemists, nuclear engineers, biologists, veterinarians, and even psychologists. Some, like me, are fresh out of graduate school, others are on sabbatical from academic or industry positions, and a couple of fellows think this is a fun way to spend their retirement. I have had some fascinating conversations with these people.

After orientation, I had to pound some pavement and find myself a position. The expression "pound the pavement" now has new meaning for me as I quickly learned that the walk between the House and Senate office buildings is not short. What I wouldn't have done to trade in my new dress shoes for my old hiking boots! The interview process itself was quite a learning experience. I interviewed on both the House and Senate side, in both Democrat and Republican offices, and for both personal and committee staff offices. It's amazing to see how each office has its own subculture. Some are very formal with everyone in suits and ties, while others are more relaxed. Senate personal offices are much larger, with 35 or 40 staff members, compared to a typical House office of just eight or nine people. As many of the staff members in a personal office come from the state or district of the member, the office culture tends to reflect the culture of that region of the country. Personal offices, which must deal with every issue that arises, seem to move at a more frantic pace than committee offices, which deal with fewer issues and can take the time to study an issue in more depth.

After about three weeks of dropping off résumés and doing interviews, I joined the minority staff, or Democratic side, of the House Committee on Science. The science committee is divided into four subcommittees, and I have been working largely with the space subcommittee. While I do not engage in daily discussions of the intricacies of space weathering on the Moon and asteroids, topics of my thesis area, I find that my background as a planetary geologist is very useful to the committee. For one thing, I already know most of the National Aeronautic and Space Administration's (NASA) acronyms and, more importantly, my point of view as a scientist allows me to come at many issues from a new and different perspective.

NASA and space exploration seem to be turning into quite a hot issue for the upcoming year. Current topics of interest to the space subcommittee this year include the fate of the Hubble telescope, returning shuttles to flight, the future of the space station, and most significant, the direction of the president's Vision for Space Exploration. I am focusing a lot of my attention on NASA's earth and space sciences programs, trying to ensure that these valuable programs don't get lost in the push for manned exploration of the Moon and beyond.

I am very grateful that GSA and the U.S. Geological Survey have given me this opportunity. Scientists have a vital role to play in creating sound science policy, and I am thrilled to be a part of that process. If you have questions about this fellowship program, or if you have suggestions for improving NASA's earth or space sciences programs, please feel free to contact me.

This manuscript is submitted for publication by Sarah K. Noble, 2004–2005 GSA–U.S. Geological Survey Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 02HQGR0141. The views and conclusions contained in this document 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. Noble can be reached at Sarah.Noble@mail.house.gov.

2005 GSA Section Meetings

NORTHEASTERN SECTION
March 14–16, 2005
Prime Hotel and Conference Center, Saratoga Springs, New York
Information: Kurt Hollocher, Union College, Department of Geology, Olin Building, Nott Street, Schenectady, NY 12308-3107, (518) 388-6518, hollochk@union.edu

SOUTHEASTERN SECTION
March 17–18, 2005
Grand Casino Biloxi, Biloxi, Mississippi
Information: Gail Russell, University of Southern Mississippi, Department of Geology, Box 5044, Hattiesburg, MS 39406-2000, (601) 266-4077, Gail.Russell@usm.edu

SOUTH-CENTRAL SECTION
April 1–2, 2005
Trinity University, San Antonio, Texas
Information: Diane Smith, Trinity University, Department of Geosciences, #45, One Trinity Place, San Antonio, TX 78212-4674, (210) 999-7656, dsmith@trinity.edu

CORDILLERAN SECTION
(*Joint meeting with American Association of Petroleum Geologists*)
April 29–May 1, 2005
Fairmont Hotel, San José, California
Information: Jonathan Miller, San José State University, Department of Geology, 1 Washington Square, San José, CA 95192-0102, (408) 924-5015, jsmiller@email.sjsu.edu

NORTH-CENTRAL SECTION
May 19–20, 2005
University of Minnesota, Minneapolis, Minnesota
Information: Carrie Jennings Patterson, University of Minnesota, Minnesota Geological Survey, 2642 University Ave. W., St. Paul, MN 55114-1032, (612) 627-4780, ext. 220, carrie@umn.edu, or Barbara Lusardi, University of Minnesota, Minnesota Geological Survey, 2642 University Ave. W., St. Paul, MN 55114-1032, (612) 627-4780, ext. 212, lusar001@umn.edu

ROCKY MOUNTAIN SECTION
May 23–25, 2005
Mesa State College, Grand Junction, Colorado
Information: Rex Cole, Mesa State College, Department of Physical & Environmental Science, 1100 North Ave., Grand Junction, CO 81501-3122, (970) 248-1599, rcole@mesastate.edu

www.geosociety.org/sectdiv/sections.htm

STUDENTS—Mark Your Calendars!

Students: Plan now to attend a Shlemon Mentor Program and/or a Mann Mentor Program in Applied Hydrogeology at your 2005 Section Meeting to chat one-on-one with practicing geoscientists. These volunteers will answer your questions and share insights on how to get a job after graduation. When programs are scheduled for multiple days, each day's program will offer a different set of mentors.

FREE LUNCHES will be served (students only) at the Shlemon Mentor Programs. Students will receive a **FREE LUNCH** ticket, along with their registration badge, to attend each Shlemon Program. However, space is limited. First come, first served.

And, it gets better: **FREE light suppers** will be served (students only) at the Mann Mentor Programs. The **Mann Programs** are specific to careers in hydrogeology; if you're interested in receiving an invitation to attend the Mann Program for a **FREE light supper** after the tech sessions end, contact Karlon Blythe, kblythe@geosociety.org. Be sure to indicate which Section Meeting you plan to attend.

Mentor Programs for 2005 Section Meetings

FOR LOCATIONS OF PROGRAMS, ASK AT THE GSA REGISTRATION DESK.

NORTHEASTERN SECTION MEETING

Saratoga Springs, New York
SHLEMON MENTOR LUNCHEON PROGRAMS:
Mon. and Tues., March 14–15, 11:30 a.m.–1 p.m.

MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM:
(by invitation; contact kblythe@geosociety.org)
Mon., March 14, 5–6:30 p.m.

SOUTHEASTERN SECTION MEETING

Biloxi, Mississippi
SHLEMON MENTOR LUNCHEON PROGRAMS:
Thurs. and Fri., March 17–18, 11:30 a.m.–1 p.m.

MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM:
(by invitation; contact kblythe@geosociety.org)
Thurs., March 17, 5–6:30 p.m.

SOUTH-CENTRAL SECTION MEETING

San Antonio, Texas
SHLEMON MENTOR LUNCHEON PROGRAM:
Fri., April 1, 11:30 a.m.–1 p.m.

MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM:
(by invitation; contact kblythe@geosociety.org)
Fri., April 1, 5–6:30 p.m.

CORDILLERAN SECTION MEETING

San José, California
SHLEMON MENTOR LUNCHEON PROGRAMS:
Fri. and Sat., April 29–30, 11:30 a.m.–1 p.m.

MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM:
(by invitation; contact kblythe@geosociety.org)
Fri., April 29, 5–6:30 p.m.

NORTH-CENTRAL SECTION MEETING

Minneapolis, Minnesota
SHLEMON MENTOR LUNCHEON PROGRAMS:
Thurs. and Fri., May 19–20, 11:30 a.m.–1 p.m.

MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM:
(by invitation; contact kblythe@geosociety.org)
Thurs., May 19, 5–6:30 p.m.

ROCKY MOUNTAIN SECTION MEETING

Grand Junction, Colorado
SHLEMON MENTOR LUNCHEON PROGRAMS:
Mon. and Tues., May 23–24, 11:30 a.m.–1 p.m.

MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM:
(by invitation; contact kblythe@geosociety.org)
Mon., May 23, 5–6:30 p.m.

For more information contact kblythe@geosociety.org

The DNAG Geologic Map of North America—A New Look at the Grand Architecture of the Continent

Mapmakers (from left to right) Jack Reed, Linda Masonic, and Will Stettner at Pikes Peak Litho in Colorado Springs for the final press check of the 2005 *Geologic Map of North America*.

The new *Geologic Map of North America* is the first such map published in the past four decades (U.S. Geological Survey, 1965). The map, which covers 15% of Earth's surface, depicts the geology of the seafloor in detail never before seen on a map of this scale. It is the first geologic map of North America to be compiled since the general acceptance of plate-tectonic theory and since radiometric dates for plutonic and volcanic rocks became widely available. Printed in 11 colors, this map distinguishes more than 900 rock units, 110 of which are offshore. It depicts more than seven times as many on-land units as are shown on the 1965 map, as well as detailed features of the seafloor, such as spreading centers, seamount chains, and subduction zones.

More than two decades went into the creation of this map. According to principal compilers John C. Reed Jr., John O. Wheeler, and Brian E. Tucholke (2005), when the preparation of a new geologic map of North America was suggested at the Decade of North American Geology (DNAG) Steering Committee meeting in early 1980, the idea was almost nixed (Reed et al., 2005). However, after further study, the map project was approved, and compilers were commissioned. The new map is a result of a cooperative effort between GSA, the U.S. Geological Survey (USGS), the Geological Survey of Canada (GSC), and the Woods Hole Oceanographic Institution (WHOI). John C. Reed Jr. (USGS) and John O. Wheeler (GSC) compiled the on-land geology; Brian E. Tucholke (WHOI) was responsible for compiling and mapping the geology of the seafloors. Cartographic design and conventional cartography was by James E. Queen; color design was by Jan Dennis. Digital cartography was largely done by Will R. Stettner and Linda Masonic, with substantial contributions from James E. Queen, Alex J. Donatich, Nancy A. Shock, and Geologic Data Systems Inc. of Denver, Colorado. A digital database is being planned by David R. Soller of the U.S. Geological Survey.

In their explanation accompanying the map, Reed et al. (2005) note that the initial time estimate for the completion of the map was just five years. But, as with its predecessor, compilation of a map of such detail was a much longer process than had been envisioned. The 1965 map, which had been commissioned in 1951 by GSA Council and then–GSA president T.S. Lovering, and headed by E.N. Goddard, took 15 years to complete (Goddard, 1967). The size and complexity of the 2005 *Geologic Map of North America*, the evolution of cartography from traditional pen and scribing to modern digital methods, and the diversion of each of the compilers to new duties and responsibilities within their respective supporting institutions all contributed to the more than 20 years separating inception and completion. Because the map has been prepared digitally, however, it should be possible to correct and update it more frequently than was previously possible.

The new map reflects the time and effort of those involved. It impresses even the non–earth scientist with the grand design of the continent and seafloor. It is a work of beauty, an educational tool, and a "thinking map," a source for new interpretations of the geology of North America, insights into the evolution of the continent, further discovery of mineral and energy resources, planning for management of lands and resources, and the understanding and mitigation of geological hazards.

REFERENCES CITED

Goddard, E.N., 1967, New Geologic Map of North America: Geological Society of America Bulletin, v. 78, p. 1061–1063.

Reed, J.C., Jr., Wheeler, J.O., and Tucholke, B.E., 2005, Geologic Map of North America—Perspectives and explanation: Boulder, Colorado, Geological Society of America, Decade of North American Geology, p. 1–28.

U.S. Geological Survey, 1965, Geologic Map of North America, scale 1:5,000,000.

CORRECTIONS

In the announcements for the North-Central Section Meeting, page 20 of the February issue of *GSA Today*, it was incorrectly noted that the *National Association of Geoscience Teachers* (NAGT) would hold a bash and business meeting. The announcement should have read: **NCGSA Bash and Business Meeting. Entertainment and dinner fare provided. Thurs., May 19, 7–9 p.m. Cost: Professional, $15; Student, $5. All are Welcome!** To further clarify: the NAGT is holding a lunch on Thurs., May 19, from noon to 1 p.m.

On page 34 of the January issue of *GSA Today*, the spelling of the surname for Sloss Award recipient and GSA Senior Fellow **George Klein** was incorrect. *GSA Today* regrets the error.

UPCOMING AWARD DEADLINES

Funds supporting all but the national awards are administered by the GSA Foundation.

Mar. 31, 2005	**John C. Frye Environmental Geology Award.***
Apr. 1, 2005	**Don J. Easterbrook Distinguished Scientist Award.**** Quaternary Geology and Geomorphology Division: Nominations due to John E. Costa, U.S. Geological Survey, 10615 S.E. Cherry Blossom Dr., Portland, OR 97216, jecosta@usgs.gov.
Apr. 1, 2005	**Farouk El-Baz Award for Desert Research.**** Quaternary Geology and Geomorphology Division: Nominations due to Alan R. Gillespie, Quaternary Research Center, P.O. Box 351310, University of Washington, Seattle, WA 98195-1360, alan@rad.ess.washington.edu.
Apr. 30, 2005	**National Awards.*** (William T. Pecora Award, National Medal of Science, Vannevar Bush Award, and Alan T. Waterman Award.)

*Details and nomination procedures for these awards are posted at www.geosociety.org/aboutus/awards/. You may also contact Diane Lorenz, (303) 357-1028, awards@geosociety.org, Grants, Awards, and Recognition, P.O. Box 9140, Boulder, CO 80301-9140, USA.

**For details on these awards, see the January 2005 issue of *GSA Today* or visit www.geosociety.org/sectdiv/divisions.htm.

The Geological Society of America

2004 OEST Award Recipients Named

The 2004 Outstanding Earth Science Teacher (OEST) Award recipients were announced in December 2004.

SECTION WINNERS

Matt Leone
Libertyville High School
Libertyville, Ill.

Mary Sue Burns
Pocahontas Co. High School
Dunmore, W. Va.

Noah Hughes
Sonora High School
Sonora, Calif.

Bruce A. Mellin
Brooks School
North Andover, Mass.

Pat Ellis
Jason Lee Elementary School
Richland, Wash.

Tina King
West Elementary
Mt. Juliet, Tenn.

Anthony L. Occhiuzzi
Tempe High School
Tempe, Ariz.

STATE WINNERS

Hurd Finnegan
Davidson High School
Mobile, Ala.

Nwakaego (Ego) Okafor
Henderson Middle School
Chamblee, Ga.

The OEST Award, recognized by the National Association of Geoscience Teachers (NAGT), is given out to pre-college teachers who have made exceptional contributions to the stimulation of interest in the earth sciences and who are outstanding teachers. Each NAGT section selects a section winner. Sections may also have state winners. For more information on this award and the NAGT, please visit www.nagt.org/awards.html. This award is administered by the Geological Society of America. GSA awards the Section recipients $500 travel money to attend a GSA meeting. The winners can also apply for up to $500 for classroom supplies. The award also includes an award certificate and a complimentary membership in GSA for three years for section recipients and a one year complimentary membership for state recipients. For more information on the administration of these awards, please visit www.geosociety.org/aboutus/awards/oest.htm.

Eileen Heady
McDonogh School
Owings Mills, Md.

Ken Fiscus
Albert Lea High School
Albert Lea, Minn.

Mark Shoengold
Roselle Park High School
Roselle Park, N.J.

Andrew P. Patrick
Fox Lane High School
Bedford, N.Y.

Philip Lacey
East Liverpool High School
East Liverpool, Ohio

William C. (Chris) Erler
Sewickley Academy
Sewickley, Penn.

Thomas E. Littlejohn
Roper Mountain Science Center
Greenville, S.C.

Tina King
West Elementary
Mt. Juliet, Tenn.

Michelle L. Adams
Spring Mills Middle School
Martinsburg, W. Va.

TEACHERS: POST YOUR LESSON PLANS!

GSA has formed a partnership with DLESE (Digital Library for Earth System Education) in an effort to support classroom teachers without access to a Web server. If you have a unique and tested lesson plan that you would like to share with your earth science colleagues, please complete our lesson plan template (Microsoft Word format) at www.geosociety.org/educate/ and submit it via e-mail to the GSA Distinguished Earth Science Educator, educator@geosociety.org. We will then extend the reach of your work by including it in the DLESE library, a community-based effort to disseminate high-quality learning materials. Individual resources may be submitted using a Web-based cataloging tool.

Visit the DLESE Web site at
www.dlese.org
or contact Chris McLelland, the current GSA Distinguished Earth Science Educator, (303) 357-1082, for further information.

We appreciate and look forward to your contributions!

TALES FROM *GSA GEOTALES*

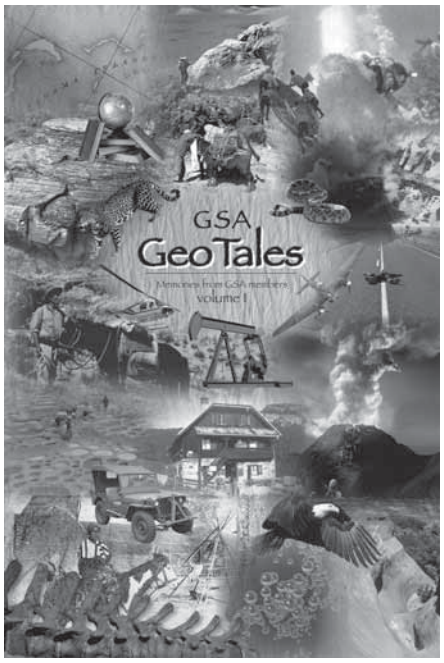
Glimpses into the lives of two GSA Senior Fellows

Cargo Cult of Papua New Guinea

In May 1985, a M7.1 earthquake hit the Island of New Britain, Papua New Guinea, triggering a huge landslide that dammed the Bairaman River. For the next 16 months the lake behind the 210-m-high natural dam slowly filled. In early September 1986, the U.S. Geological Survey sent me to New Britain as an advisor to the Geological Survey of Papua New Guinea, which was trying to protect the people downstream from a possible outburst flood from failure of the dam. At that time, the dam was close to overtopping. Because we felt that the dam would fail soon after overtopping, we recommended that natives in the village of Bairaman, some 30 km downstream from the dam, immediately be evacuated because the possible flood posed a serious hazard to the village and its occupants.

However, there was one hitch. The villagers belonged to a "Cargo Cult," a semi-religion that formed during World War II when natives saw goods such as food, Jeeps, and weapons fall via parachutes from Allied aircraft passing overhead. They felt that these "goodies" came from God. In late summer 1986, several aircraft related to the hazard-reduction strategy were again overhead. Because of this, the natives thought that a "second coming" was upon them and that gifts would soon rain from the heavens onto the village of Bairaman. Fearing that they would miss out if not in the village when the "manna" was to come from the skies, they did not want to be evacuated. It required strong persuasion from army units of Papua New Guinea and Australia to get them to move to higher ground.

On September 10 the landslide dam overtopped and failed catastrophically, sending a 100-m-deep debris flow down the canyon of the Bairaman River. When it reached the village of Bairaman, the flood was about 10 m deep; it obliterated the village. Fortunately, because of the army units, the people had remained on higher ground, and there were no casualties.



—Robert Schuster, GSA Senior Fellow

An Evening on a Tropical Beach

The night of February 14, 1969, I sat alone on the south shore of St. John in the U.S. Virgin Islands, listening to the waves lapping against a beach of coral rubble. The sky was brilliantly lit with stars, and a light, warm breeze touched my face. Introspection claimed me, for I was on the brink of trading my familiar sun and starlit world for an alien undersea environment. The following afternoon, three marine biologists and I would splash down to a seafloor habitat where we would spend the next 60 days as aquanauts in the Tektite Man-in-the-Sea Project.

I was not, I must admit, a seasoned diver. I had become certified with scuba two years earlier and had since made a few tentative dives in the southern Oregon surf zone, where we had hoped to employ underwater observation in our research of nearshore sedimentology. I suppose I had, all told, a total of 25 dives under my belt. My primary qualification for being a tektite diver was probably my willingness to commit 60 days of my life to being the first geologist-aquanaut.

As I sat in the darkness, I could hear a steel band and shouts of revelry in the distance. The Navy Seabees, who had carved a base camp out of the jungle and who were providing logistical support for the project, were justifiably celebrating Splashdown Eve. I wondered what part of my subaerial existence I would miss most over the next two months. Would it be the stars? The feeling of a breeze on my face? The underwater world seemed dark and forbidding. What did it hold? How was all this going to work?

As I mused, listening to the lap of the waves and the sound of distant partying, I became aware that there were other sounds in the night: splashes and the popping sound of feeding fish. The sea was alive! Suddenly my introspection dissolved into eagerness to explore this world in a way privileged to very few others. I sat there for a while longer listening to the sound of life in the sea and then returned to the party.

The Tektite Project proved to be a wonderful, rewarding experience. I returned to the Oregon coast the following summer and we put scuba to full use in the first comprehensive study of a high-energy surf zone. I was also an eager participant a year later in the Tektite 2 experiment, which gained me an additional 20 days of undersea habitation.

And what was it that I most missed while living underwater (other than wife and family, of course!)? It was something I had always taken for granted—the healing warmth of the sun.

—H. Edward Clifton, GSA Senior Fellow

These stories were originally published in GSA Foundation's *GSA GeoTales*, volume 1, a compilation of memories written by GSA members. It's easy to obtain your copy: just contribute $50 or more to GSA Foundation, online at https://rock.geosociety.org/donate/donate.asp, or by mail at P.O. Box 9140, Boulder, CO 80301-9140, USA.

Mark Your Calendars! The Geological Society of America Annual Meeting & Exhibition

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SLC 2005

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16–19 October 2005 • Salt Lake City, Utah

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Title Sponsor of the 2005 GSA Annual Meeting.

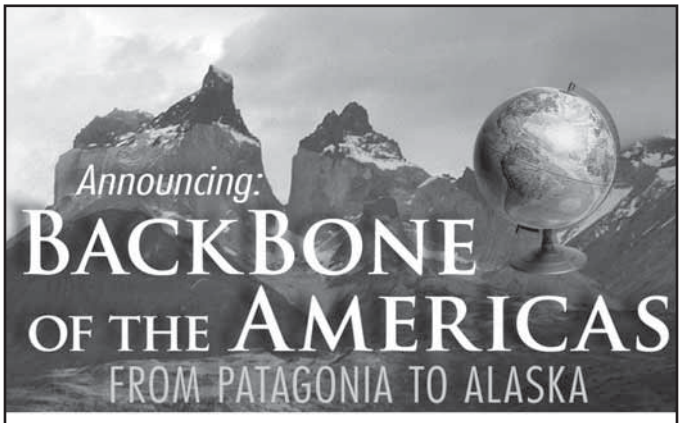
Call for Field Trip Proposals

Earth Systems Processes 2 will be an interdisciplinary, integrative, and scientific meeting which will explore the interactions among Earth's lithosphere, atmosphere, hydrosphere, cryosphere, and biota. Featured themes are Ancient Earth Systems, Modern Earth System Processes, and Earth System Futures. We are seeking proposals for premeeting or postmeeting field trips, particularly those involving topics related to the earth systems theme.

Please send proposals or questions to Glen Stockmal, gstockmal@nrcan.gc.ca.

THE GEOLOGICAL SOCIETY OF AMERICA

For more information about the conference, or to sign up for e-news, visit www.geosociety.org/meetings/esp2/.



3–7 April 2006 • Mendoza, Argentina

Backbone of the Americas: From Patagonia to Alaska is a GSA special meeting cosponsored with the Asociación Geológica Argentina. The principal themes are ridge collision, shallow subduction, and plateau uplift along the Americas. Field trips are planned to Patagonia before and the Chilean flat-slab or Central Andean Puna plateau after the meeting. Suzanne Kay and Victor Ramos are serving as meeting co-chairs.

Co-convened by:

Asociación Geológica Argentina

THE GEOLOGICAL SOCIETY OF AMERICA

See www.geosociety.org/meetings/06boa/index.htm for details and to sign up for e-news.

Foundation Silent Auction Collects $21,000 for GSA Programs

Thomas D. Fouch, *Foundation Trustee*

Thanks to several hundred donors and winning bidders, the GSA Foundation collected more than $21,000 from the auction of nearly 400 items during the Denver Annual Meeting in November. The Silent Auction has grown over the past four years from collecting a few thousand dollars to its present level of success; it is now a very important source of support for GSA programs.

The proceeds from the auction go to the Foundation's "greatest needs" fund. This year, the Foundation will use this money to support GSA research grants, student travel (domestic and international), and other education and outreach programs.

Winners bid on rare geologic books and maps, geologic software, fossils, mineral specimens, jewelry, wine, field supplies, the chance to be a character in a Sarah Andrews mystery novel, and antiques, just to name a few. Attracting many bids were vacation packages that included stays in Santa Fe, West Yellowstone, Tucson, Florida, and the Caribbean island of Tobago.

We are gearing up for the 2005 Silent Auction in Salt Lake City

You can participate: either as a contributor to the 2005 Silent Auction or as a bidder in the auction at the Foundation booth in Salt Lake City.

Do you have a timeshare that you would be willing to donate? Bidders enthusiastically pursue timeshares from a variety of places around the country.

Your donation is tax deductible based upon the retail value of the donated item. Your name will be listed as the donor on the auction item displayed in the Foundation booth. If you don't have an item, we'd be happy to accept a cash donation.

You may mail donations to the Foundation office at P.O. Box 9140, Boulder, Colorado 80301-9140, USA, attention Donna Russell.

Most memorable early geologic experience:

Walking across a gravel pit near the north shore of Long Island, New York, in the late fifties or early sixties, looking for a Cretaceous-Pleistocene contact, Tom suddenly stopped and said, "Feels like clay under here." I thought, "A real field geologist! Even thinks with his feet!"

—Joseph Upson II

GSA FOUNDATION
3300 Penrose Place, P.O. Box 9140
Boulder, CO 80301-9140
(303) 357-1054
drussell@geosociety.org

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Enclosed is my contribution in the amount of $_____.
Please credit my contribution for the:
☐ Greatest need ☐ Other: _____ Fund
☐ I have enclosed a **$50 (minimum)** contribution to GSA Foundation and would like to receive a copy of *GeoTales,* volume 1.
☐ I have named GSA Foundation in my will.

PLEASE PRINT

Name

Address

City/State/ZIP

Phone

The GSA Foundation thanks the following people and institutions for their donations to the 2004 Silent Auction:

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Anonymous
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Association of Engineering Geologists
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Joan Baldwin
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Robert Weimer
Wild Bird Center
Wild Birds Unlimited
Wildlife Experience Museum
Sabrina Williams
Wolfgang Puck Grand Cafe
Yarn Shop
Donald J. Zimmerman

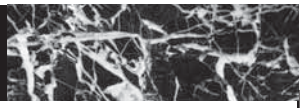
ANNOUNCEMENTS

MEETINGS CALENDAR

2005	
March 12	American Society of Civil Engineers, Seattle Section, 22nd Annual Spring Seminar, "Tunneling in the Pacific Northwest," Seattle, Washington, USA. **Information:** Mark Rohrbach, mrohrbach@geoengineers.com, (253) 383-4940.
April 5–7	Return to Rifts?—The Next Wave. Burlington House, London, The Geological Society. **Information:** Lydia Dumont, The Geological Society, Burlington House, Piccadilly, London W1J OBG, UK, +44 (0)20 7434 9944, fax +44 (0)20 7494 0579, lydia.dumont@geolsoc.org.uk.
April 17–20	2005 Ground Water Summit, San Antonio, Texas, USA. **Information:** National Ground Water Association, 601 Dempsey Road, Westerville, Ohio 43081-8978, USA. Phone: +1.800.551.7379 or +1.614.898.7791, fax: +1.614.898.7786, customerservice@ngwa.org.
April 17–20	MEMS V—5th Annual MEMS Technology Seminar, American Society of Mechanical Engineers, Minneapolis, Minnesota. **Information:** 1-800-843-2763, www.asme.org/education/techsem/MEMS/.
May 24–28	The 51st Annual Meeting of the Institute on Lake Superior Geology, Nipigon, Ontario. **Information:** www.lakesuperiorgeology.org/nipigon2005; contact e-mail: Nipigon2005@Lakeheadu.ca.
August 8–11	Earth System Processes 2 (ESP2). Ancient earth systems, modern earth system processes, and earth system futures. Cosponsored by GSA and the Geological Society of Canada. Westin Hotel, Calgary, Alberta, Canada. **Information:** www.geosociety.org/meetings/esp2/, or contact Deborah Nelson, dnelson@geosociety.org, +1.303.357.1014.
August 9–12	9th International Conference on Diffuse Pollution, Johannesburg, South Africa. **Information:** www.iwa-wisa-2005.com or contact Dr. Ralph Heath at ralphh@phd.co.za.
2006	
3–7 April	Backbone of the Americas—Patagonia to Alaska. Mendoza, Argentina. Co-convened by Asociación Geológica Argentina and GSA. **Information:** www.geosociety.org/meetings/06boa/index.htm, or contact Deborah Nelson, dnelson@geosociety.org, +1.303.357.1014.

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

In Memoriam



Thomas S. Bond
Falls Church, Virginia
notified December 14, 2004

David M. Delo
Seminole, Florida
October 31, 2004

Oscar S. Fent
Salina, Kansas
October 28, 2004

Michel T. Halbouty
Houston, Texas
November 6, 2004

H.W. Mallery
Carson City, Nevada
notified December 26, 2004

Jack W. Pierce
Washington, D.C.
February 11, 2004

Jacques R. Renault
Socorro, New Mexico
December 3, 2004

Irvin L. Tailleur
Sequim, Washington
August 27, 2004

David Archer White
Austin, Texas
November 23, 2004

William J. Winegard
Worcester, New York
September 16, 2004

Please contact the GSA Foundation at (303) 357-1054 or drussell@geosociety.org for imformation on contributing to the Memorial Fund.

About People

GSA Member **Harry Jol** of the University of Wisconsin–Eau Claire and GSA Fellow **John F. (Jack) Shroder, Jr.,** along with several other geomorphologists and geophysicists, were featured in the recent NOVA production "Ancient Refuge in the Holy Land." The exploration of the "Cave of Letters" involved the use of ground-penetrating radar, operated by Jol and University of Wisconsin–Eau Claire graduate Christopher Morton. The program was originally broadcast on PBS on Nov. 23, 2004.

Continental Divide. Photo by John Karachewski.

"Each year, after the annual GSA meeting I am certain that it can't be topped, and somehow the next year's meeting does. This meeting was no exception.

"I wanted to tell you that the scheduling of oral and poster sessions and coordination of rooms seemed to be smoother than ever this year. I did experience some compatibility problems with my power point presentation, but the technical staff in the speaker prep room were fantastic, and fixed everything very promptly."

— Sydney T. Bacchus

"I just purchased a new Subaru Forester for use by my son, a college student away from home. No negotiation, no heckling, and yet I got a very good price; even better than I would have been able to bargain. Besides, I understand that Subaru will also donate $100 to the GSA Foundation. What a deal!

"I highly recommend this program to all GSA members interested in buying a Subaru. Subaru cars are very well built and all models have all-wheel-drive system which is excellent for geology field work. Thank you again."

— C. John Suen

"Your renewal process was quite easy and a pleasure to follow. I only wish that [other societies'] web renewal processes were as easy."

— David A. Bennett

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GEON
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A National Meeting on Research Frontiers in Cyberinfrastructure for the Geosciences

May 5 & 6, 2005
Bahia Resort Hotel, San Diego, CA

GEON (www.geongrid.org) is hosting a two-day meeting on current developments and identifying further needs and opportunities in the area of cyberinfrastructure (CI) for the Geosciences. Research results from both the GEON project, as well as those from other members of the community will be presented.

Meeting Guidelines

Meeting is open to all who are interested in information technology based geoscience research and education. All participants are encouraged to submit an abstract. Speakers and posters will be selected from submitted abstracts. Presenting authors will be notified by April 15, 2005.

Registration and abstract deadline is April 11, 2005.
For further information and to apply please visit
http://www.geongrid.org/AM05/

GEON is an NSF-funded collaborative research project facilitating information integration and knowledge discovery in the Geosciences.

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The Virtual Student Expo is a joint venture among GSA, the American Association of Petroleum Geologists, the Society of Exploration Geophysicists, and the Society of Petroleum Engineers.

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Ads (or cancellations) must reach the GSA Advertising office one month prior to issue. Contact Advertising Department: advertising@geosociety.org; +1.800.472.1988 x1053; +1.303.357.1053. Complete contact information, including mailing and email address, must be included with all correspondence.

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To estimate cost, count 54 characters per line, including all punctuation and blank spaces. Actual cost may differ if you use capitals, centered copy, or special characters.

Positions Open

UNIVERSITY OF SASKATCHEWAN
COLLEGE OF ARTS AND SCIENCE
DEPARTMENT OF GEOLOGICAL SCIENCES
TERM POSITION

The Department of Geological Sciences is accepting applications for a term position for the 2005–2006 academic year. We are interested in applicants with a broad background in the geosciences, and excellent teaching ability. The successful candidate must be able to teach 1st year Introductory Physical or Historical Geology and be willing to teach 2nd year Introductory Petrology. He/she will be allowed the flexibility to teach senior undergraduate courses in his/her discipline. The Department is particularly interested in candidates with a strong background in the quantification of Earth processes. Candidates must hold a Ph.D. when appointed, which will be at the Assistant Professor level. Although the appointment will be for a 1-year term, there is potential for renewal, dependant on the availability of funding

Although this position is primarily a teaching appointment, opportunities and facilities are available in the Department for the successful candidate to conduct research. The Department has 16 full-time faculty, including four research chairs. There are excellent geochemical and isotopic analytical facilities and computing infrastructure, particularly for seismology. In addition, the University is home to the Canadian Light Source, the first synchrotron in the country.

Applications, including résumé, short statement of teaching goals, and three letters of reference, should be addressed to: Term Position Search Committee, Department of Geological Sciences, University of Saskatchewan, Saskatoon, SK S7N 5E2, Canada, Email: kevin.ansdell@usask.ca, Fax: 306-966-8593, Website: www.usask.ca/geology/.

We will begin reviewing applications after April 15th, 2005.

All qualified candidates are encouraged to apply; however, Canadians and permanent residents will be given priority. The University of Saskatchewan is committed to increasing representation of equity groups (women, people of aboriginal ancestry, visible minorities and/or people with disabilities). Applicants from these groups are encouraged to self-identify in their applications.

FACULTY POSITION, ENVIRONMENTAL GEOLOGY
NEW MEXICO HIGHLANDS UNIVERSITY

The Natural Resources Management Division invites applications for a tenure-track Assistant Professor position, effective August 2005, in Environmental Geology with specialization in "soft rock" geology and competency in the use of geographic information systems. We are seeking a dynamic teacher and broadly trained geologist who is committed to undergraduate teaching at a small institution in a rural setting.

Responsibilities include teaching Depositional Environments, Groundwater Hydrology, Surveying and GIS Analysis, sharing in the delivery of the introductory geology classes, and engaging undergraduates and graduates in research. Additional courses shall be developed according to the candidate's specialty. All courses emphasize environmental geology and science education. The teaching load is 12 hours per semester. These responsibilities are closely linked to the University's Strategic Plan, the University's vision to become the premier Hispanic Serving Institution, and the University's mission to serve the global community by integrating education, research, public service, and economic development while celebrating the distinctive Northern New Mexico culture and traditions.

Requirements for the position include a Ph.D. in geology at the time of appointment. Review of applications will begin on March 15 and continue until the position is filled. Applicants must submit a letter of application, vita, three letters of recommendation, transcripts, a statement of research interests and needs, a one (1) page essay explaining how you will contribute (personally and professionally) to the New Mexico Highlands University Strategic Plan (www.nmhu.edu), and a one-page statement describing your teaching philosophy. Send all materials to: New Mexico Highlands University; Office of Academic Affairs; Assistant Professor of Geology Search; Box 9000, Las Vegas, New Mexico 87701. NMHU is an EOE. For disabled access or services, call (505) 454-3311 or TDD# (505) 454-3003.

REMOTE IMAGERY ANALYSIS/GIS
MIDWESTERN STATE UNIVERSITY

Geology Assistant/Associate Professor—tenure-track Fall 2005. Teach Introductory Geology, Mineralogy/Petrology, and upper-level courses in Remote Sensing/GIS and its applications; develop a research program involving undergraduates. Required: Ph.D. in a geological discipline, broad geology background, and strong interpersonal skills. Preference will be given to individuals with research background and resultant publication in refereed journals. MSU is a comprehensive public university serving approximately 6,500 students. Send application letter, vita, and names and addresses of three references to Dr. M. John Kocurko, Chair, Department of Geology, Midwestern State University, 3410 Taft, Wichita Falls, TX 76308; e-mail: john.kocurko@mwsu.edu Screening starts April 1, 2005. Applications will be accepted until position is filled. EOE/EDA.

INVERTEBRATE PALAEONTOLOGIST
THE ROYAL ONTARIO MUSEUM

The Royal Ontario Museum (ROM) is Canada's preeminent international museum and houses some of Canada's most important collections in both Natural History and World Cultures. The ROM currently invites applications for the position of Invertebrate Palaeontologist to conduct research related to the ROM's collection of fossils from the Burgess Shale.

The successful applicant will be expected to develop a program of externally funded, collections-based, scholarly research and publications; curate and continue building the disciplinary collection; and participate in the development and rotation of new permanent galleries, traveling exhibitions and other public programming.

Qualifications: Applicants must have a Ph.D. in systematic palaeontology, palaeoecology, evolutionary biology, or a related field at the time of appointment, a strong research interest in the ecology and evolutionary dynamics of the Ediacaran-Cambrian biodiversification; facility in multivariate analysis of large data sets; familiarity with current phylogenetic methodologies; a record of scholarly publication in peer-reviewed journals, be qualified for cross-appointment to the University of Toronto and be eligible for NSERC funding in support of research (i.e., proven record of successful grant applications). Experience in a museum or equivalent environment is preferable.

Salary and rank are commensurate with experience as stipulated in the Collective Agreement between the ROM and ROM Curatorial Association.

All qualified candidates are encouraged to apply; however Canadians and permanent residents will be given priority. Applications for the position will be accepted until April 1, 2005. Applicants should provide a curriculum vitae, a summary of their research and an outline of their proposed research and should arrange to have three confidential letters of recommendation sent on their behalf to: Human Resources Department, The Royal Ontario Museum, 100 Queen's Park, Toronto, Ontario, Canada M5S 2C6, Fax (416) 586-5827.

TEXAS A&M UNIVERSITY
TENURE TRACK FACULTY POSITION
PETROLEUM GEOSCIENTIST

The Department of Geology and Geophysics at Texas A&M University invites applications for a tenure-track position at the Assistant Professor level in Petroleum Geosciences, although starting appointments at higher ranks will be considered for suitably qualified individuals. Texas A&M University will hire twenty new faculty within the College of Geosciences over the next four years and this tenure-track position will be an essential part of this planned growth.

We seek an individual who can develop a forward-looking, externally funded research program that integrates geological, geophysical, or petrophysical data in the investigation of subsurface geological systems. The applicant should be able to demonstrate an understanding of modern tools used in petroleum-related research (e.g., seismic and well log interpretation software, innovative approaches to rock-property modeling, 3-D visualization techniques, quantitative basin modeling, hydrogeology of petroleum systems, integration of petrophysical data with seismic response, etc.), although we will consider all outstanding candidates with relevant research or educational experience. The successful candidate is also expected to advise graduate students and teach undergraduate and graduate courses in Petroleum Geology.

Faculty in our department have opportunities to collaborate with colleagues in Petroleum Engineering, Chemical Engineering, Oceanography, the Integrated Ocean Drilling Program, and the Geochemical and Environmental Research Group. Departmental facilities and programs can be reviewed at our Web site (http://geoweb.tamu.edu).

Applicants should submit a curriculum vita, recent reprints, a statement of research and teaching interests, and the names, postal and e-mail addresses, and fax numbers of three references to: Chair of Petroleum Geoscientist Search Committee, Department of Geology and Geophysics, Texas A&M University, College Station, TX 77843-3115. We will interview candidates until a qualified applicant is found. A Ph.D. is required at the time employment begins.

Texas A&M University, a land-, sea-, and space-grant university, is located in College Station, Texas, a dynamic and international community of 140,000 people. Texas A&M University is an affirmative action/equal opportunity employer committed to excellence through the recruitment and retention of a diverse faculty and student body and compliance with the Americans with Disabilities Act. We encourage applications from minorities, women, veterans, and persons with disabilities.

STRUCTURAL GEOLOGY—BATES COLLEGE

The **Bates College Department of Geology** invites applications for a **one-year sabbatical leave replacement** in the general area of **tectonics** and **structural geology** beginning in **Fall 2005**.

Bates College is a highly selective liberal arts college of approximately 2,000 students, located in Maine, 1 hour north of Portland and 2.5 hours north of Boston. Bedrock outcrops along the Maine coast and the White Mountains, which the department uses for labs, fieldtrips, and research, expose world-class structures produced by Acadian and Alleghenian collisions and Mesozoic rifting.

Teaching responsibilities include an introductory tectonics course with multiple lab sections, a sophomore-level structural geology course with a lab, and an advanced junior/senior-level geology course on a topic of the candidates choosing. The replacement is also expected to advise one to three senior theses during the year as part of the department's required senior thesis program. A Ph.D. is preferred, but consideration will be given to applicants who have not yet completed their Ph.D.

Review of applications begins April 1, 2005, and will continue until the position is filled. Please **mail** a letter of application, curriculum vitae, transcripts, three complete letters of recommendation and sample syllabi for one or more of the courses above to: **Geology Search Committee (#R2354), c/o Bates College Academic Services, 2 Andrews Road, 7 Lane Hall, Lewiston, ME 04240**

For more information, please contact Prof. Dykstra Eusden, Chair, at deusden@bates.edu. www.bates.edu.

Bates College values a diverse college community and seeks to assure equal opportunity through a continuing and effective Affirmative Action program.

THREE TENURE TRACK POSITIONS
AT UNC–CHAPEL HILL IN GEOLOGICAL
OCEANOGRAPHY AND/OR SEDIMENT DYNAMICS

The Marine Sciences Program of the University of North Carolina at Chapel Hill seeks to fill three (3) tenure track faculty positions spanning the areas of Geological Oceanography, Marine Geology and Sediment Dynamics. Two positions will be at the Institute of Marine Sciences (IMS) on the coast in Morehead City, and one

will be in the Department of Marine Sciences (MASC) in Chapel Hill.

Department of Marine Sciences Position: All aspects of geological oceanography will be considered. We encourage applicants whose research complements existing strengths and/or cuts across traditional disciplinary boundaries (see www.marine.unc.edu/MASC.html for further information). The candidate filling the MASC position will be expected to teach one course per semester.

Institute of Marine Sciences Positions: Estuarine, coastal and continental shelf processes are focal areas at IMS, and interest in observational studies is desirable (see www.marine.unc.edu/IMS.html for more information). The IMS positions carry no formal teaching requirement, although undergraduate and graduate teaching opportunities exist.

The selected individuals will be expected to develop vigorous, externally funded research programs, publish in peer-reviewed journals, and direct graduate students. Qualifications include a Ph.D. in Geological Oceanography, Marine Geology, Engineering or a related field. Post-doctoral experience is preferred. We anticipate that these positions will be filled at the Assistant Professor level; one position at IMS might be filled at the Associate Professor level. Nine months' salary support is provided for each position.

Applicants should submit a CV and statements of research and (for MASC) teaching interests. Also arrange for four letters of reference to be sent to the Chair, Geological Oceanography Search Committee, UNC–Chapel Hill, Dept. of Marine Sciences, Venable Hall CB#3300, Chapel Hill, NC 27599. Please indicate whether you would like to locate at IMS or MASC. Applications will be considered beginning March 1, 2005. The University of North Carolina at Chapel Hill is an equal opportunity employer.

ASSISTANT PROFESSOR, GEOPHYSICS
UTAH STATE UNIVERSITY

The Geology Department at Utah State University seeks candidates for a tenure-track position at the assistant professor rank in geophysics to start in August 2005. A Ph.D. in geophysics or a closely related field is required for the position, and candidates should have demonstrated research excellence and a commitment to teaching. Successful candidates will be expected to develop an independent research program, to teach graduate and undergraduate courses in geophysics, and to integrate with existing strengths in the department. We encourage geophysicists with expertise in [but not limited to] seismology, exploration geophysics, geodesy, potential fields, geodynamics, and paleomagnetism and who examine processes within the continental crust/lithosphere to apply. Further information is available at http://www.usu.edu/geoldept/. Applicants should send a detailed CV, statements of teaching and research interests, and names and addresses of at least three references to: Prof. James P. Evans, Chair, Search Comm., Dept. of Geology, Utah State University, Logan, UT 84322-4505. Review of applications will begin Feb. 1, 2005. USU is an AA/EO employer with an NSF Advance Grant to promote opportunities for minorities and women in the sciences and engineering.

RESEARCH SPECIALIST
EARTH AND ENVIRONMENTAL SCIENCES

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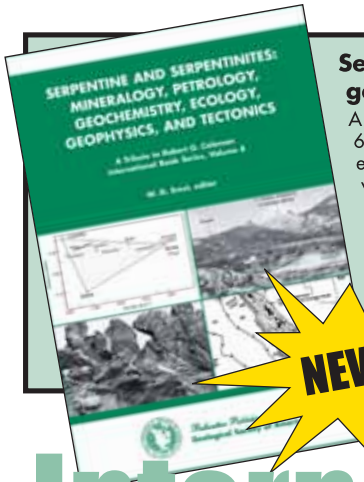

Serpentine and serpentinites: Mineralogy, petrology, geochemistry, ecology, geophysics, and tectonics: A tribute to Robert G. Coleman *edited by W.G. Ernst, 2005*

A symposium dealing with the plate-tectonic origin, geochemical evolution, and environmental impact of serpentinites was held 6–7 December 2003 at Stanford University, in honor of Professor Emeritus Robert G. Coleman. The technical sessions to some extent reflected his broadly diversified research thrusts. The up-to-date scientific contributions that resulted from the symposium were published in issues of International Geology Review and are collected in this International Book Series volume. The volume represents a unique collection of research subjects spanning an unusually broad spectrum of disciplines that overlap chiefly in their focus on hydrated mantle material. The book is divided into topical areas, mirroring some of Coleman's scientific contributions in mineralogy; petrology, regional geology, and plate tectonics; geochemistry; geophysics; and environmental geobotany. In aggregate, it constitutes a scholarly attempt of the scientific community to recognize some of Coleman's lifetime of extraordinary scientific achievements—especially those concerning a fuller understanding of serpentine and serpentinites.

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

edited by W.G. Ernst, 2002

The technical papers resulting from a symposium entitled "Frontiers in Geochemistry," held at Stanford University in honor of Professor Konrad B. Krauskopf, were published in separate installments in International Geology Review and are collected here in an attempt to recognize Krauskopf's lifetime of extraordinary achievement in both geology and geochemistry. Krauskopf has published a diverse set of international-quality investigations broadly arching across the fields of hard-rock geology, petrology, geochemistry, and mineral deposits. Detailed studies include illuminating the parageneses of granitoids and basement terranes in the Pacific Northwest, the volcanic eruptions of Parícutin in the Transmexican volcanic belt, and the regional petrologic evolution of coastal Norway. He has generated both mineral deposit and general geologic maps for the California Division of Mines and the U.S. Geological Survey, chiefly in the Sierra Nevada and the White-Inyo ranges of eastern California. He pioneered books applying the principles of physics and chemistry to Earth and provided geoscientists with discipline-defining texts in geochemistry and physical geology over five decades. Special emphases have included elucidation of aqueous solution–metal complex equilibria as well as thermodynamic applications to solid-melt-fluid partitioning. Few geochemists have contributed to the earth sciences in such far-ranging ways as geologist, geochemist, and science and technology advisor to the nation. This two-volume set is an insufficient tribute to the legendary scientific accomplishments of Krauskopf, but it's a start!

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

co-edited by W.G. Ernst, and J.G. Liou, 2000

Collisional belts that retain the effects of Phanerozoic ultra-high pressure (UHP) metamorphism are increasingly being recognized, especially in Eurasia. Neighboring regions generally lack evidence of coeval arc volcanism or plutonism. Following the consumption of intervening oceanic lithosphere, each UHP orogen marks the site of astonishingly deep subduction of a microcontinental promontory or island-arc fragments. Mafic and ultramafic rocks are volumetrically minor in such belts. Maximum recorded pressures in UHP complexes approach or even exceed 2.8 GPa at temperatures of 600–900 °C. Subduction zones involve low-T prograde trajectories, and constitute the only plate-tectonic environment where such conditions exist. Internal portions of descending lithospheric plates may be characterized by yet lower geothermal gradients, but the crustal upper margins are typified by less extreme high-P, low-T paths of 5–10 °C/km. Mineral parageneses, physical conditions of recrystallization, and the tectonics of subduction and exhumation are thoroughly documented in this volume. Extensional collapse and erosion of rising sialic masses evidently aid in the continued ascent of deeply subducted but buoyant material. Surviving UHP terranes consist of relatively thin slabs of continental crust. Slices evidently rose to mid-crustal levels rapidly at remarkably high exhumation rates—approaching or exceeding 10 mm/yr. Back reaction attending decompression in all cases was nearly complete; where UHP relics have persisted, retrogression evidently was limited by declining temperatures, coarse grain size of host minerals, and relative impermeability of the rocks to catalytic aqueous fluids. Clearly, UHP terranes provide important new constraints on the origin and tectonic evolution of collisional mountain belts.

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

co-edited by W.G. Ernst and R.G. Coleman, 2000

The late Benjamin M. Page, professor of geology of Stanford University, was a geologic mapper, regional geologist, and plate tectonician par excellence. His many research areas included western Nevada, the Apennines, southern Taiwan, and southwestern Japan, but Page's most notable and extensive works involve elucidation of the geology of the California coast ranges. Page devoted a lifetime to unraveling the geologic architecture and plate-tectonic evolution of this continental-margin mountain belt. Indeed, nearly half of the papers in this volume, including a posthumous contribution by Page, involve the tectonic history of the central California coast ranges. Topics of special concentration include the origin, evolution, and geologic occurrence of ophiolites, accretionary mélanges, continental-margin structural and/or geophysical transects, transform faults, and convergent-margin mountain belts. In 1993, the Geological Society of America recognized Page's numerous seminal scientific papers with the Career Award in Structural Geology and Tectonics.

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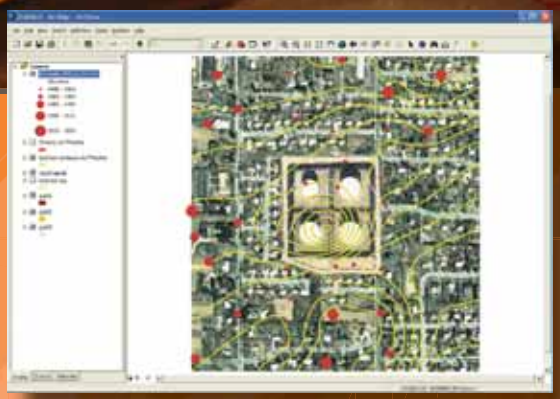

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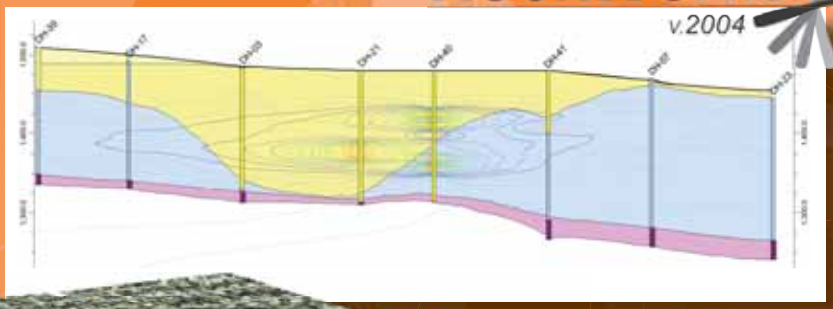

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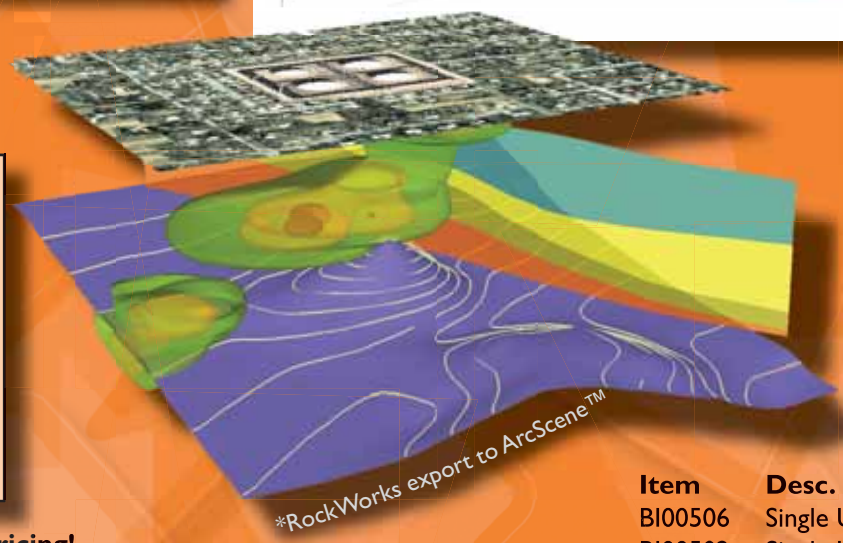

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