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INSIDE

Alternative Hypotheses for the Mid-Cretaceous Paleogeography of the Western Cordillera

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ABSTRACT

Two conflicting hypotheses specifying the paleogeographic disposition of the Insular and Intermontane superterranes at ca. 95 Ma are based on different evidence. One group of models, resting entirely on geologic evidence such as magmatic or stratigraphic links among terranes, places the two superterranes exclusively to the north of the Franciscan-Sierran subduction-arc system during late Mesozoic time. An alternative hypothesis, fully accommodating four sets of paleomagnetic data from Cretaceous rocks in the northwest Cordillera, restores most of the Intermontane superterrane ~1200 km south and the entire Insular superterrane (including Wrangellia) ~2900 km south of their expected (that is, current) latitudinal positions with respect to North America. In this model, the Insular superterrane and the orogenic belt that formed along its eastern edge during mid-Cretaceous collision lay south of the Franciscan-Sierran system in California at ca. 95 Ma; the entire crustal element was subsequently displaced northward by coast-parallel dextral slip between 80 and 60 Ma.

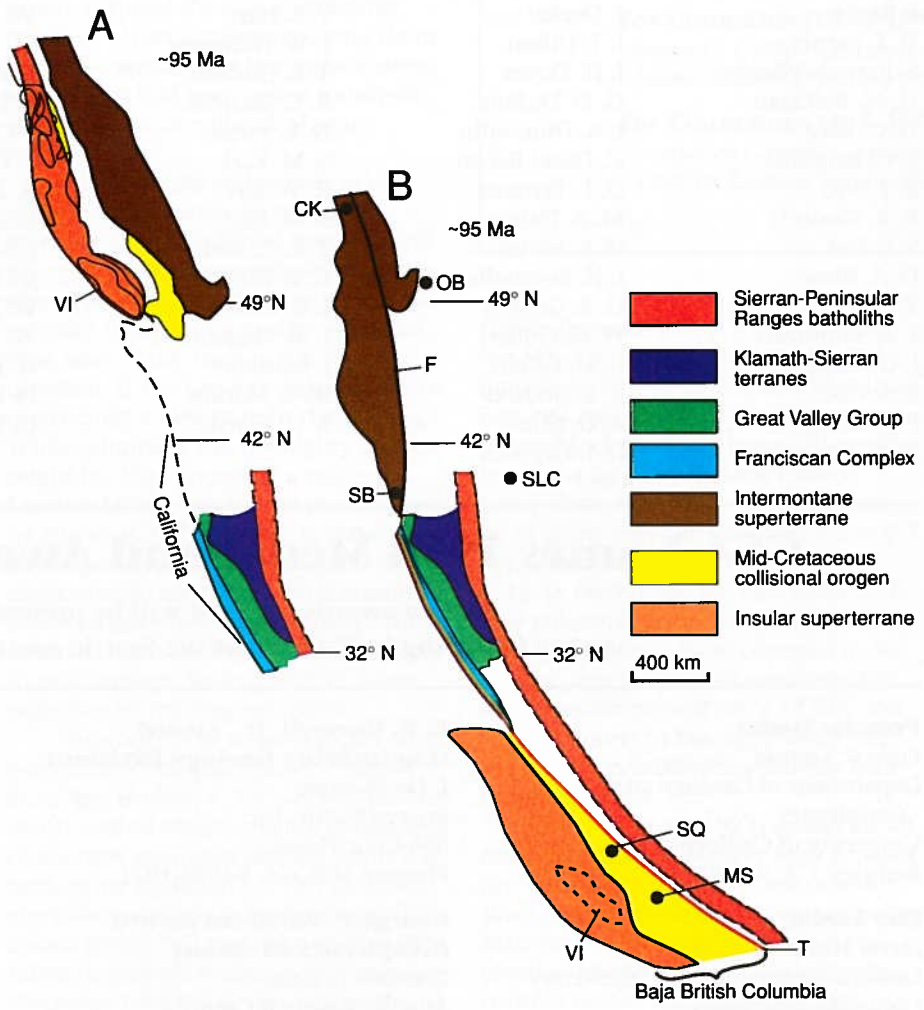

Figure 1. Greatly simplified maps illustrating alternative models for mid-Cretaceous paleogeography based on geologic arguments (A) or paleomagnetic data (B). The palinspastic base used in both incorporates two restorations: about 275 km of Cenozoic east-west extension in the Basin and Range province; and about 400 km of dextral slip on intrabatholithic transcurrent faults, restoring the Klamath-Sierran terranes, Great Valley Group, and Franciscan complex south of their present positions. Current location of Salt Lake City (SLC) and Vancouver Island (VI). Latitude 49°N is U.S.–Canada boundary; 32°N approximates U.S.–Mexico boundary. (A) After the collision ca. 90–100 Ma of Insular superterrane with the margin of North America, which already included the Intermontane superterrane, both superterranes lay north of the Franciscan-Sierran subduction zone–magmatic arc in California. (B) Insular superterrane collides south of the Franciscan-Sierran system in California. Heavy line marked "T" is the approximate position of the transcurrent (transform) fault along which Baja British Columbia was displaced northward after 90 Ma. F denotes a hypothetical fault now within the Intermontane superterrane along which its western two-thirds was translated northward after 70 Ma. CK, SB, SQ, MS, and OB locate the paleomagnetic data discussed in text. MS currently is ca. 180 km farther south of SQ due to Tertiary dextral strike-slip on the intervening Fraser–Straight Creek fault (partly shown as F in Fig. 2).

INTRODUCTION

One of the key objectives of tectonic analysis is to establish what I call here the *paleogeography* of a particular region through geologic time: the former configuration and geographic position of major crustal elements, regional structures, and plate boundaries. Typically, tectonic geologists use a diverse array of structural, sedimentologic, and isotopic evidence to support or corroborate a favored paleogeographic hypothesis. Paleomagnetic data that record the paleolatitude of a rock unit at certain times can also provide invaluable information about the positions and displacements of a tectonic element. It goes without saying that paleogeographic maps based on these data should be recognizably similar to maps based on geologic evidence alone. Models for the early Late Cretaceous (ca. 95 Ma) paleogeography of the western Cordillera of North America conflict with this truism (Fig. 1), and Cordilleran geologists are far from a consensus regarding which model is "correct."

NORTHWEST CORDILLERA

The whole debate over mid-Cretaceous paleogeography is summed up by the following two questions: Where were the Insular and Intermontane superterranes situated ca. 90–100 Ma? Did one or both lie exclusively north of the Franciscan-Sierran subduction system (subduction zone, fore-arc basin, and magmatic arc), which marked the continental margin in what is now California? Notwithstanding this particular controversy, it is important to emphasize that there *is* a consensus, affirmed at the May 1992 Penrose Conference on "Tectonic Evolution of the Coast Mountains Orogen" (reported in *GSA Today,* October 1992), on many aspects of the geology of the northwest Cordillera. Most notably, points of agreement include the identities of the two superterranes and the coincidence of the eastern boundary of the Insular superterrane with a zone of mid-Cretaceous and locally early Tertiary deformation extending at least 1300 km from northwestern Washington through the Coast Mountains of British Columbia into southeastern Alaska (Rubin et al., 1990). The Insular and Intermontane superterranes, as depicted in Figure 2, are each composed of a few dominantly late Paleozoic and Triassic terranes, which are themselves defined by stratigraphic sequences or complexes that extend for thousands of square kilometers. These terranes had been assembled into the larger superterranes by late Middle Jurassic time (see Monger et al., 1991, for stratigraphic details). One of the components of the Insular superterrane is the Wrangellia terrane. Some readers may be surprised that the paleogeographic disposition of Wrangellia—which has assumed legendary status as the prototype of Cordilleran tectonostratigraphic terranes—is still in contention.

Because the boundary zone along the eastern edge of the Insular superterrane figures prominently in the paleogeographic debate, I briefly review its nature and history below. In Figures 1 and 2 the zone is depicted as the "mid-Cretaceous collisional orogen." I believe most workers would agree on the following broad outline. Along the entire known length of the boundary, stratigraphic and plutonic units belonging to the Insular superterrane extend onto the mainland to an eastern limit marked by a zone of predominantly east-dipping, west-vergent imbricate thrust faults. U-Pb isotopic data from granitoid plutons (e.g., Rubin and Saleeby, 1992; Journeay and Friedman, 1993), and stratigraphic evidence (e.g. Brandon, et al., 1988) indicate that thrusting and high-pressure metamorphism occurred in the boundary zone between ca. 90 and 100 Ma.

The character and width of this zone of mid-Cretaceous deformation differ along strike. Between latitudes 54°N and 58°N (the "northern sector"), the imbricate zone is a maximum of 50 km wide (Fig. 2). It includes slices derived principally from Insular superterrane and the depositionally overlying Upper Jurassic and Lower Cretaceous Gravina sequence along its easternmost edge. North of 55°N some of the thrust sheets in the imbricate zone lithologically resemble the Intermontane superterrane, according to Rubin and Saleeby (1992), and others resemble the Yukon-Tanana terrane, widely exposed north and east of the Intermontane superterrane (Gehrels et al., 1992; Rubin and Saleeby, 1992). Between 54°N and 55°N, the upper plate of the imbricate zone consists of high-grade and locally migmatitic metamorphic rocks, but their "terrane affinity" is unknown (Crawford et al., 1987). North of 54°N, the Intermontane superterrane sensu stricto, which is widely exposed in central British Columbia (Fig. 2), evidently lies exclusively east of the thrust system. The two are separated by a continuous belt of Late Cretaceous and Paleogene plutons of the Coast plutonic complex (e.g., Wheeler and McFeely, 1991). The western margin of the plutonic complex was deformed about 60 Ma in the 600-km-long, steep, northwest-striking Coast shear zone shown in Figure 2 (e.g., McClelland et al., 1992a).

At about 52°N, the zone of mid-Cretaceous deformation along the eastern edge of the Insular superterrane emerges from the Coast plutonic complex and expands southward to a maximum width of ~225 km at 48°30'N. For the sake of simplicity, I refer here to the entire zone in this southern sector as the "Cascade–Southern Coast Belt orogen" (Fig. 2). The orogen is much wider than its along-strike counterpart in the northern sector. More important, it contains a greater variety of rock units. The western third of the orogen is an imbricate stack of nappes that structurally overlies the Insular

Paleogeography *continued on p. 184*

IN THIS ISSUE

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DNAG News

A. R. Palmer

Great News!

The final two DNAG volumes to be produced by GSA, *Geology of Alaska*, edited by George Plafker and Hank Berg, and *Phanerozoic Evolution of North American Continent-Ocean Transitions*, edited by Bob Speed, are now complete. The editors checked the texts in late April, and production is now in our hands. We hope to have both volumes available for sale at the 1994 GSA Annual Meeting in Seattle.

It's been a long fight. Many thanks to all authors for their contributions, and particularly to those patient contributors to both volumes whose chapter texts were received by GSA up to 6(!) years ago. The authors and co-authors listed below bring the total number of contributors to all DNAG volumes to 2116. Those of us who are constantly referring to the DNAG books and maps really appreciate the immense contributions made by this large segment of the international geological community. ■

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Letter to the Editor

Dear Editor Moores:

I am writing you concerning the interesting paper "Landers-Mojave Earthquake Line: A New Fault System?" by Amos Nur, Hagai Ron, and Greg Beroza, (*GSA Today,* v. 3, no. 10, October 1993). These authors proposed that a new strike-slip fault system is forming in the Mojave Desert. It is believed to be cutting across older, but still active right-lateral strike-slip faults of the region that are losing an orientation in the regional stress field necessary for their continued operation. I am quoted (p. 257) as communicating to Nur that the idea that new faults might be forming now is "naive," and by inference that I and other colleagues who might be critical of a new Landers-Mojave fault zone do not "believe ... that the mechanics of fault and fault set formation is a crucial subject for research." Nothing could be further from the truth! However, the paper by Nur et al. does raise two interesting questions: (1) are faults being born today?; (2) if so, is the "Landers-Mojave earthquake line" one of them?

The answer to the first question must be a resounding "of course!" Is there really anyone who doubts this? The contention of Nur et al. that some earth scientists (their "critics") doubt that new faults can be born and that the study of such tectonic births is unimportant appears to me to be rather far-fetched. New thrust faults, for but one example, are forming in "protothrust zones" seaward of the toes of active accretionary prisms. In these zones, progressive dewatering of soon-to-be offscraped sediments is the initial step toward new thrust-front development (e.g., Moore et al., 1990, *JGR,* v. 95, p. 8753). As plate interactions evolve, waning deformations in some regions are replaced by waxing deformations elsewhere. Faults, folds, and ductile shear zones have formed throughout geologic time, and the present is not an exception to the past.

The answer to the second question—Does the "Landers-Mojave earthquake line" represent a new fault (or one in the process of being organized)?—is less clear. Although I admit to using the word "naive" in my review of an early Nur et al. manuscript (September 1992), the context of my usage was not that presented by Nur et al. in their 1993 *GSA Today* paper. In that earlier, unpublished manuscript, Nur and coworkers took the position that a "new" Landers-Mojave fault had developed in a contemporary time frame—i.e., in *this century!* Here from my earlier review is the context of the word "naive": "It is geologically/scientifically naive (terribly so!) to believe that in the last half of this century we have seen the birth of a soon-to-be-important fault zone formed by seismic events in 1947(?), 1975, 1979, and 1991 (April and June)." "What do the authors know about last century's Mojave Desert earthquakes? Or the century (18th) before that? Or the millenia before that? ... California is replete with faults that have gone unnoticed until either (1) someone finally mapped the area containing them, or (2) an earthquake along them led to re-rupturing of the surface along a trace that had been active hundreds or thousands or millions of years before."

I stand by the statements made above with reference to the *earlier* manuscript. I am pleased that Nur and his co-authors now put development of a hypothetical Landers-Mojave fault into the context of a greatly extended time scale. Now, back to the second question. Is the Landers-Mojave "earthquake line" a new fault in the making? While admitting the possibility that it might be, the concept of a nascent Landers-Mojave fault zone as proposed by Nur et al. (1993) seems to have been developed in a geologic vacuum. It is distressing to me that so little attention seems to have been paid either to the Mojave Desert geologic record itself or to publications dealing with it. Some examples of this neglect follow.

The concept of a new Mojave fault was founded on the belief (cf. Nur et al., 1986, *Geology,* v. 14, p. 746) that the south-central Mojave region containing older, now waning strike-slip faults has undergone significant (~15°) counterclockwise rotation in the geologically recent (small "r") past. Nur et al. (1993) failed to provide evidence that counterclockwise rotation in this part of the Mojave occurred after formation of the supposedly now-rotated Lenwood, Camp Rock, Emerson Lake, Calico, and other parallel faults. Dokka and Travis (1990, *Tectonics,* v. 9, p. 311), referencing Meisling and Weldon (1989, *GSA Bulletin,* v. 101, p. 106), concluded that regional right shear in the Mojave Desert block probably began 10–6 million years ago, and that the Calico–Camp Rock–Lenwood–Helendale family of faults was initiated only 1.5 to 0.7 Ma. Valentine et al. (1993, *Tectonics,* v. 12, p. 666) made the case from available paleomagnetic data that (1) no significant rotations have occurred in the Mojave area (with the exception of its northeastern corner) since 18 Ma, and that (2) "post–10 Ma right-lateral faulting there has produced relatively little crustal rotation."

The Nur et al. (1993) model for an emerging Landers-Mojave fault is based on "soft" arguments of stress orientations (about which we know relatively little for the Mojave region) and on paleomagnetic data not placed in the context of late Cenozoic time and events. I regard the current Nur et al. hypothesis as relying almost solely on the geometric, but not necessarily genetic, alignment of six earthquake epicenters in the past half-century (including Galway Lake, 1975, and Homestead Valley, 1979). Where, for example, as I once asked Nur (see above) were the Mojave epicenters in the 19th century? Or in the millenium before then? We simply don't know.

In conclusion, although skeptical of it, I do not discount the possibility that Nur et al. might be right. We may indeed be witnessing the development of a regional Mojave fault zone that cuts discordantly across still-active, but waning, right-slip faults. I hope that their interesting hypothesis can be tested with geologic studies (field mapping, trenching, geochronology, analysis of satellite imagery) that have the potential to resolve the age(s) of faults responsible for the Galway Lake (1975) and Homestead Valley (1979) earthquakes, and the question of their continuity, or lack of it, with the 1992 Landers rupture zone.

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GSA Officer and Councilor Nominees for 1995

Council announces the following officer and councilor candidates. Biographical information on all candidates will be mailed with the ballot to all voting members in August.

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Graduate Students Get the Vote

Bylaw Change for Student Members

William R. Dickinson, GSA President

At its May meeting, the GSA Council acted to broaden participation in Society affairs by student members. The effect of a change in the GSA bylaws passed unanimously by the Council is to extend full membership privileges to graduate students. These include the right to vote in all Society elections and to serve on committees at both Society-wide and section levels.

The bylaws change corrects a past anomaly in membership status. Our stated qualifications for membership include all those who have earned undergraduate degrees in geology or a related science, and those who are graduate students working toward a degree in some branch of the geosciences.

All graduate students currently affiliated with GSA are thus qualified for full membership, but most have opted for Student Associate status in order to take advantage of reduced student dues and fees. The GSA Constitution provides, however, that only Fellows and Members have full and equal voting rights. Consequently, Student Associates do not vote because they are not duly enrolled Members in the sense of the Constitution.

The new bylaw language does not change the fundamental principle that only full members have the vote. The bylaw change simply provides that "Members who are in-residence graduate students enrolled in a degree-granting institution and majoring in geology or related sciences may pay reduced dues equivalent to the dues for Student Associates."

This new provision, *effective in 1995,* opens the door for graduate students to become full Society members without financial sacrifice and to take their deserved place as bona fide junior colleagues in every respect. The change also makes it possible for Members who have been working as professional geologists to return to school and take advantage of reduced dues and fees, while in residence, without giving up their standing as full Society members.

The Council believes strongly that the new arrangements for affiliated students preserves the character of GSA as a fully professional society while giving every encouragement to those geoscientists furthering their education in graduate school to participate fully in Society affairs. The schedule of reduced dues and fees available to Student Associates simply becomes available to all Members who are in school as well. ■

To convert membership status . . .

Student Associates who are graduate students may convert their membership status to that of Member by selecting that option on the 1995 dues statement. To qualify for the dues rate offered to students, validation of student status will still be required; return your dues statement with a copy of your student ID or the signature of a department chair or GSA campus representative. For additional information, contact the Membership Services Department, phone (303) 447-2020, Ext. 116, or fax 303-447-1133.

Paleogeography *continued from p. 181*

superterrane. The nappes (San Juan–Cascade system south of 49°N) consist of supracrustal rock units ranging in age from early Paleozoic and possibly Precambrian to late Early Cretaceous (e.g., Brown, 1987; Brandon et al., 1988). Journeay and Friedman (1993) hypothesized that a minority of these units were derived from the eastern margin of the Insular superterrane. The majority, however, have no known Insular counterparts, so their tectonic provenance or homeland must have lain elsewhere.

The eastern two-thirds of the Cascade–Southern Coast Belt orogen, constituting the upper plate to the nappes (e.g., McGroder, 1991; Journeay and Friedman, 1993), includes a core of high-grade metamorphic rocks and orthogneiss flanked on the east by lower-grade rocks of the "Eastern Coast Belt" (Fig. 2). The latter includes several upper Paleozoic and lower Mesozoic units that originated in volcanic arcs or ocean basins, together with one or more sequences of Upper Jurassic and Lower Cretaceous clastic sedimentary rocks that were deposited partly in the Methow-Tyaughton basin. All the units are intricately juxtaposed along thrust and strike-slip faults of chiefly Late Cretaceous and early Tertiary age. Some workers (e.g., Rusmore et al., 1988) have speculated, on the basis of lithologic similarities, that pre-Upper Jurassic terranes in the Eastern Coast Belt and Intermontane superterrane were contiguous as early as Middle Jurassic time. Currently, however, the Intermontane superterrane sensu stricto is separated from possibly correlative units in the Eastern Coast Belt by the Pasayten, Yalakom, and Fraser fault systems (Fig. 2), all of which record Late Cretaceous or early Tertiary strike slip of at least several tens of kilometers (e.g., Monger, 1985; Hurlow, 1993).

Many lines of evidence demonstrate that all the elements of the Cascade–Southern Coast Belt orogen were contiguous and linked to one another and to the Insular superterrane by early Late Cretaceous time, ca. 90 Ma. In the Eastern Coast Belt, Albian and Cenomanian strata overlap diverse Jurassic and older basement terranes (Garver, 1992). Postkinematic plutons as old as 86–90 Ma intruded the Eastern Coast Belt and contiguous metamorphic rocks in the upper plate (e.g., Miller et al., 1993); U/Pb isotopic data from pre-, syn-, and postkinematic plutons in and adjacent to the imbricate zone indicate that most thrusting occurred between 97 and 91 Ma (Journeay and Friedman, 1993). The Turonian and younger Nanaimo Group, resting unconformably on the Insular superterrane, contains detritus derived from nappes in the imbricate zone (Brandon et al., 1988).

In summary, it is generally agreed that a zone >1300 km-long of mid-Cretaceous deformation and metamorphism in the northwest Cordillera coincides with the eastern edge of the Insular superterrane. Crustal shortening of tens (northern sector) to hundreds (southern sector) of kilometers was largely accommodated in a west-vergent imbricate thrust system. Deformation resulted from the Insular superterrane being driven against what was almost certainly the North American continental margin in an event variously referred to as "accretion," "collision," or "intra-arc contraction." Stratigraphic and plutonic links require that, by 90 Ma, the Insular superterrane and the flanking mid-Cretaceous orogenic belt were contiguous. The entire mid-Cretaceous orogen is sometimes referred to as the "boundary between the Insular and Intermontane superterranes," even though the latter, as strictly defined, is separated from the orogen by intervening Late Cretaceous and early Tertiary plutons and faults.

HYPOTHESIS 1: INSULAR SUPERTERRANE NORTH OF CALIFORNIA

Although the points in the preceding paragraph are widely accepted, there is as yet no consensus on the pre–Late Cretaceous disposition of the Insular superterrane. Where was it before it "collided," and where along the western margin of North America did the collision take place? On the basis of geologic evidence alone, several hypotheses have been proposed. Most workers (e.g., van der Heyden, 1992; McClelland et al., 1992b) specify that (1) the Insular and Intermontane superterranes had been juxtaposed with one another by Middle Jurassic time, and (2) they lay in approximately their present position with respect to California—that is, to the north of the Late Jurassic and younger Franciscan-Sierran system. The Jurassic boundary between the superterranes subsequently became the locus of intra-arc rifting or transform faulting, followed by intra-arc shortening to give rise to the mid-Cretaceous "collisional" orogen.

These models rest on interpretations holding that Upper Jurassic and Lower Cretaceous strata in the Gravina sequence (northern sector) and Eastern Coast Belt (southern sector) accumulated in the intra-arc basins that formed along the preexisting boundary between the superterranes. Additional evidence thought to indicate the proximity of the superterranes to one another and to the North American plate during late Mesozoic time includes (1) magmatic links—arcs built across terrane boundaries, and (2) provenance links—detrital zircons or populations of grains tying sediments to sources in one of the superterranes or in North America (e.g., McClelland et al., 1993; Garver, 1992).

In spite of minor variations among these models, they all yield a paleogeography in which the late Mesozoic (ca. 150–90 Ma) disposition of the Insular and Intermontane superterranes was essentially the same as today's: both lay north of the Franciscan-Sierran system (Fig. 1A). According to hypothesis 1, the Cascade–Southern Coast Belt orogen and imbricate thrusts along strike to the northwest formed as the Insular superterrane impinged against the currently contiguous Intermontane superterrane to the east.

PALEOMAGNETIC DATA FROM CRETACEOUS ROCKS

The paleogeography in hypothesis 1 is based on geologic evidence. Paleogeography can also be inferred using paleomagnetic data. Paleomagnetic directions in rocks can yield paleolatitudes, provided certain assumptions are satisfied. The usual procedure (reviewed in Beck, 1989) is to compare the measured paleomagnetic directions with the directions expected had the rocks in question been in their present latitudinal position with respect to cratonic North America. Equivalently, paleopoles calculated from the measured data can be compared with cratonic reference paleopoles.

continued on p. 185

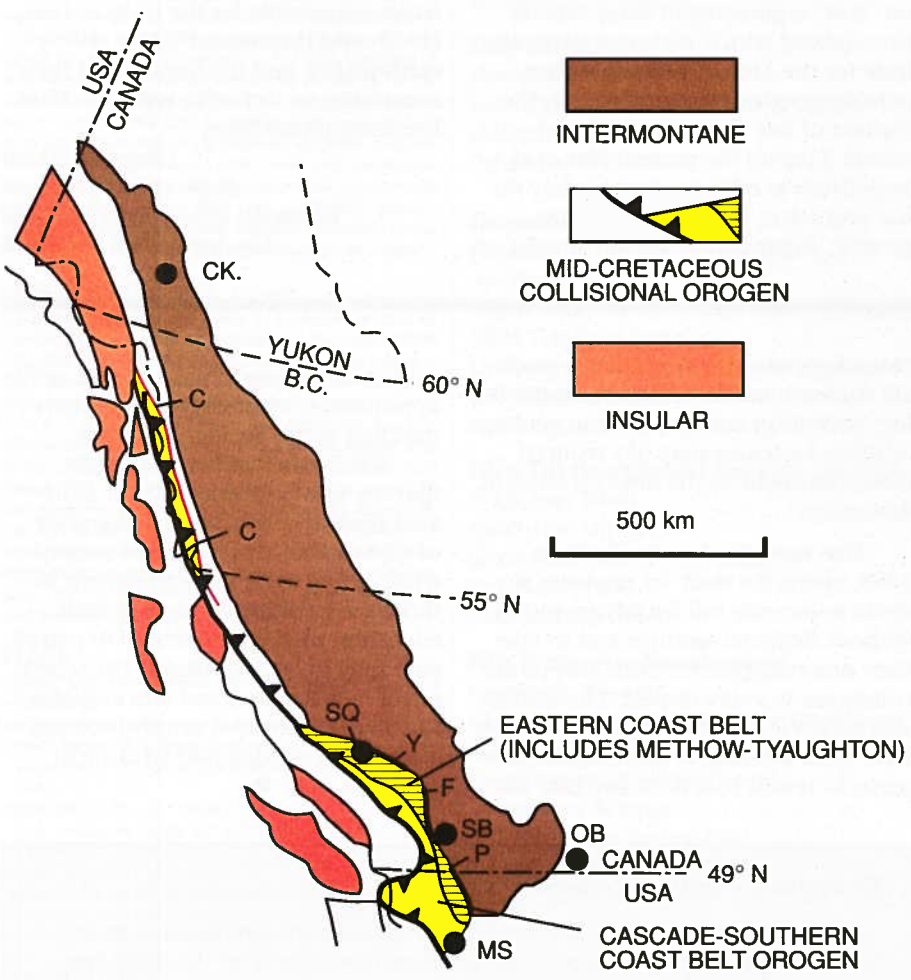

Figure 2. Map of present-day northwest Cordillera depicting the Insular superterrane and the Intermontane superterrane, and the mid-Cretaceous orogen along the eastern boundary of the Insular superterrane. The eastern Coast Belt within the orogen is denoted by horizontal lined pattern. The eastern boundary of the Cascade–Southern Coast Belt orogen is locally the high-angle Yalakom (Y), Fraser (F), and Pasayten (P) faults. North of lat 54°N, C denotes the early Tertiary Coast shear zone. CK, SQ, SB, MS, and OB are paleomagnetic localities discussed in text.

Paleogeography *continued*

Since the 1970s, many paleomagnetic studies have been conducted on rocks from the northwest Cordillera (summarized by Beck, 1989; Irving and Wynne, 1990). Nearly all of the investigations dealing with mid-Cretaceous magnetizations have reported paleomagnetic inclinations shallower than those expected for cratonic North America. This type of discordance could be due to either (1) postmagnetization, northward latitudinal displacement relative to the craton, (2) tilting about a horizontal axis, or (3) a combination of displacement and tilt. Selecting the correct explanation requires knowing the direction and amount of postmagnetization tilting. For plutons, this feat is seldom achieved because unambiguous criteria for the paleohorizontal in plutons or country rock are commonly lacking.

Most paleomagnetic data relevant to the mid-Cretaceous paleogeography of the northwest Cordillera come from plutons ca. 90–100 Ma. These discordant data have been interpreted differently by two groups, both of which fully acknowledge the "paleohorizontal problem." One school of thought, represented by Beck et al. (1981), and Irving et al. (1985), assumes that the batholiths yielding the data have not been appreciably tilted and so favors the interpretation that post–middle Cretaceous northward displacements account for the discordance. Irving (1985) introduced the concept of Baja British Columbia to describe the crustal element that lay at least 2000 km farther south in mid-Cretaceous time and that subsequently moved northward. Irving et al. (1985), Umhoefer (1987), Umhoefer et al. (1989), and Oldow et al. (1989) viewed Baja British Columbia as consisting of the Insular superterrane and most of the Intermontane superterrane and placed it 2000–3000 km south, at the latitude of northwestern Mexico, at ca. 100 Ma. The other school, led by Butler et al. (1989), challenges the whole concept of Baja British Columbia and favors the alternative hypothesis that discordant paleomagnetic directions in plutons are due to regional, in situ tilt of the Coast plutonic complex.

Controversies like this one are understandably fed by perceived weaknesses in the paleomagnetic studies; for example, absent or ambiguous evidence for the paleohorizontal; poor controls on ages of magnetization; and failures of the fold test. It can be argued, however, that there are four data sets that overcome these weaknesses and allow highly reliable interpretations of discordance supporting post–middle Cretaceous translation rather than tilting. (1) Locality CK in Figures 1B and 2. Marquis and Globerman (1988) presented data from the 70 Ma layered volcanic rocks of the Carmacks Group, resting unconformably on the northern Intermontane terrane (Fig. 2). They calculated a northward displacement of 1490 ±940 km (13.4° ±8.5°). Butler (1990), using a different average of site-mean virtual geomagnetic poles, re-calculated a displacement of 1190 ±1140 km (10.7° ±10.3°). (2) Locality SB in Figures 1B and 2. Irving et al. (1993) expanded the earlier study of Irving and Thorkelson (1990) on the well-bedded volcanic and volcaniclastic Spences Bridge Group. The section is late Early Cretaceous age (104 Ma) and lies unconformably on several units of the southern Intermontane superterrane. Irving et al. (1993) reported a "best estimate of ... displacement from the south since mid-Cretaceous time of 1200 km." (3) Locality SQ in Figures 1B and 2. Maxson et al. (1993) calculated a paleolatitudinal northward displacement of ~2900 ±1000 km (26°) for the upper Lower to lower Upper Cretaceous Silverquick sedimentary unit and overlying Powell Creek volcanics, which are, at least in part, 94 Ma. The section is part of the Eastern Coast Belt and lies at the eastern edge of the mid-Cretaceous orogen. (4) Locality MS in Figures 1B and 2. Ague and Brandon (1992) used hornblende barometry to determine a paleohorizontal datum for the ca. 93 Ma age of emplacement and magnetization of the southwestern lobe of the Mount Stuart batholith. The pluton intruded the western nappes and metamorphic core of the Cascade–Southern Coast Belt orogen. Their analysis indicates a post–middle Cretaceous northward displacement of 2900 ±700 km, an amount fully in accord with the earlier results (~3100 km) of Beck et al. (1981) for Mount Stuart, and with displacements calculated for other plutons in the Coast plutonic complex by Irving et al. (1985).

HYPOTHESIS 2: INSULAR SUPERTERRANE SOUTH OF CALIFORNIA

The mid-Cretaceous paleogeography hypothesized in Figure 1A is based exclusively on geological evidence and interpretations; it ignores or rejects paleomagnetic data. Alternatively, we can hypothesize a ca. 95 Ma paleogeography based exclusively on the four paleomagnetic data sets listed above. The premises underlying Figure 1B are as follows: (1) The paleomagnetic directions have been corrected for postmagnetization tilting and, in the case of bedded volcanic rocks, do not contain systematic errors derived from regionally consistent paleoslopes. Consequently, the discordant inclinations are due entirely to paleolatitudinal displacements. (2) The mean value of each calculated displacement is used to restore a crustal element to its mid-Cretaceous position. Following the analysis of Marquis et al. (1990, Fig. 1) and Irving and Thorkelson (1990, Figs. 18 and 19), the mean is statistically the most probable displacement; displacements less than or greater than the mean but still within the 95% error limits are less probable. (3) Discordant declinations reported in some of the studies listed above are assumed to be due to local rotations about vertical axes, rather than to the wholesale clockwise rotation of an entire superterrane. (4) Mid-Cretaceous plutons that intruded the margin of cratonic North America east of the Intermontane superterrane, and for which tilts are known from bathozonal studies, yield concordant paleodirections (OB in Fig. 1B; Irving and Archibald, 1990) indicative of no net latitudinal displacement.

Two restorations, accommodating the four data sets, were used to

Paleogeography *continued on p. 186*

Paleogeography *continued from p. 185*

construct Figure 1B. In one, the western two-thirds of the Intermontane superterrane is restored southward 1200 km, as required by the comparable displacements calculated for the Carmacks (CK) and Spences Bridge (SB) data sets. The more conservative estimate is used for Carmacks. Because geologic evidence (Brown et al., 1986) indicates that the eastern part of the Intermontane superterrane was attached to now adjacent North America by Middle Jurassic time, the latitude of the eastern third of the superterrane at 95 Ma is fixed in Figure 1B by the OB data set. In the other restoration, the displacement of ~2900 km calculated for both the Mount Stuart batholith (MS) and the Silverquick– Powell Creek section (SQ) is applied to the entire 1500-km-long crustal element, lying between 49°N and 58°N, that resulted from the collision of the Insular superterrane 90–100 Ma. As discussed above, it is widely accepted on geological grounds that this element included the Insular superterrane and the Cascade–Southern Coast Belt orogen (location of both MS and SQ). The restored position of the element is entirely south of present lat 32°N, the U.S.-Mexico border.

The restoration in Figure 1B has several implications, some of which I note here. Baja British Columbia is redefined in this paper to consist of the Insular superterrane and the contiguous mid-Cretaceous orogen flanking it to the east; in contrast to earlier hypotheses (e.g., Irving et al., 1985; Umhoefer, 1987), it does not include the Intermontane superterrane sensu stricto. The Insular superterrane collided in latest Early to earliest Late Cretaceous time with the North American margin where it extended south from the convergent plate boundary represented in California by the Franciscan subduction complex and Sierran magmatic arc. I hypothesize here that the collision occurred along the southern continuation of the Franciscan subduction zone. The mid-Cretaceous collisional orogen was fashioned from a heterogeneous fore-arc sliver situated continentward of the subduction zone. In what became the Cascade–Southern Coast Belt orogen in southeastern Baja British Columbia (Fig. 1B), the Early Cretaceous fore-arc basin is represented locally by the Methow-Tyaughton succession. The arc itself was probably the Peninsular Ranges batholith, which paleomagnetic data indicate originally lay at these paleolatitudes (e.g., Lund and Bottjer, 1991; Ague and Brandon, 1992).

As newly defined here, Baja British Columbia moved northward along a transform-fault system, parallel to the coast of California but west of the Franciscan Complex, between ca. 80 and ca. 60 Ma (modeled by Umhoefer, 1987, and Umhoefer et al., 1989). A logical inference is that during this interval, the Franciscan ceased growing as an accretionary wedge fed by sediments scraped off of descending oceanic crust; convergence between Pacific plates and North America was accommodated instead along the western margin of the Insular superterrane. Baja British Columbia and the Intermontane superterrane were juxtaposed north of California along dextral transcurrent faults in the northern part of the transform system during this interval; the likeliest candidates are the Pasayten fault, a "proto-Yalakom" fault parallel to but northeast of the present Tertiary trace of the Yalakom fault, and the Coast shear zone. The amalgamated superterranes were displaced northward ~1200 km with respect to cratonic North America, along an as-yet-unspecified fault system in the eastern Intermontane superterrane (F in Fig. 1B) originally hypothesized by Umhoefer (1987). All northward displacements were largely completed by 50–55 Ma (e.g., Irving and Brandon, 1990; Irving and Wynne, 1990).

COMMENTS

My purpose here, given the space available, is simply to present and compare two maps that each depict hypothetical mid-Cretaceous paleogeography. One map is based exclusively on paleomagnetic data and the other on geological arguments. It is obvious that at least one of these hypotheses is invalid; perhaps both are. It may turn out that the assumptions underlying the paleomagnetically derived displacements are flawed. However, the reliability of the assumptions and geological evidence invoked to support the "stabilist" hypothesis portrayed in Figure 1A should also be debated. I contend that this geological evidence at present does not support hypothesis 1 to the exclusion of hypothesis 2; rather, the evidence is compatible with more than one paleogeographic interpretation. In addition to continuing to compile lines of evidence thought to corroborate one hypothesis or the other, geologists should attempt to resolve the controversy by devising specific tests designed to rule out the predictions of hypothesis 2.

ACKNOWLEDGMENTS

I thank Mark Brandon, John Garver, Margi Rusmore, and Paul Umhoefer for encouraging me to write this article, and for willingly exploring and discussing hypothesis 2. I have also been influenced by many discussions with Ted Irving on the philosophies underlying the formulation and testing of hypotheses. Ted Irving, Sarah Roeske, and Robert Twiss read and commented on an earlier version of the manuscript.

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GSAF UPDATE

Robert L. Fuchs

Case History of a Lasting Gift

In 1988, at the time of GSA's Centennial, Fred A. Donath and his wife Mavis made an important gift to the GSA Foundation. The gift established the endowment for what has become a prestigious GSA medal and award—the Donath Medal and the Young Scientist Award. The initiation, development, and growth of the endowment that makes this annual award possible is an excellent example of the impact that carefully crafted contributions to GSA can have upon individual scientists, and upon geology in its entirety.

In 1987 GSA President Jack Oliver appointed an *ad hoc* committee of prominent GSA members to look beyond the 1988 Centennial and suggest programs and activities that would be an integral part of GSA's direction in the early years of its second century. One of the recommendations of this Committee on the Path to the Year 2000 was the creation of a young geologist award. The Committee felt that such an award would indicate to bright young scientists that they and their work are appreciated. The GSA Council approved such an award at its 1987 fall meeting.

Shortly thereafter, Fred Donath contacted GSA Executive Director Mike Wahl about making a gift to the Society. A Fellow and 33-year member of GSA, Donath was concluding a successful tenure as Vice President for Research and Development of Earth Technology Corporation. He had decided that a gift to GSA of shares in that company from his personal holdings would be a fitting recognition of his long attachment to geology and to GSA. Wahl discussed the funding of this award as one of several opportunities that could be supported by a major gift to the Society.

In describing his reasons for selecting an award for young geologists as the object of an endowment gift, Fred Donath cited his own career. As a professor at Columbia University at the age of 31, he was one of five geologists chosen to receive a Semicentennial Medallion from Rice University for outstanding contributions to the geological sciences. The direct effect on him was encouragement and motivation to probe deeper into fundamental problems in dynamic structural geology. He felt that the GSA Young Scientist Award could have a similarly pronounced effect on future young geologists working on a variety of important problems in the earth sciences.

A second reason for providing this gift was Donath's strong, career-long association with GSA. When the Society was still located in New York City in the 1960s, Henry Aldrich retired as Executive Director, Agnes Creagh assumed his responsibilities, and Fred Donath was asked to serve as Acting Editor. This exposed him to the contributions of many authors and to the evaluations of their papers by outstanding scientists in the various geological disciplines, an extremely valuable education. During his career Donath has published several of his more important papers in the GSA *Bulletin* and the Memoir series. Today he is a Trustee of the Foundation and the Executive Director of GSA's Institute for Environmental Education.

The endowment for the Young Scientist Award was established with an initial gift of 25,000 shares of Earth Technology stock to the Foundation in late 1988, with a value of $100,000. A second gift of 25,000 shares in 1989 raised the value of the fund to $237,500. Since the endowment was established, five annual awards of $10,000 each and five gold medals have been made. Under the guidance of GSA's Committee on Investments and portfolio managers, the fund has grown to its present value of about $250,000. In 1994 the award will be increased to $15,000.

In reflecting on this now important part of GSA's awards program, Fred Donath recently commented, "Mavis and I have been extremely pleased with the way that our gift has worked out. When we made the two contributions of appreciated shares, the tax attributes in 1988 and 1989 were important to our estate planning, and there were significant tax advantages through the elimination of capital gains taxes on this stock. Since that time the endowment fund has grown through careful investment, so that the size of the award is being increased. Finally, and best of all, five outstanding young scientists have been recognized for their accomplishments early in their careers. We look forward to the recognition of many more worthy recipients, and we hope that others who contemplate such a gift will be encouraged to proceed by noting our experience."

Unocal Pledge to the Second Century Fund

Unocal Corporation, an integrated energy resources company based in Los Angeles, with operations around the world, has made a five-year pledge of $50,000 to GSA's Second Century Fund. This contribution will be in the form of annual installments of $10,000, the money to be used by GSA for its earth science education, research, publications, and meetings programs.

The grant is under the auspices of Unocal's Worldwide Exploration Organization, located in Sugar Land, a suburb of Houston, Texas, and of the Unocal Foundation of Los Angeles, California. In 1994, GSA will use the Unocal money for SAGE activities and for student research grants.

Unocal Corporation was an important contributor to GSA during the 1980s as a participant in the DNAG funding. GSA President Bill Dickinson responded to news of the pledge by noting that Unocal and other natural resource companies have supported the Society's work for many years. "It is gratifying to see the continuation of this financial assistance at a time when companies are paying very close attention to the bottom line. GSA and industry have enjoyed a mutually beneficial relationship. I believe Unocal's grant manifests this ongoing, healthy partnership."

CORRECTION—Student Travel Grants

Some of *GSA Today's* readers were quick to point out our first mistake of the year. In the GSAF Update for April, a partial total for 1993 was inadvertently entered. The Foundation has correctly disbursed a total of $70,653 in student travel grants since the program began in 1988. ■

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WASHINGTON REPORT

Bruce F. Molnia

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

Meet Gordon P. Eaton, New Director of the U.S. Geological Survey—Part 1

Gordon Eaton

In early June 1994, *GSA Today* visited Gordon P. Eaton, new Director of the U.S. Geological Survey (USGS) to learn about his views of the USGS and federal science, and to discuss the future of the earth sciences in the United States and abroad. Eaton became the twelfth director of the USGS on March 14, 1994, when Secretary of the Interior Bruce Babbitt administered the oath of office. Babbitt described Eaton as "the ideal candidate to lead the Nation's premier water and earth science information agency, at a time when we are facing many critical decisions on the environment." Babbitt continued, "I am confident that he will lead the USGS to an even stronger role in providing us with the scientific information needed for wise policy decisions."

At the March ceremony, Eaton said, "The unbiased pursuit of earth science questions has been an invaluable resource both to our Nation's citizens and to every administration. It is my firm intention to strengthen and further what is already an admirable legacy created during more than a century of pursuing earth science in the public service."

Eaton continued, "I see superb opportunities, even in these rather constrained economic times, to reshape, rededicate and refocus the collective efforts of all the USGS's employees in directions that will continue to be relevant, valuable, and responsive to the scientific information needs of the nation even as the needs change and evolve."

Eaton, 65, an Ohio native, received his bachelor of science degree in geology at the Wesleyan University (1951) and both his master (1953) and doctorate (1957) degrees at the California Institute of Technology. He is a highly distinguished earth scientist, administrator, and former employee of the USGS. His most recent post was as Director of the Lamont-Doherty Earth Observatory of Columbia University. In addition to nearly 18 years of previous experience with the USGS, Eaton has served as president of Iowa State University in Ames, and provost and vice president for academic affairs at Texas A&M University. He is a Fellow of the Geological Society of America.

GSA Today: How has the USGS changed during the 13 years that you were away from it?

Eaton: Actually, it has changed in very impressive ways. The balance among competing priorities has changed. The role of water and its limitations as a natural resource in some regions of the country and environmental concerns relating to water, for example industrial and agricultural pollution, have grown greatly in importance in the Survey's portfolio of resource issues.

At the same time, the USGS mapping program has emerged from what, before I left, was strictly a topographic support activity, to an entity that can stand alone. Mapping now has a computer science focus and is not just a cartographic activity. The mapping program produces products that are very relevant to national needs.

The interest in funding levels for hazards has grown. When you lump earthquakes, volcanoes, and landslides together, hazards are the largest single major element in the geologic program of the Geologic Division.

In the 115-year history of the USGS, the decrease in priority for locating, assessing, and understanding the processes of the origin of mineral deposits is a major change. This nation doesn't have a minerals shortage problem now, nor is one foreseeable. Other developed nations, like Japan and Germany, have demonstrated the capacity to get along without their own mineral resources. The industrial revolution is over, and the cold war is over. Consequently, the mineral resources surveys on which the USGS was first based during Clarence King's directorship (1879–1881), don't have the same priority they once did, even as recently as a decade ago. Today, we are recycling. We have substituted fiber optics for copper in the transmission of signals. We are in the process of substituting composite materials for aluminum in the construction of aircraft. Our minerals resource program is turning its attention to post-mining environmental impacts and remediation, issues like metals pollution of streams and acid mine drainage.

A lot of these changes have been driven by changes in societal needs, changes in societal attitudes about basic research. It all comes together in a very complex sort of way. At the same time, the academic community has doubled the number of Ph.D. researchers in all fields of science from 1968 to 1991. However, adjusted for inflation, the funding for science has increased only 20%. So we've got twice as many people trying to exist on one-and-a-fifth times as much money. The USGS is caught up in that crunch as well.

GSA Today: What do you envision the USGS looking like when you step down as director, whether it's five years from now or a much longer time in the future?

Eaton: I think the National Research Council [NRC] in its 1993 report, "Solid-Earth Sciences and Society" [see May 1993 Washington Report], was right when it saw that some part of the future strategic research opportunities in the earth sciences would be dominated by environmental matters and aspects of engineering geology. In those two areas, the USGS already has a full portfolio of issues. We must address them with up-to-date, impartial earth science information. This will require taking a holistic view of the planet and its resources. We need to understand all of the aspects of a resource, and its interrelationships and interdependencies on other resources. This means fundamental work in water, in geology, and in mapping.

I think we need to take a moment and look into the future, which is not going to be very much like the past. I don't think the past is going to come back. Here and there, in this program and that, funding levels may increase slightly. But overall the levels of funding are not going to rise in the next decade in significant ways. I think the USGS needs to sit down now and design its future, to figure out how it is going to respond in order to remain relevant and responsive. I'm going to be pushing the development of this response very hard.

GSA Today: Two years ago, the Geological Survey of Canada held a meeting on the future of geological surveys, called the International Conference on Geological Surveys [see July 1992 Washington Report]. We learned that most geological surveys, like the USGS, have changed, and the emphasis on traditional minerals has moved to third world countries. These are countries with a general absence of basic geological information. The developed surveys, like those of Great Britain, Germany, and Canada, were all getting into far more focused applied, national-needs-oriented types of activities.

Eaton: Exactly.

GSA Today: Several surveys, such as the British Geological Survey, have discovered that in order to survive they must contract out their services, either to government or to industry, in order to maintain a critical level of funding.

Eaton: My understanding is that this year more than half of the British Survey's funding comes from outside sources. It's not direct parliamentary appropriations. I think that the USGS water program has responded appropriately to this worldwide reality. This fiscal year, more than half of its funding comes from outside sources. The same is true for our EROS Data Center in Sioux Falls, South Dakota.

The U.S. Geological Survey as a whole needs to become much more aggressive in pursuing outside funding in other program areas. Now, that has implication, because as soon as you seek to serve "customers," to use the term that is popular around town these days, but which I don't happen to like terribly well, you have to tailor and package what it is you do for each audience. This is in essence a survival issue.

GSA Today: Who do you perceive as the customers of the USGS?

Eaton: Well, I think we need to look very hard at that issue. I'll start close to home. I think that all of the other Interior bureaus that have regulatory or resource management obligations are potential customers, both for us and for the new National Biological Survey [NBS]. And, indeed, the Bureau of Land Management [BLM], and the Bureau of Indian Affairs [BIA] have been Survey customers for some time. Even back in the time before I left the Survey in 1981, we were performing mineral resource evaluations on BIA lands. We have done things for the Minerals Management Service in the past that relate to environmental studies in coastal areas.

Secretary Babbitt is very enthusiastic about the potential for his two science bureaus, the USGS and the NBS [see December 1993 Washington Report]; to serve the geoscience and biological science information needs of the Department of Interior. I think that we can do a lot within Interior to seek customers.

Certainly, other federal agencies, such as the Environmental Protection Agency [EPA] and the Department of Energy, are potential customers. Because EPA is primarily a regulatory as opposed to a research organization, there are some things that we do that can help them. I don't know how familiar you are with the USGS radon program. It's enormously impressive and highly relevant. We have helped prepare materials for state-by-state reports in conjunction with EPA. They have taken our Open-File Report materials and packaged them with some of their own materials to publish some very, very useful documents. We need to scan the horizon for other federal agencies beyond our sister bureaus in Interior. EPA is certainly one of them. Also the National Aeronautics and Space Agency and the National Oceanic and Atmospheric Administration are agencies we are working with, and with whom we certainly can do more.

None of this is new. We've had partnerships of all kinds. But there is a new emphasis on partnering in government. Different agencies are not going to maintain separate and somehow equal competitive components. The streamlining of the government is going to drive that very hard. In the May 1994 issue of *Geotimes* there was an article on the new look at the Bureau of Mines. What they are proposing to do there is very much what our minerals program has been proposing to do. Somehow we are going to have to sort through that and see what is properly the domain of the USGS and what is properly the domain of the Bureau of Mines. The Congress and the Secretary of Interior aren't going to fund duplicative efforts in the area of mine land remediation.

There is a serious question about the extractive industries and the fact that they have shut down a lot of their research labs. The mining industry went first. That was happening even as I left the USGS in the earliest part of the 1980s. Now the petroleum industry has shut down some of its labs. For a variety of reasons, both of these industries have also abandoned a lot of domestic activity and are working overseas. That's where the new deposits and fields are being found. It seems to me there might be efforts in terms of basic research within the USGS that might serve those industries, since they have closed down their own research labs. But I have to tell you that a lot of universities are eyeing these industries for the very same reason. We did at Lamont.

This discussion with Gordon Eaton will continue in the August Washington Report in next month's issue of GSA Today. ■

Congressional Hearings—An Avenue to the Heart of the Process

Murray W. Hitzman, 1993–1994 GSA Congressional Science Fellow

Congressional hearings—or the prospect of them—have been in the news lately.

Although many of the most famous congressional hearings have dealt with oversight of government programs or confirmations of political appointments, the majority of hearings are intended as fact-finding forums to educate members of Congress about specific problems or issues. Aside from appropriation hearings, where public witnesses are rare, hearings provide a means for direct input of ideas and views into Congress from private citizens and interest groups.

Earth scientists can use congressional hearings to bring their expertise to bear on relevant policy decisions. Many aspects of the earth sciences are of great interest to the public and to policy-makers—earthquakes, volcanoes, floods, coastal erosion, dinosaurs, global change, and environmental cleanup—and many other hearings could include important aspects of the earth sciences. I recently helped organize a hearing for Senator Joseph I. Lieberman (D–CT) on the interrelationship of President Clinton's Climate Change Action Plan, the future of the U.S. insurance industry, coastal geology, and sea level. Earth scientists need to be more aware of how we can focus attention on our messages. One means that we have not utilized fully is the congressional hearing.

Organizing a Hearing

Hearings are initiated by a congressional committee or subcommittee chair. She or he and their staff decide what issue the hearing will focus on, who the witnesses will be, and when the hearing will occur.

The first step is establishing the focus of a hearing. Some hearings are specific, such as one I recently helped to organize on the Nuclear Regulatory Commission's licenses and material user fees. Broader topics, such as the current reauthorization of CERCLA (Superfund), may be approached either in a wide-ranging hearing or through several individual hearings. Because of its complexity, CERCLA has recently been the subject of several individual hearings on such aspects as remediation, allocation of costs, and state participation.

During hearings, committees or subcommittees receive testimony from witnesses—administration officials, interest-group representatives, independent experts, and constituents. On issues involving science, I have found most congressional staff members utilize their network of contacts, the popular press, nongovernmental organizations such as the American Geological Institute or the American Petroleum Institute, and one or two technical journals (generally *Science* or *Nature*) for identifying potential witnesses. The chair can instruct the committee staff to choose witnesses having views similar to his or hers, or can arrange the witnesses so that favorable ones are on the first panels and unfavorable witnesses appear at the end of a hearing, when time pressure may cut questioning short. Although there are many ways to "stack" or "slant" a hearing, my experience thus far has been that most committee and subcommittee chairs try to provide for relatively balanced hearings with witnesses of varying positions. They also consult with the minority ranking member of the committees and subcommittees, and their staff, to get witnesses that support the minority point of view.

Deciding when a hearing will occur helps establish what its impact will be. A chair who opposes legislation may simply refuse to schedule hearings on it until it is too late to finish action on the bill during the session. The same result can be achieved by scheduling several hearings which drag on interminably. Hearings that the chair wishes to be spotlighted will be scheduled on the mornings of days when it is believed there will be little other major news, so that the media can get video clips and soundbites for the evening news programs. Conversely, a hearing held on a Friday afternoon prior to a major league play-off is likely to attract little media attention. The prominence of the witnesses is also a factor in how the hearing will be covered—cabinet secretaries and famous individuals, such as Nobel laureates, will attract media attention.

Hearings can have from one or two to more than 20 witnesses. Most commonly, there will be two panels of witnesses. The first often comprises one to three Administration witnesses, while the second panel will have two to five expert witnesses on the specific issues. Witnesses are asked to submit written testimony at least 48 hours prior to the hearing. Written testimony can be virtually any length, but it is usually 8 to 15 typewritten pages and may include black-and-white charts and diagrams. The testimony is distributed to all committee members, and their staff, who examine it and prepare questions. Witnesses who fail to submit testimony on time are putting themselves at a disadvantage, because they will probably receive fewer questions from members and will have less opportunity to explain their point of view.

The staff prepares a briefing book for their Congress member prior to the hearing. The book contains a report written by the committee or subcommittee staff on the background and major issues of the hearing, a separate report by the member's staff highlighting specific aspects that are of interest to the member, an opening speech on the topic of the hearing, questions for the witnesses (plus expected answers that can lead to follow-up questions), and copies of the written testimony. This book is given to the member the day before the hearing so that she or he can review the information. The member then meets with staff to clarify any outstanding issues and review the questions.

What Happens at a Hearing?

At the hearing, members in attendance give brief (generally less than five minutes), opening statements. Witnesses then speak, generally for about five to seven minutes. The most effective witnesses condense their more voluminous written testimony into a brief, nontechnical speech that highlights important points. Witnesses may be questioned either immediately after their testimony or, more commonly, after the entire panel has finished their presentations. In both presenting testimony and answering questions it is critical for witnesses to be succinct and to realize that the members, and the staff advising them, are usually intelligent generalists, not specialists.

Because members of Congress have differing political viewpoints on the issues being examined in a hearing, witnesses should expect friendly and hostile questions. Questions should be answered directly but in lay terms. When answering questions where there is disagreement within the scientific community, it is probably most helpful to simplify and present an idea of the preponderance of opinion, such as "approximately 90% of earth scientists concur that this is the case." Questions requiring answers that are not easily given at the hearing, such as those requiring specific data not immediately available to the witness, may be answered in writing following the hearing if the committee or subcommittee chair leaves the record open.

The opening statements of the members, together with the witnesses' verbal testimony and the questions and answers, are recorded and published as a report of the hearing. Written testimony is included in the report as an addendum to the proceedings, as are written replies to questions. These reports are frequently quoted in subsequent committee reports on proposed legislation and may eventually be consulted by legal authorities seeking to clarify the legislative intent.

How Earth Scientists Can Use the Hearings Process

If you know of an issue that you think deserves to be brought to the attention of Congress or that relates to upcoming legislation, contact your senator or representative, or a member of Congress on the relevant committees or subcommittees, and suggest that a hearing be conducted. You should make the request simple and understandable, and indicate how the findings will help with the legislative process. Clearly, topics that put the member in a good light and could result in favorable publicity will be best received. If you know, or believe, that hearings will be held on a particular issue, you can also influence the hearing by suggesting witnesses or questions for witnesses to members, their staff, or public policy committees of earth science organizations.

Politically astute scientific organizations maintain contacts and lists of potential witnesses from different constituencies for the various issues facing Congress. Earth scientists need to let their professional organizations know what issues interest them and be willing to testify at hearings if called upon. However, note that Congress does not pay for witness expenses. If you are called as a witness, make sure you submit clear, succinct, and understandable written testimony on time. Before writing your testimony, talk to the committee or subcommittee staff organizing the hearing. Understand exactly why the hearing is being held and address those issues that are directly relevant to the purpose of the hearing.

Oral testimony should be a summary of your written testimony. It should be comprehensible to the general public. While graphics can be used, they are unwieldy; simple posters with large lettering are the most effective. More complicated illustrations may be entered in the written record.

Participating in congressional hearings is an exciting experience—not just because of the TV cameras and the impressive setting of the hearing rooms, but, more importantly, because of the opportunity to have direct input into the legislative process. From collecting fossils on public lands, to mining law reform, to the interrelation between coastal erosion and insurance, the earth sciences are increasingly a direct part of the legislative agenda. Earth scientists now more than ever need to make their expertise available for wise policy decisions. Although not as high-tech as the Information Superhighway, the congressional hearing process is a public avenue to the heart of the legislative process. As earth scientists, we need to use it more effectively.

Murray W. Hitzman, 1993–1994 GSA Congressional Science Fellow, is serving on the staff of Senator Joseph I. Lieberman (CT). Hitzman may be contacted at (202) 224-4041. *The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 1434-93-G-2382. 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.* ■

New Center at Stanford Focuses on Crustal Fluid Research

The school of earth sciences at Stanford University (California) has established a new center for the study of fluids in Earth's crust. The purpose of the center is to bring together the diverse groups in the school which are already involved in crustal fluid research. Extensive crustal fluid–related research is being conducted in the school's three departments: Geological and Environmental Sciences, Petroleum Engineering, and Geophysics. It is concentrated in several active but separate research projects within the departments. The new center's aim is to build on these existing projects a program that will focus on remaining key crustal problems whose solutions require truly interdisciplinary efforts.

The center's highest priority is to provide opportunities for earth science students with a strong background in physics, math, chemistry, and computer sciences who wish to pursue interdisciplinary research in these and related topics together with faculty from all three Stanford departments. The current director of the center is Amos Nur, Department of Geophysics, Stanford University, Stanford, CA 94305-2215, (415) 723-0839, fax 415-723-1188, E-mail: nur@pangea.stanford.edu.

SAGE REMARKS

Beth Schwarzman, Chair, GSA Education Committee

Inquiry-oriented Science Teaching

There is a revolution in science education, a revolution as unsettling and as important as the revolution in geology that gave us the plate tectonics paradigm. The overt goal of this revolution is the overthrow of the lecture-and-textbook method that now dominates science teaching. The fact that a revolution is occurring is not odd, given what research shows about how people learn. What is odd is the obscurity of that revolution outside of schools. Because this unstoppable revolution will affect us all, it behooves us to understand what is going on and to join the vanguard, not to defend the barricades of the past.

Simply put, the aim of the revolution is to make science education more like science. That means teaching how to ask questions, how to collect appropriate data, and how to analyze those data for meaning; in short, teaching how to think scientifically. Although traditional methods may seem to teach scientific thinking, it turns out that for the majority of students those methods do not succeed. Much science teaching has produced students who can reproduce selected facts or perform particular operations for exams but who can't make sense of those facts or think critically about the results.

As long as the goal of science education was to produce a few highly qualified scientific and technical minds, the textbook-and-lecture method could pass. There are always a few exceptional students who see the big picture and quickly surpass their teachers. They will learn no matter what. But that is clearly not America's education goal. In a democracy increasingly affected by advanced technology and limited by finite resources, a few scientific minds are not enough. Everyone must have some ability to think about issues that turn on scientific considerations. From American Association for the Advancement of Science (AAAS) to newspaper editorial pages there are calls both for more scientists and for a more scientifically literate populace. And so the revolution in science teaching: new goals require new methods.

Science teaching post-revolution is turning away from lecturing and textbooks toward engaging students directly in doing science, not only because it is more fun, but because it is more educational. This is known as inquiry-oriented, hands-on science teaching. It might sound as though this could be accomplished by the kinds of lab exercises we did in high school chemistry: the workbook laid out the inquiry, we handled the materials and followed the steps to get the answer. But the new paradigm is fundamentally different in three ways: first, the students ask the questions, second, the students design the process for answering the questions and, third, learning the processes of inquiry, design, investigation, and analysis is given as much importance as finding the right answer. Using inquiry-oriented, hands-on science teaches more than facts. It teaches critical thinking about scientific issues, a skill increasingly necessary for all members of our society.

Hands-on, inquiry-oriented science teaching will bring some revolutionary changes. For one thing, the process of coaching students as they develop the skills of inquiry and analysis takes time, especially at first. This means that a class using this method will cover less material. As it is clear that coverage does not necessarily imply mastery, this shift in emphasis is probably all to the good. Most people, reflecting on their own education and early careers, find that personal experience corroborates research: real learning comes from doing, not from being told. This is particularly true for the large numbers of people, including most pre-college students, who are concrete rather than abstract learners, the ones that in the past have been filtered out of science early by the make-or-break courses. For them this new approach to science education is a revelation; science is no longer the hateful drudgery of memorizing meaningless facts and definitions. With inquiry-oriented science teaching they too can experience the satisfaction of understanding.

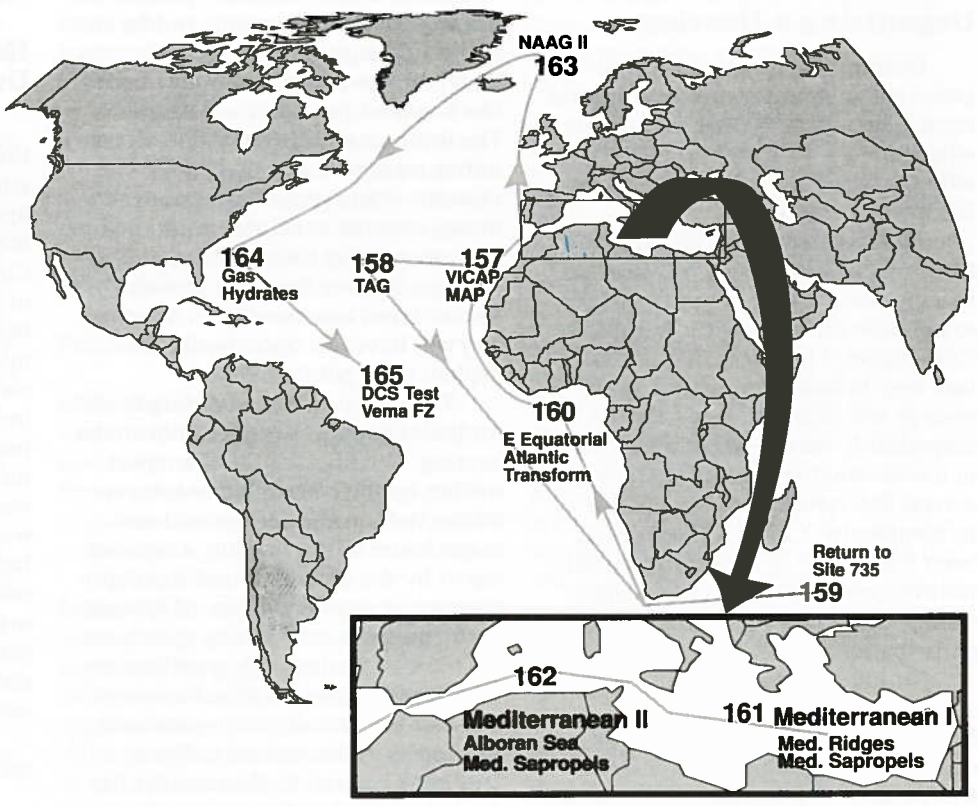
Reducing the amount of material covered (though perhaps not the amount learned) is not the only change implied by this revolution. Teachers will also begin to see themselves as facilitators of learning rather than as imparters of knowledge. Equipment and materials budgets will increase, perhaps offset by decreasing textbook costs, and testing will undoubtedly change toward assessing performance rather than retention of facts. Many teachers are embracing these changes despite the work they require because of the results they see in their students.

Charlie Puglia, recently retired from NSF's Education Division, often phrased the goal of the current revolution in science education as an effort to make science classes function as pumps rather than filters. To produce both scientists and citizens literate in science, science classes must feed students' interest and pump them along to the next level of science education. Inquiry-oriented, hands-on science seems to do just that. And that, too, is a major revolution.

For more information on the science education revolution read "Science for All Americans" from AAAS, talk to a member of the GSA Education Committee, or ask a teacher. ■

ODP Sets FY 1995 Drilling Objectives

The Ocean Drilling Program Planning Committee has set the drilling objectives for six legs in Fiscal Year 1995 and two legs of Fiscal Year 1996.



LEG 158: TAG (September 28–November 23, 1994)

The objective of this leg is to drill into the TAG hydrothermal mound on the mid-Atlantic ridge and characterize the fluid flow, geochemical fluxes, and associated alteration and mineralization of an active hydrothermal system on a slow-spreading ridge.

LEG 159: Return to Site 735 (January–February 1995)

The purpose of this leg is to return to ODP site 735, on the southwest Indian Ridge, and deepen hole 735B to a nominal depth of 2 km below sea floor to understand the nature of the processes involved in the generation of the lower crust, and to put some constraints on the lower crustal stratigraphy at the slowest end of the spreading spectrum.

LEG 160: Eastern Equatorial Atlantic Transform (March–April 1995)

Objectives focus on an evaluation of the tectonic and sedimentary processes involved in the creation of the main morphostructural features generated at the Côte d'Ivoire–Ghana transform margin and assessment of the timing, rate, and degree of vertical motion.

LEG 161/162: Mediterranean I & II (May–August 1995)

The proposed two legs of drilling in the Mediterranean will address basin formation in a collisional setting in the Alboran Sea (western Mediterranean), processes on the Mediterranean accretionary complex (eastern Mediterranean), and an east-west transect to sample and study paleocirculation and the formation of organic-rich layers called sapropels.

LEG 163: North Atlantic Arctic Gateways (September–October 1995)

This second of two North Atlantic–Arctic Gateways legs will focus on Cenozoic paleoceanography by investigating the North Atlantic and Arctic, deep and shallow water exchange and millennial-scale climate variability, which could provide links to ice-core data.

LEG 164: Gas Hydrates (November–December 1995)

The main objectives of this leg are to investigate the in situ characteristics of gas hydrates (solid phase composed of water and low molecular weight gases common in the upper few hundred metres of rapidly accumulating marine sediments), including the amounts of trapped gas, lateral variability of gas hydrates, and the role of gas hydrates in stimulating or modifying fluid circulation.

LEG 165: Test of the Diamond Coring System (January–February 1996)

This engineering leg is dedicated to the testing of a diamond coring system currently under development by ODP and a secondary heave-compensation system, which is necessary to maintain proper weight on the bit in a dynamic marine environment.

ODP is currently staffing Legs 159 onward. Shipboard participation is by invitation from ODP's science operator at Texas A&M University. Information and applications can be obtained by contacting Ocean Drilling Program, Texas A&M University, 1000 Discovery Drive, College Station, TX 77845-9547, (409) 845-2673, fax 409-845-4857, E-mail (Omnet) Ocean.Drilling.TAMU, or (Internet) baldauf@nelson.tamu.edu.

Expressions of interest or proposals for drilling are accepted at all times of the year and are reviewed following January 1 and July 1 deadlines. Opportunities also exist for post-leg sample and data acquisition. ODP is a consortium of countries, led by the United States, with a broad mandate to drill in the world's oceans. For more information, contact JOIDES Office HA-30, University of Washington, Seattle, WA 98195, (206) 543-2203; e-mail (Internet) address is joides@ocean.washington.edu. ■

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*correction from May issue.

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SOUTHEASTERN SECTION
April 6–7, 1995
Knoxville Hilton Hotel, Knoxville, Tennessee

Abstract Deadline:
December 16, 1994

Submit completed abstracts to:
Robert D. Hatcher, Jr.
Department of Geological Sciences
University of Tennessee
Knoxville, TN 37996-1410
(615) 974-6565

NORTH-CENTRAL/SOUTH-CENTRAL SECTIONS
April 27–28, 1995
University of Nebraska, Lincoln, Nebraska

Abstract Deadline:
January 6, 1995

Submit completed abstracts to:
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332 Bessey Hall, University of Nebraska
Lincoln, NE 68588-0340
(402) 472-2647

ROCKY MOUNTAIN SECTION
May 18–19, 1995
Montana State University, Bozeman, Montana

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January 20, 1995

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Bozeman, MT 59717-0348
(406) 994-6913

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May 24–26, 1995
University of Alaska, Fairbanks, Alaska

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January 30, 1995

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Fairbanks, AK 99775-0800
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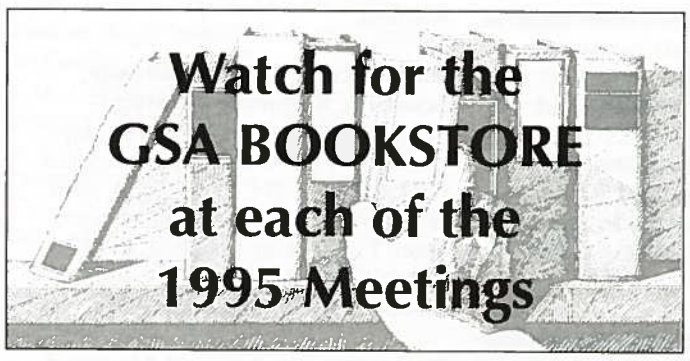

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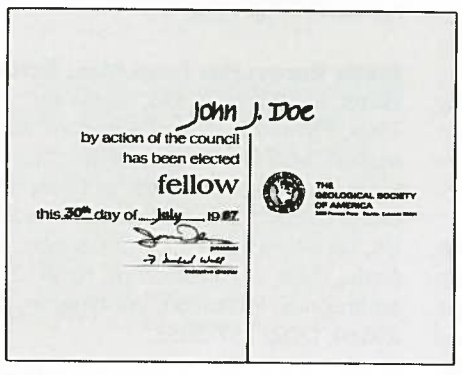

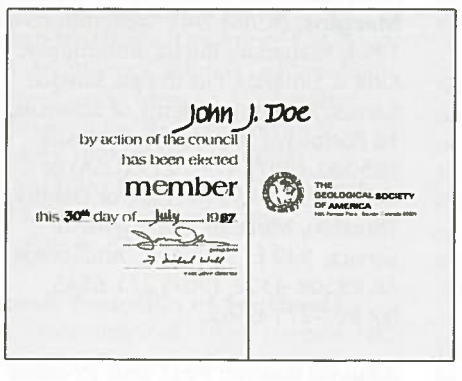

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MEETINGS

1994 Meetings

July

FORAMS '94: International Symposium on Foraminifera, July 5–9, 1994, Berkeley, California. Information: FORAMS '94, Museum of Paleontology, University of California, Berkeley, CA 94720, (510) 642-1821, fax 510-642-1822.

Third Annual Meeting, History of the Earth Sciences Society, July 7–9, 1994, Troy, New York. Information: Northeastern Science Foundation, Inc., Rensselaer Center of Applied Geology, 15 Third Street, P.O. Box 746, Troy, NY 12180, (518) 273-3247

Earthquake Engineering Fifth U.S. National Conference, July 10–14, 1994, Chicago, Illinois. Information: Claudia Cook, Newmark Civil Engineering Laboratory, University of Illinois, 205 N. Mathews, Urbana, IL 61801-2397, (217) 333-0498.

Geological Indicators of Rapid Change, International Workshop, July 11–18, 1994, Corner Brook, Newfoundland. Information: A. R. Berger, Chairman, Geo-Indicators Working Group, 528 Paradise St., Victoria, BC V9A 5E2, Canada, (604) 480-0840, fax 604-480-0840.

Basement Tectonics 11th International Conference, July 25–29, 1994, Potsdam, Germany. Information: Onno Oncken, Conference Chairman, Geo-Forschungs Zentrum, Telegrafenberg, D-0-1561 Potsdam, Germany, phone 49-331-310601, fax 49-331-310306.

Society for Industrial and Applied Mathematics Annual Meeting, July 25–29, 1994, San Diego, California. Information: SIAM Conference Coordinator, 3600 University City Science Center, Philadelphia, PA 19104-2688, (215) 382-9800, fax 215-386-7999, E-mail: meetings@siam.org.

August

New Perspectives in the Appalachian-Caledonian Orogen: A Symposium in Honour of Hank Williams, August 12–13, 1994, (field trip August 14–19), Corner Brook, Newfoundland, Canada. Information: J. Hibbard, MEAS, Box 8208, NCSU, Raleigh, NC 27695, (919) 515-7242, fax 919-515-7802, E-mail: hibbard@meavax.nrrc.ncsu.edu; or C. van Staal, Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8, Canada, (613) 995-4333, fax 613-995-7997, E-mail: vanstaal@cc2sutp.emr.ca.

Clay Minerals Society 31st Annual Meeting, August 13–18, 1994, Saskatoon, Saskatchewan, Canada. Information: Ahmet R. Mermut, Dept. of Soil Science, Saskatchewan Institute of Pedology, University of Saskatchewan, Saskatoon S7N 0W0, Canada, (306) 966-6839, fax 306-966-6881, E-mail: mermut@sask.usask.ca.

West Australian Basins Symposium, August 14–17, 1994, Perth, Australia. Information: Petroleum Exploration Society Australia, Attn.: J. B. O'Reilly/N. K. Guppy, P.O. Box 1102, West Perth, W.A. 6872, Australia, phone 61-9-481-6666, fax 61-9-481-1952.

The South Atlantic: Present and Past Circulation, August 15–18, 1994, Bremen, Germany. Information: South Atlantic Symposium, Barbara Donner, Fachbereich Geowissenschaften der Universität, Postfach 33 04 40, D-28334 Bremen, Germany.

45th Highway Geology Symposium, August 17–19, 1994, Portland, Oregon. Information: Scott Burns, Dept. of Geology, Portland State University, Portland, OR 97207-0751, (503) 725-3389, fax 503-725-3025.

14th International Sedimentological Congress, Equatorial Gateway in Atlantic Symposium, August 21–26, 1994, Recife, Brazil. Information: Luba Jansa, Bedford Institute of Oceanography, Dartmouth, N.S., Canada B2Y 4A2, (902) 426-2734, fax 902-426-4465, E-mail: jansa@agcrr.bio.ns.ca.

International Geographical Union Regional Conference, Environment and Quality of Life in Central Europe: Problems of Transition, August 22–26, 1994, Prague, Czech Republic. Information: Conference Secretariat, IGU RC 1994, Albertov 6, 128 43 Praha 2, Czech Republic, phone 42-2-24912060, or 42-2-296025, fax 42-2-24915817 or 42-2-296025, E-mail: kucera@prfdec.natur.cuni.cz

Mapping & Remote Sensing Tools for the 21st Century, August 26–29, 1994, Washington, D.C. Information: ASPRS, Dept. DP, 5410 Grosvenor Lane, Suite 210, Bethesda, MD 20814-2160, (301) 493-0290, fax 301-493-0208, E-mail: e7g4hem@toe.townson.edu

International Symposium on Paleoenvironmental History of East and South Asia and Cretaceous Correlation (IGCP 350), August 24–29, 1994, Taegu, Korea. Information: Ki-Hong Chang, Dept. of Geology, Kyungpook National University, Taegu, Korea 702-701, phone 82-53-950-5355, fax 82-53-957-0431, E-mail: khchang@bh.kyungpook.ac.kr.

■ **Environmental Issues and Waste Management in Energy and Mineral Production Third International Conference,** August 29–September 1, 1994, Perth, Western Australia. Information: Co-Ordinated Functions Pty Ltd., P.O. Box 1305, West Perth, WA 6872, Australia, phone 61-9-324-2555, fax 61-9-324-2666.

Proterozoic Crustal and Metallogenic Evolution, August 29–September 1, 1994, Windhoek, Namibia. Information: G.I.C. Schneider, Geological Society of Namibia, P.O. Box 699, Windhoek, Namibia, phone 264-61-37240, fax 264-61-228324.

V.M. Goldschmidt Conference, August 29–September 2, 1994, Edinburgh, Scotland. Information: B. Harte or P. Symms, V.M. Goldschmidt Conference 1994, Dept. of Geology and Geophysics, University of Edinburgh, Grant Institute, West Mains Road, Edinburgh EH9 3JW, Scotland, UK.

September

Cyclicity in Global Geology, Australian Geological Convention Symposium, September, 1994, Perth, Australia. Information: Bryan Krapez or C. McA. Powell, Dept. of Geology, University of Western Australia, Nedlands, 6009, Australia.

Arctic Ocean Grand Challenge, Scientific Rationale–Strategy–Science Plan, Helsinki, Finland, September 2–7, 1994. Deadline for applications: May 6, 1994. Information: Josip Hendekovic, European Science Foundation, 1 quai Lezay-Marnésia, 67080 Strasbourg Cedex, France, phone 33-88-76-71-35, fax 33-88-36-69-87.

Prospecting in Areas of Glaciated Terrain—Tenth Conference, September 5–7, 1994, St. Petersburg, Russia. Information: The Conference Office, The Institution of Mining and Metallurgy, 44 Portland Place, London W1N 4BR, England, phone 44-71-580-3802, fax 44-71-436-5388.

Biotic Recoveries from Mass Extinctions, IGCP Project 335, September 5–8, 1994, Plymouth, United Kingdom. Information: Malcom B. Hart, Dept. of Geological Sciences, University of Plymouth, Drake Circus, Plymouth, Devon P1A 8AA, UK, fax 44-745-233-117; or Douglas H. Erwin, Dept. of Paleobiology, NHB-121, Smithsonian Institution, Washington, DC 20560, (202) 357-2053.

International Conference on Arctic Margins, (ICAM '94), September 5–9, 1994, Magadan, Russia. Information: Kirill V. Simakov, North East Science Center, Russian Academy of Sciences, 16 Portovaya St., Magadan, Russia 685000, (907) 474-7219 (USA) or 7-41-3-223-0953 (Russia); or Dennis K. Thurston, Minerals Management Service, 949 E. 36th Ave., Anchorage, AK 99508-4302, (907) 271-6545, fax 907-271-6565.

Alluvial Basins: Past and Present Environments, Lunteren, The Netherlands. September 10–15, 1994. Information: Josip Hendekovic, European Science Foundation, 1 quai Lezay Marnésia, 67080 Strasbourg Cedex, France, phone 33-88-76-71-35, fax 33-88-36-69-87.

First International Airborne Remote Sensing Conference and Exhibition: Applications, Technology, and Science, September 11–15, 1994, Strasbourg, France. Information: Robert Rogers, ERIM, Box 13001, Ann Arbor, MI 48113-4001, (313) 994-1200, ext. 3234; fax 313-994-5123.

Illinois Basin Energy and Mineral Resources Workshop, September 12–13, 1994, Evansville, Indiana. Information: Theola Evans, Kentucky Geological Survey, 228 MMRB, University of Kentucky, Lexington, KY 40506, (606) 257-5500, E-mail: theola@kgs.uky.edu.

Salt Tectonics, September 14–15, 1994, London, England. Information: Ian Alsop, Derek Blundell, and Ian Davison, Dept. of Geology, Royal Holloway, University of London, Egham, Surrey, UK, phone 44-784-443615, fax 44-784-471780.

Underground Technology Research Council, September 16–18, 1994, Chicago, Illinois. Information: John MacDonald, Meeting Chairman, Guy F. Atkinson Construction Company, P.O. Box 428, Enumclaw, WA 98022, (206) 825-1410, fax 206-825-2514; or Frank Kendorski, UTRC Chairman, Morgan Mining & Environmental Consultants, Ltd., 4921 Chase Avenue, Downers Grove, IL 60515, (708) 305-7900, fax 708-305-9841.

Fifth International Mine Water Congress, September 18–23, 1994, Nottingham, UK. Information: Conference Secretary, IMWA Conference, c/o Department of Mineral Resouces Engineering, University of Nottingham, University Park, Nottingham NG7 2RD, UK.

Geomorphology and Natural Hazards (25th Annual Binghamton Geomorphology Symposium), September 24–25, 1994, Binghamton, New York. Information: Marie Morisawa, Dept. of Geol. Sciences and Environmental Studies, State University of New York, Binghamton, NY 13902-6000, (607) 777-2837, fax 607-777-2288, E-mail: marieem@bingvmb.cc.binghamton.edu.

Society for Organic Petrology 11th Annual Meeting, September 25–30, 1994, Jackson, Wyoming. Information: Ron Stanton, U.S. Geological Survey, 956 National Center, Reston, VA 22092, (703) 648-6462, fax 703-648-6419, E-mail: rstanton@ncrds.usgs.er.gov.

Geochemical Event Markers in the Phanerozoic, final meeting of IGCP Project 293, September 26–28, 1994, Erlangen, Germany. Information: Michael M. Joachimski, Institute of Geology and Mineralogy, University of Erlangen/Nürnberg, Schlossgarten 5, 91054 Erlangen, Germany, 49-9131-852615, fax 49-9131-859295; or Helmut H. J. Geldsetzer, Geological Survey of Canada, 3303-33rd St., N.W., Calgary, Alberta T2L 2A7, Canada, (403) 292-7155, fax 403-292-5377.

Littoral 94, European Coastal Zone Association for Science and Technology Second International Symposium, September 26–29, 1994, Lisbon, Portugal. Information: Associação EUROCOAST-Portugal, a/c Instituto de Hidráuclica e Recursos Hídricos, Faculdade de Engenharia-Universidade do Porto, Rua dos

Bragas, 4099 Porto Codex Portugal, fax 351-2-310870, 351-2-318787, 351-2-319280.

12th Australian Geological Convention, September 26–30, 1994, Perth, Australia. Information: Secretary, 12AGC, P.O. Box 119, Cannington, WA 6107, Australia, 61-9-351-7968, fax 61-9-351-3153.

Eco Rio '94, International Symposium on Resource and Environmental Monitoring, September 26–30, 1994, Rio de Janeiro. Information: National Institute of Space Research—INPE c/o Mônica Oliveira, CRI, P.O. Box 515, Av. dos Astronautas, 1758-CEP 12227-010, San José dos Campos, SP-Brazil, phone 55-123-22-9816 or 41-8977, ext. 250, fax 55-123-21-8543 or 22-9325.

October

Association of Engineering Geologists Annual Meeting, October 2–7, 1994, Williamsburg, Virginia. Information: AEG, 323 Boston Post Rd., Suite 2D, Sudbury, MA 01776, (508) 443-4369 or (508) 443-3639.

Federation of Analytical Chemistry and Spectroscopy Societies Annual Conference, October 2–7, 1994, St. Louis, Missouri. Information: FACSS, 198 Thomas Johnson Dr., Suite S-2, Frederick, MD 21702-4317, (301) 846-4797.

International Association for Mathematical Geology Annual Meeting, October 3–5, 1994, Mont Tremblant, Quebec, Canada. Information: C.-J. Chung, Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8, Canada, (613) 996-3413, fax 613-996-3726, E-mail: chung@gsc.emr.ca.

German Geological Society (DGG) Annual Meeting, October 4–7, 1994, Heidelberg, Germany. Information: Th. Bechstädt and R. O. Greiling, Geologische-Paläontologisches Institut, Ruprecht-Karls-Universität, Im Neuenheimer Feld 234, D-6900 Heidelberg, Germany.

Symposium on Porphyry Copper Deposits from Alaska to Chile, October 5–7, 1994, Tucson, Arizona. Information: Jim Laukes, University of Arizona Extended University, 1955 East Sixth Street, Tucson, AZ 85719-5224, 1-800-955-UofA, fax 602-621-3269, E-mail (Internet): jlaukes.ccit.arizona.edu.

■ **Moving Industrial Minerals into the 21st Century,** October 5–7, 1994, Nashville, Tennessee. Information: Meetings Dept., SME, P.O. Box 625002, Littleton, CO 80162-5002, (303) 973-9550, fax 303-979-3461.

9th National Conference on Hydrogeology and Engineering Geology of Karst Terranes, October 16–18, 1994, Nashville, Tennessee. Information: James F. Quinlan, Box 110539, Nashville, TN 37222, (615) 833-4324; or Geary M. Schindel, (615) 255-2288.

Symposium on the Petroleum Geology and Hydrocarbon Potential of the Black Sea Area, October 16–18, 1994, Varna, Bulgaria. Information: Liz Lador, Petroconsultants S.A., Information Research Division, P.O. Box 152, 24 Chemin de la Mairie, 1258 Perly, Geneva, Switzerland, phone 41-22-721-1717, telex 413-541-PETR CH, fax 41-22-721-1747.

Applications of Sedimentary Geology and Paleontology into the 21st Century, October 16–20, 1994, Snowbird, Utah. Information: Myra Rogers, SEPM, P.O. Box 4756, Tulsa, OK 74159-0756, (800) 865-9865, fax 918-743-2498, E-mail: myralee@ aip.edu.

Ninth Annual Conference on Contaminated Soils, October 17–20, 1994, Amherst, Massachusetts. Information: Paul Kostecki, Environmental Health and Sciences, N344 Morrill, University of Massachusetts, Amherst, MA 01003, (413) 545-2934, fax 413-545-4692.

LIRA Workshop on the Ross Orogen: Crustal Structure and Tectonic Significance, October 21–23, 1994, Dallas, Texas. Information: John W. Goodge, Dept. of Geological Sciences, Southern Methodist University, Dallas, TX 75275, (214) 768-4140, E-mail: jgoodge@sun.cis.smu.edu.

November

Carolina Geological Society Annual Meeting and Field Trip, November 4–6, 1994, Raleigh, North Carolina. Information: Skip Stoddard, Dept. of MEAS, Box 8208, North Carolina State University, Raleigh, NC 27695-8208, (919) 515-7939, fax 919-515-7802, E-mail: stoddard@meavax.nrrc.ncsu.edu.

■ **Glacial-Interglacial Sealevel Changes in Four Dimensions,** November 5–10, 1994, St. Martin, Germany. Information: Josip Hendekovic, European Science Foundation, 1quai Lezay-Marnésia, 67080 Strasbourg Cedex, France, phone 33-88-76-71-35, fax 33-88-36-69-87.

International Symposium on the Cenozoic Tectonics and Volcanism of Mexico, November 7–11, 1994, Puerto Vallarta, Jalisco, Mexico. Information: Hugo Delgado Granados, Inst. de Geofísica, UNAM, Circuito Exterior, C.U., Coyoacán 04510, México D.F., phone (525) 622-4145, 622-4119, 622-4124, fax 525-550-2486, Internet: hugo@tonatiuh.igcofcu.unam.mx; or Gerardo Aguirre Díaz, Estación Regional del Centro, Inst. de Geología, UNAM, Apdo. Postal 376, Guanajuato, Gto, 36000, México, phone and fax 524-732-3038.

Geology and Resources of the Eastern Frontal Belt, Ouachita Mountains, Oklahoma, November 15–17, 1994, Poteau, Oklahoma. Information: Neil H. Suneson, Oklahoma Geological Survey, Sarkeys Energy Center, Room N-131, 100 East Boyd St., Norman, OK 73019-0628, (405) 325-3031.

International Geological Correlation Program Project 351, Early Paleozoic Evolution in Northwest Gondwana, November 29–December 7, 1994, Rabat, Morocco. Information: Naima Hamoumi, Dépt. de Géologie, Faculté des Sciences de Rabat, B.P. 1226 RP Rabat, Morocco, phone 212-7-7719-57, fax 212-7-77-42-61, telex 36607 M.

December

■ **25th Annual Underwater Mining Institute,** December 1–4, 1994, Monterey, California. Information: Karynne Chong Morgan, Underwater Mining Institute, 811 Olomehani St., Honolulu, HI 96813-5513, (808) 522-5611, fax 808-522-5618, Internet: 70673.534@compuserve.com, Compuserve 70673,534.

Tectonic Evolution of Southeast Asia, December 7–8, 1994, London, UK. Information: Robert Hall, Geological Sciences, University College, Gower St., London WC1E 6BT, UK, phone 44-784-443592, fax 44-71-387-1612, E-mail (Internet): robert.hall@ucl.ac.uk.

Symposium on Inverse Problems: Geophysical Applications, December 12–14, 1994, Yosemite Fish Camp, California. Information: SIAM Conference Coordinator, 3600 University City Science Center, Philadelphia, PA 19104-2688, (215) 382-9800, fax 215-386-7999, E-mail: meetings@siam.org.

1995 Meetings

February

■ **U.S. Geological Survey McKelvey Forum on Energy and the Environment: Application of Geosciences to Decision Making,** February 13–16, 1995, Washington, D.C. Information: Dudley D. Rice, U.S. Geological Survey, P.O. Box 25046, MS 971, Denver, CO 80225, (303) 236-5711, fax 303-236-8822, E-mail: rice@bpgsvr.cr.usgs.gov.

March

■ **American Association of Petroleum Geologists and Society for Sedimentary Geology (SEPM) Annual Convention,** March 5–8, 1995, Houston, Texas. Information: Michelle Mayfield, AAPG Annual Meetings Manager, P.O. Box 979, 1444 S. Boulder Ave., Tulsa, OK 74101-0979, (918) 584-2555, fax 918-584-2274.

■ **GSA Northeastern Section Annual Meeting,** March 20–22, 1995, Hartford, Connecticut. Information: Norman H. Gray, Dept. of Geology and Geophysics, University of Connecticut, 354 Mansfield Road, Storrs, CT 06269-2045, (203) 486-4434.

■ **Oklahoma Geological Survey Workshop on the Ames Structure and Similar Features,** March 28–29, 1995, Norman, Oklahoma. Information: Kenneth S. Johnson and Jock A. Campbell, Oklahoma Geological Survey, University of Oklahoma, 100 East Boyd, Rm. N-131, Norman, OK 73019, (405) 325-3031, fax 405-325-7069.

April

■ **Sinkholes and the Engineering and Environmental Impacts of Karst Fifth Multidisciplinary Conference,** April 2–5, 1995, Gatlinburg, Tennessee. Information: Barry F. Beck, P. E. LaMoreaux & Associates, Inc., Box 4412, Oak Ridge, TN 37831, (615) 483-7483.

Geological Society of South Africa Centennial Geocongress, April 3–7, 1995, Johannesburg, South Africa. Information: Congress Secretariat, Centennial Geocongress, P.O. Box 36815, Menlo Park, 0102, South Africa, phone and fax 27-12-47-3398.

■ **GSA Southeastern Section Annual Meeting,** April 6–7, 1995, Knoxville, Tennessee. Information: Harry Y. McSween, Dept. of Geological Sciences, University of Tennessee, 306 G&G Building, Knoxville, TN 37996-1410, (615) 974-5498.

Geological Society of Nevada Symposium III: Geology and Ore Deposits of the American Cordillera, April 10–13, 1995, Reno, Nevada. Information: Bob Hatch, Chairperson, Geological Society of Nevada, P.O. Box 12021, Reno, NV 89510, (702) 323-4569, fax 702-323-3599.

Third International Symposium on In Situ and On-Site Bioreclamation, April 24–27, 1995, San Diego, California. Information: Betty Weaver, Symposium Coordinator, The Conference Group, 1989 West Fifth Ave., Suite 5, Columbus, OH 43212-1912, toll-free (U.S. and Canada) 800-783-6338, or (614) 424-5461, fax 614-488-5747. *(Abstract deadline: July 1, 1994.)*

■ **GSA South Central/North Central Sections Joint Annual Meeting,** April 27–28, 1995, Lincoln, Nebraska. Information: Robert F. Diffendal, Conservation and Survey Division, 133 Nebraska Hall, University of Nebraska, 901 N. 17th Street, Lincoln, NE 68588-0517, (402) 472-7546; Page C. Twiss, Dept. of Geology, Kansas State University, Thompson Hall, Manhattan, KS 66506, (913) 532-6724.

May

■ **Water Pollution Modelling, Measuring and Prediction Third International Conference,** May 1–3, 1995, Porto Carras, Greece. Information: Liz Johnstone, Wessex Institute of Technology, Ashurst Lodge, Ashurst, Southampton SO40 7AA, UK, phone 44-703-293-223, fax 44-703-29-2853, E-mail: CMI@uk.ac.rl.ib.

Geotechnica 95, Geosciences and Geotechnology Amid Ecological and Economic Considerations, May 2–5, 1995, Cologne, Germany. Information: Alfred Wegener Stiftung, Wissenschaftszentrum, Ahrstrasse 45, 53175 Bonn, Germany.

Water Resources at Risk, May 14–18, 1995, Denver, Colorado. Information: Helen Klose, American Institute of Hydrology, 3416 University Ave., S.E., Minneapolis, MN 55414, (612) 379-1030.

Meetings *continued on p. 194*

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451 invertebrate
452 vertebrate
453 micropaleontology
454 paleobotany
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750 Structural Geology
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753 rock mechanics
800 Volcanology

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◀ APPLICANT FORM

Meetings *continued from p. 193*

17th International Geochemical Exploration Symposium, Exploring the Tropics, May 15–19, 1995, Townsville, Queensland, Australia. Information: Russell Myers, 171GES, National Key Centre in Economic Geology, James Cook University, Townsville, Q4814, Australia, phone 61-77-814486, fax 61-77-815522.

Geological Association of Canada–Mineralogical Association of Canada Joint Annual Meeting, May 17–19, 1995, Victoria, British Columbia, Canada. Information: Chris Barnes, General Chair, SEOS, University of Victoria, P.O. Box 1700, Victoria, B.C. V8W 2Y2, Canada, fax 604-721-6200.

■ **GSA Rocky Mountain Section Annual Meeting,** May 18–19, 1995, Bozeman, Montana. Information: Stephan G. Custer, Dept. of Earth Sciences, Montana State University, Bozeman, MT 59717-0348, (406) 994-6906.

1995 World Geothermal Congress, May 18–31, Florence, Italy. Information: George Frye, Executive Director, International Geothermal Association, LBL 50C, Rms. 106–108, One Cyclotron Road, Berkeley, CA 94720, (510) 486-4584, fax 510-486-4889.

■ **Fifth Annual Goldschmidt Conference,** May 24–26, 1995, University Park, Pennsylvania. Information: Suzanne St. Pierre, (814) 865-7557, fax 814-865-3749.

■ **GSA Cordilleran Section Annual Meeting,** May 24–26, 1995, Fairbanks, Alaska. Information: David B. Stone, Dept. of Geology and Geophysics, University of Alaska, Fairbanks, AK 99775-0760, (907) 474-7565.

■ **Walter A. Bell Symposium on Paleobotany and Coal Science,** May 28–June 1, 1995, Sydney, Nova Scotia. Information: Erwin L. Zodrow, University College of Cape Breton, P.O. Box 5300, Sydney, Nova Scotia, B1P 6L2, Canada, fax 902-562-0119, or Paul C. Lyons, U.S. Geological Survey, MS 956, Reston, VA 22092, fax 703-648-4227.

June

■ **SEG International Field Conference on Carbonate-hosted Lead-Zinc Deposits,** June 3–6, 1995, St. Louis, Missouri. Information: Martin Goldhaber, U.S. Geological Survey, P.O. Box 25046, MS 973, Federal Center, Denver, CO 80225-0046, fax 303-236-3200, E-mail: mgold@helios.cr.usgs.gov.

■ **Seventh International Symposium on the Ordovician System,** June 12–16, 1995, Las Vegas, Nevada. Information: Margaret N. Rees, 7th ISOS, Dept. of Geoscience, University of Nevada, Las Vegas, NV 89154-4010, (702) 739-3890, fax 702-597-4064, E-mail: rees@nevada.edu.

July

■ **Eleventh Symposium on Coastal Sedimentology,** July 3–9, 1995, Niteroi, Brazil. Information: Cleverson Guizan Silva, Dept. de Geologia/LAGEMAR, Universidade Federal Fluminense, Av. Bento de Maria da Costa 115-a, Charitas, Niteroi, R.J. 24.370-190, Brazil, fax 55-21-711-9917.

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You will receive a printout that includes the applicants' names, addresses, phone numbers, areas of specialty, type of employment desired, degrees held, years of professional experience, and current employment status. Résumés for each applicant are sent with each printout at no additional charge. For 1994, the cost of a printout of one or two specialty codes is $150. (For example, in a recent job search for an analyst of inorganic materials, the employer requested the specialty codes of geochemistry and petrology.) Each additional specialty is $50. A printout of the applicant listing in all specialties is available for $350. (Specialty codes printed in boldface type are considered major headings. If you request a listing of one of the subspecialties, applicants coded under the major category will be included but not those coded under the other related subspecialties.) If you have any questions about your personalized computer search, GSA Membership Services will assist you.

The GSA Employment Service is available year round. However, GSA also conducts the Employment Interview Service each fall in conjunction with the Society's Annual Meeting (this year in Seattle, Washington, October 24–27). You may rent interview space in half-day increments from GSA. Our staff will schedule all interviews with applicants for you, the recruiter. In addition, GSA offers a message service, complete listing of applicants, copies of résumés at no additional charge, and a posting of all job openings.

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The Geological Society of America

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101 coal geology
102 geothermal, etc.
103 metallic deposits
104 nonmetallic deposits
105 mining geology
120 Engineering Geology
150 Environmental Geology
160 Public Education & Communication
200 General Geology
220 Geochemistry
221 organic
222 high temperature
223 low temperature
224 stable isotopes
225 geochronology
250 Geomorphology
300 Geophysics
301 seismic
302 gravity/magnetics
303 seismicity
304 paleomagnetism
320 Hydrogeology
321 hydrochemistry
322 ground water
323 surface water
330 Library
350 Mathematical Geology
351 computer science
352 statistical geology
400 Mineralogy
401 crystallography
402 clay mineralogy
410 Museum (curator)
420 Oceanography
421 marine geology
422 coastal geology
450 Paleontology
451 invertebrate
452 vertebrate
453 micropaleontology
454 paleobotany
455 paleoecology
500 Petroleum Geology
501 exploration
502 subsurface strat.
520 Petrology
521 igneous
522 metamorphic
523 sedimentary (clastic)
524 sedimentary (carb.)
525 experimental
550 Planetology
575 Quaternary Geology
600 Regional Geology
620 Remote Sensing
621 photogeology
622 photogrammetry
630 Science Editing
650 Sedimentology
651 sed. processes
652 sed. environments
720 Stratigraphy
750 Structural Geology
751 tectonics
752 tectonophysics
753 rock mechanics
800 Volcanology

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***Minimum* degree required:**
☐ None ☐ B.A. or B.S. ☐ M.A. or M.S. ☐ Ph.D.

***Minimum* professional experience:**
☐ None ☐ 1–5 years ☐ 6-plus years

Experience desired (years):

	None	1–5	6-plus
Administrative	☐	☐	☐
Exploration/Production	☐	☐	☐
Field	☐	☐	☐
Research	☐	☐	☐
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Employment in: ☐ U.S. only ☐ U.S. with foreign assignments ☐ Either

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2. I agree that no placement charges will be assessed to any applicant participating in the GSA Employment Matching Service.

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Total fee enclosed ..... **$** _____

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Seventh International Williston Basin Symposium, July 23–25, 1995, Billings, Montana. Information: W. Kipp Carroll, General Chairman, (406) 245-2367. *(Abstract deadline: July 15, 1994.)*

August

■ **3rd International Field Conference and Symposium on Intraplate Magmatism (IGCP 336): Petrology and Metallogeny of Volcanic and Intrusive Rocks of the Midcontinent Rift System,** August 22–September 1, 1995, Duluth, Minnesota. Information: Penny Morton, Dept. of Geology, University of Minnesota, Duluth, MN 55812, (218) 726-7962, fax 218-726-8275; E-mail: pmorton@ua.d.umn.edu.

■ **Orogenic Lherzolites and Mantle Processes 2nd International Workshop,** August 24–September 5, 1995, Granada, Spain. Information: H. G. Barsczus, Géofluides GBE/ISTEEM-C.P. 057, Université de Montpellier 2, 34095 Montpellier Cedex 5, France, phone 33-6714-3933, fax 33-6714-4774, E-mail: barsczus@dstu.univ-montp2.fr.

■ **Mineral Deposits: From their Genesis to Their Environmental Impacts,** 3rd Biennial SGA Meeting, August 28–31, 1995, Prague, Czech Republic. Information: Jan Pasava, Czech Geological Survey, Klarov 131/3, 118 20 Praha 1, Czech Republic, phone 42-2-537011, fax 42-2-7980965.

Tectonics and Metallogeny of Early/Mid Precambrian Orogenic Belts, August 28–September 1, 1995, Montreal, Canada. Information: J. A. Percival, Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8, Canada, (613) 995-4723, fax 613-995-9273, E-mail: jpercival@601C.gsc.emr.ca, or J. N. Ludden, Dept. de Géologie, Université de Montréal, CP 6128, Succ. A, Montréal, Québec H3C 3J7, Canada, (514) 343-7389, fax 514-343-5782, E-mail: luddenj@ere.umontreal.ca.

Third Hutton Symposium: The Origin of Granites, August 28–September 2, 1995, College Park, Maryland. Information: Michael Brown, Dept. of Geology, University of Maryland, College Park, MD 20742, (301) 405-4082, fax 301-314-9661.

September

■ **Karst Waters and Environmental Impacts Fifth International Symposium and Field Seminar,** September 10–20, 1995, Antalya, Turkey. Information: Gültekin Günay, P.O. Box 357, Kızılay, 06420 Ankara, Turkey, (312) 235-2543, fax 312-235-2862.

■ **Remote Sensing for Marine and Coastal Environments,** September 18–20, 1995, Seattle, Washington. Information: (313) 994-1200, ext. 3453, fax 313-994-5123.

October

■ **American Institute of Professional Geologists 1995 Annual Meeting,** Prosperity and Professional Geology, October 1–5, 1995, Denver, Colorado. Information: Ron W. Pritchett, 8244 S. Leyden Ct., Englewood, CO 80112, phone and fax (303) 741-0670.

Meetings *continued on p. 196*

GSA ANNUAL MEETINGS

■ 1994

Seattle, Washington
October 24–27
Washington State
Convention and Trade Center
Sheraton Seattle Hotel

Call for Papers: ***April and June*** **GSA Today**
Abstract Deadline: ***July 6***
Preregistration Deadline: ***September 16***
Technical Program Schedule: ***September*** **GSA Today**

For information call the GSA Meetings Department,
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fax 303-447-0648, E-mail: mball@geosociety.com

Registration Materials in JUNE *GSA Today*
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■ 1995

New Orleans, Louisiana, November 6–9
Ernest N. Morial Convention Center, Hyatt Regency New Orleans

General Chairman: ***William R. Craig, University of New Orleans***
Technical Program Chairman: ***Laura Serpa, University of New Orleans***

Call for Field Trip Proposals: *Please contact the Field Trip Chairmen listed below.*

Whitney Autin
Louisiana Geological Survey
P.O. Box G, University Station
Baton Rouge, LA 70893-4107
(504) 388-5320

Duncan Goldthwaite
4608 James Drive
Metairie, LA 70003
(504) 887-4377

For general information call the GSA Meetings Department,
1-800-472-1988 or (303) 447-2020.

Call for 1995
CONTINUING EDUCATION COURSE PROPOSALS

PROPOSALS DUE BY DECEMBER 1, 1994

The GSA Committee on Continuing Education invites those interested in proposing a GSA-sponsored or cosponsored course or workshop to contact GSA headquarters for proposal guidelines. Continuing Education courses may be conducted in conjunction with all GSA annual or section meetings. We are particularly interested in receiving proposals for the 1995 New Orleans Annual Meeting or the 1996 Denver Annual Meeting.

Proposals must be received by December 1, 1994. Selection of courses for 1995 will be made by February 1, 1995. For those planning ahead, we will also consider courses for 1996 at that time.

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

■ FUTURE

Seattle	October 24–27	1994
New Orleans	November 6–9	1995
Denver	October 28–31	1996
Salt Lake City	October 20–23	1997
Toronto	October 26–29	1998
Denver	October 25–28	1999

For general information on technical program participation (1995 or beyond), contact Sue Beggs, Meetings Manager, GSA headquarters.

Meetings *continued from p. 195*

Fifth International Conference on Seismic Zonation, October 17–19, 1995, Nice, France. Information: Earthquake Engineering Research Institute, 499 14th St., Suite 320, Oakland, CA 94612-1902, (510) 451-0905, fax 510-451-5411; or Association for Earthquake Engineering, Domaine de Saint-Paul, BP 1, 78470 Saint-Rémy-lès-Chevreuse, France, 30-85-22-03, fax 30-52-75-75.

■ **SEPM Research Conference on Alluvial Fans: Processes, Forms, Controls, Facies Models, and Use in Basin Analysis,** October 17–21, 1995, Death Valley, California. Information: Myra Rogers, SEPM, P.O. Box 4756, Tulsa, OK 74159, (918) 743-9765, fax 918-743-2498.

Send notices of meetings of general interest, in format above, to Editor, *GSA Today*, P.O. Box 9140, Boulder, CO 80301.

July *BULLETIN* and *GEOLOGY* Contents

The Geological Society of America
BULLETIN
Volume 106, Number 7, July 1994

CONTENTS

GEOLOGY
VOLUME 22
NO. 7
P. 577–672
JULY 1994

A Crisis in Waste Management, Economic Vitality, and a Coastal Marine Environment: Boston Harbor and Massachusetts Bay

A summary of the Annual Environmental Forum sponsored by the GSA Institute for Environmental Education and the Geology and Public Policy Committee, Boston, Massachusetts, October 24, 1993

Frank T. Manheim and Bradford Butman
U.S. Geological Survey, Branch of Atlantic Marine Geology, Quissett Campus, Woods Hole, MA 02543

INTRODUCTION

Discharge of sewage sludge and effluent from 43 communities in the greater Boston metropolitan area has helped make the harbor one of the most polluted in the nation. As part of a court-mandated plan to end pollution of the harbor, effluent will no longer be discharged into the harbor, but, instead, by 1995 it will be discharged into Massachusetts Bay through a record-long 15.3 km tunnel. By the year 2000 all of the sewage is scheduled to receive full secondary treatment. Cost of the construction is estimated at about $4 billion in current dollars and will be borne almost entirely by users. Annual water and sewer rates in Boston are estimated to reach about $1,200 for a typical household, moving Boston from among the lowest rates in the nation to near the top.

The Massachusetts Bay area is used extensively for transportation, commercial trade, fishing, recreation, and tourism. The public is concerned about long-term effects of the new ocean outfall on the environment, including Cape Cod Bay and Stellwagen Bank, which is an important habitat for whales and a newly designated national marine sanctuary. The bay has been additionally stressed by dumping of low-level radioactive and other hazardous wastes during the 1950s and 1960s.

The harbor requires periodic deepening of navigation channels to maintain Boston's economic viability and transportation safety. Dredging operations produce variably contaminated materials that require disposal and pose additional problems.

To examine all aspects of the ongoing developments, the forum brought together a broad spectrum of experts and representatives of citizen organizations for candid presentations and exchange of views. In addition, the public was provided the opportunity to question speakers and panel members extensively. The forum was developed and moderated by Butman and Manheim, and by Herman Karl of the U.S. Geological Survey's Branch of Pacific Marine Geology in Menlo Park, California. Fred Donath, Executive Director of the Institute for Environmental Education (IEE), provided the logistic support and unwavering commitment that made possible candid exploration of a publicly sensitive subject of this type.

This summary provides highlights of the thought-provoking presentations from recordings of the proceedings and from the authors' abstracts. Time did not permit examination of this summary by all participants; hence, the authors must accept responsibility for inadvertent errors, improper emphasis, or treatment that falls short of our goal of objectivity. The account generally follows the order of the presentations. Editorial additions are indicated by references.

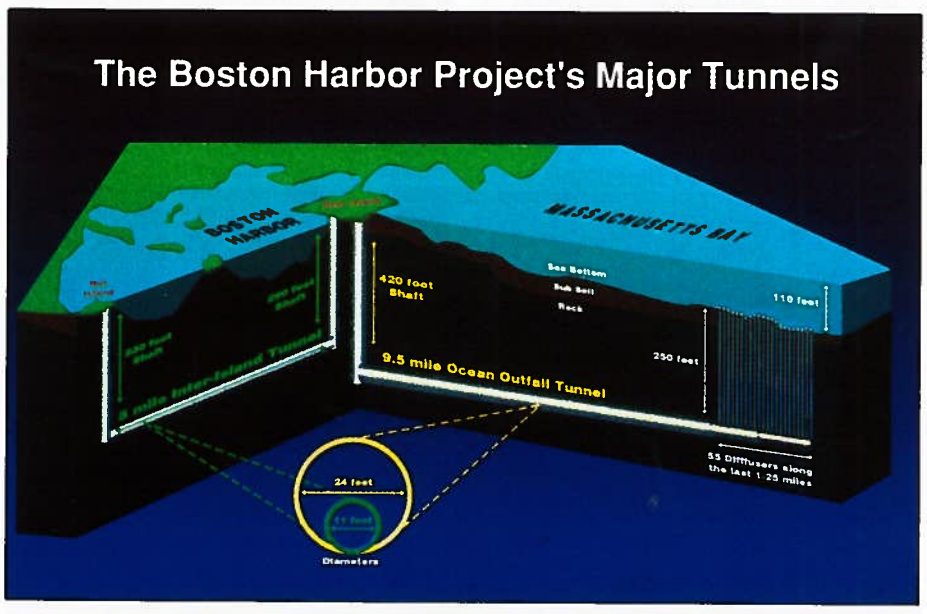
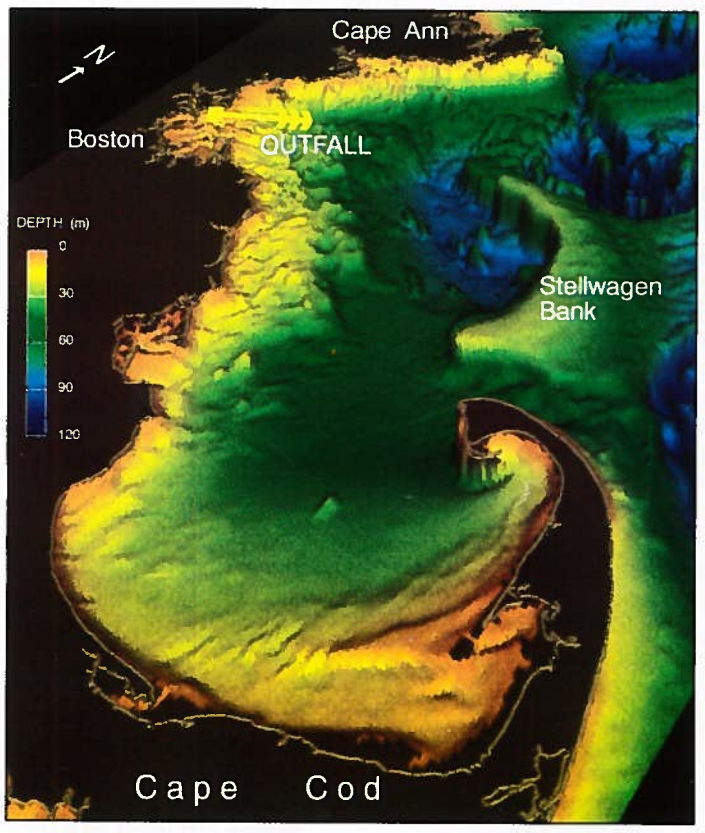


Figure 2. Schematic diagram showing the location and dimensions of the sewage effluent tunnels in progress. (Courtesy W. Leo and M. Connor)

COURT ORDER BRINGS ABOUT MAJOR REMEDIATION OF WASTE TREATMENT BUT POSES NEW PROBLEMS

Peter Shelley of the Conservation Law Foundation, Boston, recounted the 10-year history of CLF lawsuits, ultimately joined by the U.S. Environmental Protection Agency (EPA), that forced the Metropolitan District Commission to reconstruct the metropolitan area's inadequate sewage treatment system. The system was discharging primary, and often untreated, effluent as well as sludge into the harbor in violation of provisions of the Clean Water Act of 1972 and EPA regulations. Variances and delays deferred until 1984 the final federal court order that required initiation of the renovation program and a new agency, the Massachusetts Water Resources Authority, to take responsibility for the work. The MWRA began its work in January 1985. By this time, federal subsidies for construction costs for municipal wastewater treatment plants were no longer available, and costs had to be borne locally with little federal assistance.



Vertical Exaggeration = 100

Figure 1. Computer-generated, color-coded, hypsometric map of Massachusetts Bay, showing Boston Harbor, the outfall pipe and discharge area, Cape Cod, and Stellwagen Bank, now designated as a national marine sanctuary. The figure was prepared from edited National Oceanographic and Atmospheric Administration digital bathymetry by R. Signell, U.S. Geological Survey, Woods Hole, Massachusetts.

BALANCING ENVIRONMENTAL, SCIENTIFIC, TECHNICAL, AND ECONOMIC ISSUES

Michael Connor, director of environmental quality at the MWRA, and Anne Aylward, then maritime director of the Massachusetts Port Authority (Massport), outlined the massive, technical construction of new wastewater treatment facilities on Deer Island, harbor-deepening projects, and the status of fisheries resources. Even though the Boston Harbor Project is only halfway to completion, contaminant loads to the harbor have been significantly reduced by ceasing the discharge of sewage sludge and floatables. By 1993, 187 of the 370 km of interceptor pipes delivering wastewater to the Deer Island Treatment Plant had been internally inspected by closed-circuit television, pumping systems were improved so that untreated combined sewer overflows to the harbor had been halved, and industrial discharges to the sewerage system have been controlled so that zinc and copper loadings to treatment facilities have decreased by 75% since the early 1980s (Alber et al., 1993). "Choking" (time when treatment areas had to be closed due to overload) had been reduced from 5395 hours in 1987 to 584 hours in 1992.

HARBOR DEEPENING AND DREDGED MATERIAL DISPOSAL

The harbor deepening required to maintain transport of oil supplies to the region and to sustain shipping, shipbuilding, and maritime activities of all types is the primary responsibility of the U.S. Army Corps of Engineers (COE). Tom Fredette, representing the New England division of COE, summarized the responsibility of the corps in maintaining major navigation systems, administering permits for dredging projects by public and private organizations, and conducting monitoring of past dump sites of dredged material.

A significant part of channel dredgings would not meet provisions of the London dumping convention for offshore waste disposal, according to data from a cooperatively developed database of nearly 2500 sediment samples (including COE data) reported in later technical sessions of the GSA meeting (Manheim et al., 1993; Buchholtz ten Brink et al., 1993). Because the United States is a signatory to the convention, much of the dredged material could not be disposed offshore. Panelist Judy Pederson of the Massachusetts Office of Coastal Zone Management (CZM) stated her office's firm commitment to general waste reduction to the lowest possible levels and to the outfall program. But, she objected to disposal of dredged materials in former offshore disposal sites (*foul area* for industrial waste, and the Massachusetts Bay Disposal Site [MBDS], used for dredged material disposal) or in deeper areas near the Stellwagen Bank National Marine Sanctuary (Fig. 1). COE's Fredette pointed out the high cost and politically contentious problem of land or island disposal, which could cost up to $100 million. With these more traditional disposal options not favored, Pederson indicated that innovative inshore methods, such as borrow-pit disposal capped with clean fill, were being explored jointly with COE and EPA. David Tomey, representing EPA, pointed out that in addition to EPA's role in the National Estuary Program and its regulatory responsibilities for industrial and municipal waste disposal, the 1989 Offshore Dumping Act required EPA to take a more active role in monitoring dredging operations and the waste disposal that would result from them.

CHALLENGES TO THE COURT-MANDATED PROGRAMS

Environmental challenges were presented by two environmental orga-

Waste *continued on p. 198*

Waste *continued from p. 197*

nizations from Cape Cod: Stop the Outfall Pipe (STOP), represented by Mary Loebig, and the Association for the Preservation of Cape Cod, represented by Susan Nickerson. They protested the plan to dispose 500 million to 1.3 billion gallons of wastewater per day from Boston area communities into Massachusetts Bay. In addition to threats to endangered species, excess nutrients and reduced-salinity waters could be a stimulus to toxic microorganisms (*e.g.*, red tide) that could affect the environment of Cape Cod Bay, a partially enclosed water body. In addition, they pointed out that the pathways of particulate detritus along the sea floor are still poorly known. They called for strict compliance with state and federal regulations, including completion of secondary treatment facilities before discharge of effluent through the outfall system. They favored investigation of alternative systems, possibly including tertiary treatment of waste effluents, so that no outfall discharge system would be needed. They requested alternative procedures if a problem were detected, and concrete definition of what effects would trigger these actions.

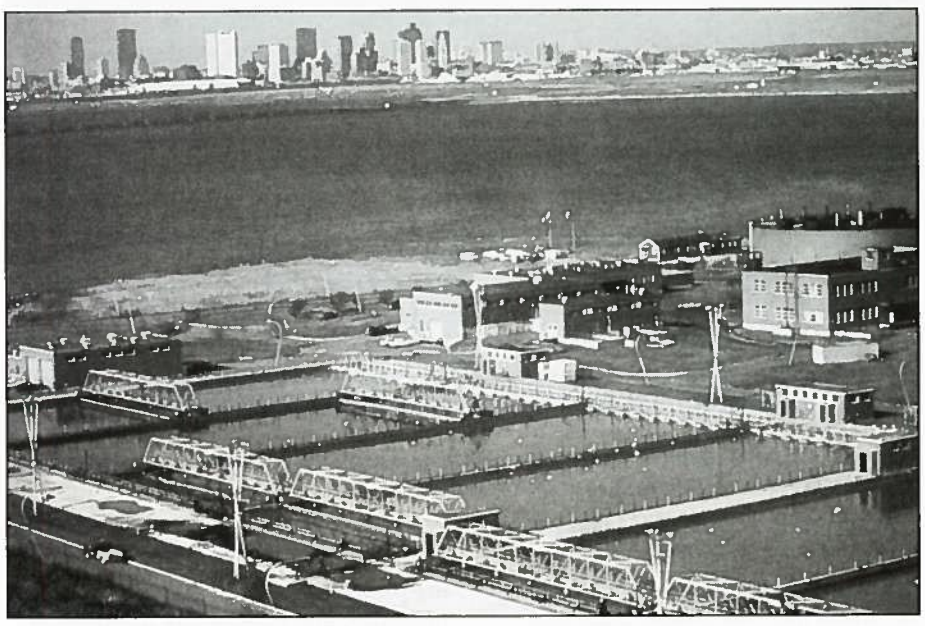


Figure 3. View of Boston Harbor showing the Deer Island Treatment Plant and the Boston skyline in the background.

In contrast, the Massachusetts Audubon Society (MAS), a state-wide organization represented by Robert Buchsbaum, accepts the outfall pipe as a necessity to achieve a cleaner Boston Harbor. However, MAS favored a monitoring program with "real teeth" in the event harmful effects are found. Buchsbaum suggested that non-point-source pollution will become the greatest threat to nearshore water quality.

OUTDATED TREATMENT STRATEGY AND TECHNOLOGY?

Challenges to the efficacy of in-progress MWRA methodologies, which involve a unified treatment center on Deer Island for all 43+ constituent Boston area communities, were posed by Donald Harleman and Susan Murcott of the Massachusetts Institute of Technology Department of Civil Engineering. Harleman stated that the plan of first employing standard primary treatment of effluent and, ultimately, further removal of solids and organics through secondary treatment, ignored advances in chemically enhanced primary treatment (CEPT). CEPT now provides a more efficient treatment for removal of particulate organics and toxic metals, reducing the need for conventional activated-sludge secondary treatment, a turn-of-the-century technology that was specified in the 1972 Clean Water Act. The conventional technology is costly, requires extensive space, and fails to reduce critical nitrogen concentrations significantly. They pointed out that federal subsidies for these accepted but outdated methodologies had preempted the market for newer, innovative, and more efficient wastewater treatment technologies. Murcott criticized engineering consulting firms, state and federal regulations, and environmental groups who have directly or indirectly created barriers to new technologies that are being developed in Europe and Japan.

John Teal, a biologist at the Woods Hole Oceanographic Institution and pioneer in experimental sewage treatment facilities for individual Cape Cod communities, described further innovative approaches. He advocated wetland ecosystem (bioremediation) treatment systems, and questioned the wisdom of the "all eggs in one basket" massive collector system, which accounts for half of the MWRA system costs. He provided illustrations of Cape Cod town facilities using efficient, year-round, greenhouse-enclosed treatment systems that were not malodorous. Besides the cost savings on piping and future maintenance of collector systems, he indicated that decentralized bioremediation facilities could be built rapidly in modular fashion to meet community needs. These would take no more space than traditional treatment systems and would provide individual communities with decision-making input and with incentives for assuming local responsibility and for further technological development. Moreover, the systems could provide enhanced treatment to reach tertiary treatment levels (drinking water standards), should that be deemed necessary.

Sludge disposal, however, remains a common requirement for both the current and alternative systems, and its problems were little discussed during the forum.

THE SCIENTISTS' INPUT

According to Keith Stolzenbach, UCLA Department of Civil Engineering, and Gordon Wallace, of the University of Massachusetts at Boston, one of the most encouraging developments coming from the Massachusetts Bay issue has been greatly improved communication between scientists and decision makers. The need for research on key applied problems has opened the way toward greater cooperation among scientists in addressing pressing societal issues. In turn, the seriousness, cost, and complexity of the problems has required decision makers to seek wide-ranging scientific input. However, Stolzenbach and Wallace showed charts demonstrating that research expenditures typically followed rather than preceded major operational decisions, and that 5 to 10 years of *advance* studies would be needed to provide the background for optimum decision-making.

For Boston the key issues are

- Establishing acceptable levels of nutrient addition that will avoid nuisance algal blooms and long-term eutrophication.
- Maintaining controls on sources of pathogens and toxic components that cause contamination of shellfish beds, affect recreational and fishing areas, and have esthetic consequences.
- The role of extant contaminated sediments—their transport and ultimate fate. Will these remain as sources of contamination after active contaminant contributions have stopped?
- Strategies for disposal of sediments that must be dredged for navigation or other purposes.
- Establishing a predictive capability to test various management scenarios, and maintaining regional scientific expertise on a long-term basis.

A three-dimensional numerical model of bay-wide circulation provided an example of scientific studies used to help resolve controversial questions. Richard Signell of the U.S. Geological Survey (Woods Hole), in cooperation with Eric Adams of the MIT Department of Civil Engineering, presented results from modeling studies that showed that nutrients discharged into Boston Harbor are already largely transported to Massachusetts Bay. On current evidence from winter and summer models, levels of treated effluent in Massachusetts and Cape Cod Bays will be nearly the same for the new outfall as for the present outfall in Boston Harbor, except for the immediate vicinity of the deep diffusers. Nutrient levels in Boston Harbor are significantly reduced. The net residence time and transport of heavy metals between the harbor and Massachusetts Bay, as well as the along-bottom movements of contaminants within the Bay, are not well understood. In the long term, the initial level of pollutants entering the sewage system must be reduced.

NATIONAL PERSPECTIVES

J. R. Schubel, currently chairman of the Marine Board of the National Research Council and director of the Marine Sciences Research Center (MSRC), SUNY, Stony Brook, New York, and R. L. Swanson, Director of the Waste Management Institute at MSRC, stated that, nationally, wastewater management strategies have failed to achieve satisfactory improvements in ecosystem quality and accommodation of multiple uses in spite of high costs. For example, during the same period that all communities that were discharging municipal waste to Long Island Sound were equipped with full secondary treatment systems, hypoxic (low oxygen) conditions increased markedly in eastern Long Island Sound. Schubel and Swanson proposed that a concept called *integrated coastal management* (ICM) could improve results by shifting the focus from technology-based approaches to environmental-quality–based goals. ICM focuses on real and documented rather than perceived problems, ranks threats to uses and values, and assesses strategies to reduce or eliminate risks for individual areas. It would monitor progress and disseminate results broadly.

Obstacles to such a paradigm are scientific and technical limitations, public perceptions, and political pressures. The authors of this summary note that Schubel and Swanson might draw support for their point from five critical articles on the front page of the New York *Times* during March 1993. These articles called attention to the often poor cost-effectiveness of environmental legislation generated in the emotional aftermath of highly publicized events such as the finding of AIDS-infected syringes on New York Bight beaches in 1988.

Selected Public Questions and Responses

Q. (to Susan Nickerson): Do STOP and APCC really want to force Boston to discharge 380 million gallons of sewage effluent into the mouth of Boston Harbor? How much would scientific uncertainty have to be reduced to make the APCC comfortable?

A.: We are not proposing that any area be sacrificed. Our position is that the treatment system must be fully built and assured before discharge takes place. Whether enhanced primary treatment is to play a role or perhaps Dr. Teal's bioremediation would lead to a more finished product, we want assurance that the effluent will not pose hazards to endangered species and that other concerns that have been raised are addressed. Moreover, a lot of information is yet to come in on sediment transport and resuspension, and there is need for additional baseline information. Before the project is turned on we want to see that it will not have a damaging effect. But, if it should, what will be done about it?

Q. (to Stolzenbach): When is a science project finished?

A.: Scientists feel uncomfortable about releasing information before it reaches publication standards, because one never knows in which way things might go or how data from early stages of work might be used. At all stages, more is better. But engineers often do a poor job of communicating, and we need to provide more detail and be less fearsome.

Q. (to group as whole): What kind of science policy is most effective from a management standpoint?

A. (Harleman): An institutional factor contributes to our failure to compete in innovative technology with the Europeans. When a community here in the United States has a task, it engages a consulting firm and develops a working plan. Only *then* does it open the plan for competitive bidding for construction—and perhaps yet another bidding for operation of the facility. There is no competition for the basic plan itself. In fact, alternatives are likely to be dismissed with only subjective or superficial justification. In France, they do things completely differently. The entire package is open to bid, from design to construction to operation. As a result, innovative plans might be offered, and the firms that offer them must have research facilities to develop and test the plans to make sure they work. They also have to operate them. We need to consider an overhaul of our system.

Q. (to R. Signell): Have you considered the role of unexpected episodic events vs. a model based on a discrete time sample?

Waste *continued on p. 199*

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Inquiries are welcome. Applicants are requested to send their curriculum vitae, transcripts, a statement of research and teaching interests, and the names and addresses of three references to Dr. Robert W. Ritzi, Department of Geological Sciences, Wright State University, Dayton, OH 45435, (513) 873-3455. Review of applications will begin October 1, 1994, and continue until the position is filled. Wright State University is an equal opportunity/affirmative action employer.

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Waste *continued from p. 198*

A.: The model can handle episodic events, although one would have to identify what kind of conditions are to be considered.

Q. (to Mike Connor): Boston is said to be one of the nation's most sensitive areas for potential large earthquakes. What would happen if a big quake cut the feeder pipes?

A: The question would be how to repair them. If the outfall were cut, one might have to improvise emergency outfalls at Deer Island. A serious quake might cause some pretty overwhelming sewage problems.

Q. (to all): Has thought been given to the spaceship technology concept—i.e., making each area, or even each dwelling, as self-sufficient as possible?

A. (Judy Pederson): Some communities have already come part way with gray water recycling, but there's no doubt that much more could be done.

Q: Several questions for John Teal were raised about the possibility of implementing community-based bioremediation. In his absence, Susan Nickerson and Judy Pederson suggested that near-site is the best technology, and also the most visible, if it can be managed. Eric Adams suggested that, regardless of the merits of the present outfall plan, it, too, has a finite life span, and it is not too early to start planning for alternative and future solutions to disposal of wastes.

Q. (to Larry Swanson): What are the realistic chances for ICM? Has any place adopted it?

A: What has occasionally worked in the past is when someone was able to take leadership, as Schubel did in Chesapeake Bay and as Richard Delaney did here in the Boston area. The big problem is how to get the public involved. But, public participation is rarely actively sought. Every organizational plan has public relations written into it, but not in an active, participatory sense. One model may be southern California, where several municipalities formed the Coastal Water Research Project as a quasi-public operation and got people activated.

A. (Peter Shelley): The public is often treated as a problem, but rarely given respect as a player. The public is given news handouts and high-sounding rhetoric, but no resources to help it participate and provide input. Under these circumstances, just about all the public has left are guerrilla tactics.

Q. (to Harleman): How can the MIT group justify proposing abandonment of secondary treatment when it is required by law?

A.: That is a misconception. We do not propose to trade chemically enhanced primary treatment for secondary treatment. Rather, the enhanced primary treatment will do much of what secondary treatment would have done, so that a smaller secondary treatment plant would be required. In fact, the space saved could even make room for tertiary treatment later if that were needed. But if one opts for the traditional primary and secondary treatment systems, there will be no space whatever for tertiary treatment, which would thus be excluded from consideration.

CONCLUSIONS

The sense of most participants was that Boston has a difficult set of problems, many historical in origin, but others that stem from the regulatory and operative systems way in which the United States has come to address its coastal environmental problems. Schubel and Swanson believe that such problems are nationwide and need changing. The consensus seemed to be that MWRA was an open and conscientious organization, attempting to fulfill its basic operating mandate in the face of considerable controversy. However, a substantial number of the participants suggested that it was forced to do and sponsor research to justify plans that had already been largely fixed at its inception.

The scientists tend to agree that the research should come earlier. The Conservation Law Foundation, which catalyzed the legal changes, believes that a much more informed and active public will help with such problems in the future. Navigational improvements also carry certain hallmarks of deferring research on disposal of dredged material specific to the area until plans become a matter of urgency. Schubel and Swanson propose integrated coastal management to reverse this process, to anticipate and define problems carefully, and then to examine potential solutions with equal care before beginning corrective action. They recognize that to win public and, therefore, governmental support for this approach, the public needs to be much better informed, and it needs to acquire more confidence in governmental leadership.

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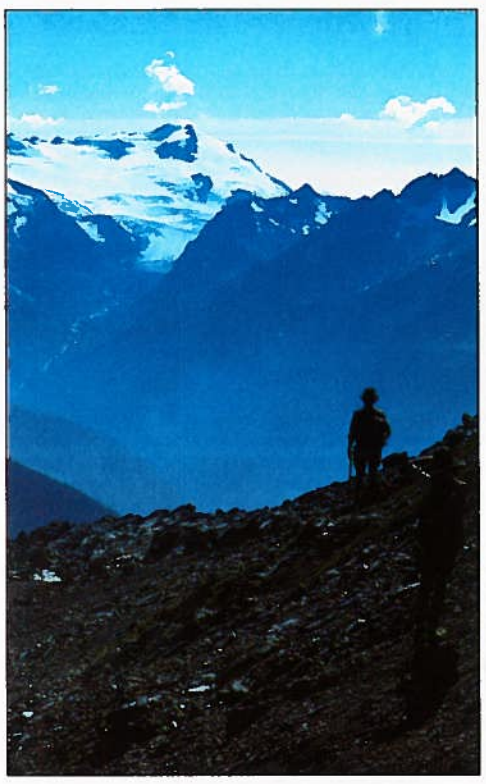

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