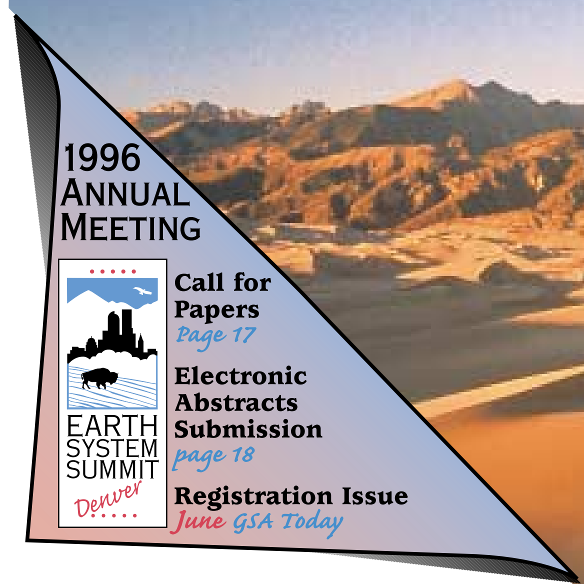
Vol. 6, No. 4 April 1996

GSA TODAY

A Publication of the Geological Society of America



Dipping Reflectors Beneath Old Orogens: A Perspective from the British Caledonides

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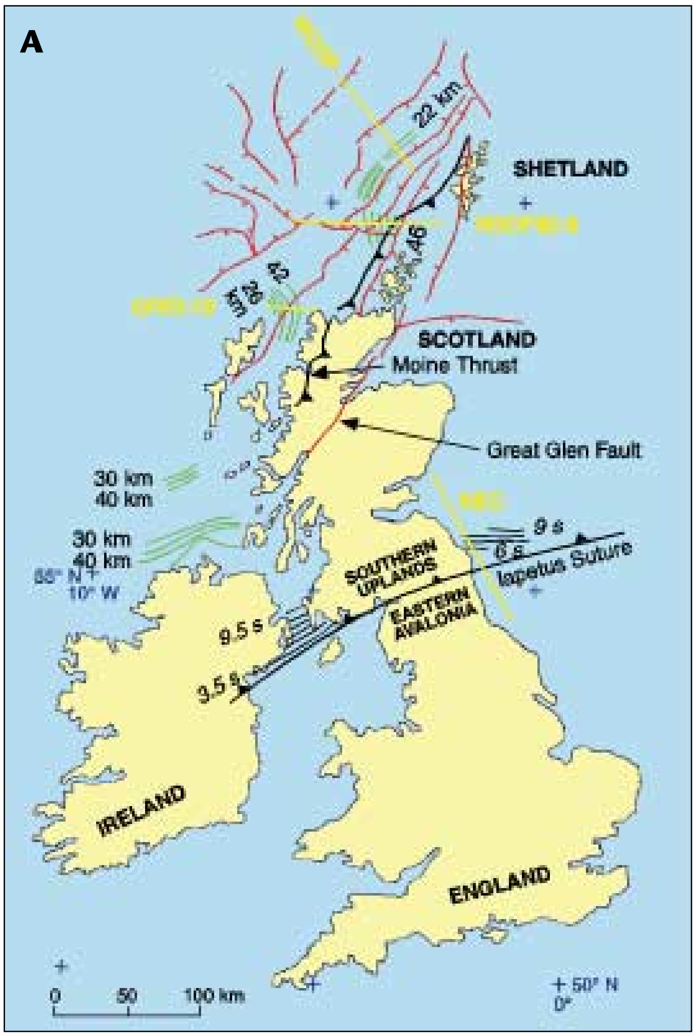

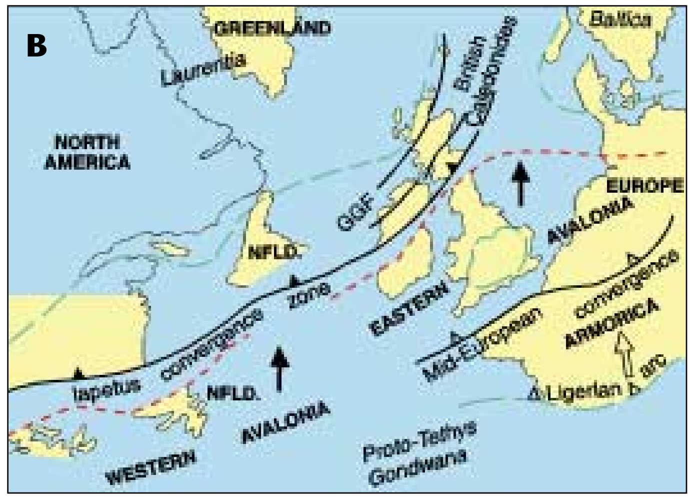

Figure 1. A: Generalized location map of the British Isles showing principal structural elements (red and black) and location of selected deep seismic reflection profiles discussed here. Major normal faults are shown between mainland Scotland and Shetland. Structural contours (green) are in kilometers below sea level for all known mantle reflectors north of Ireland, north of mainland Scotland, and west of Shetland (e.g., Figs. 2A and 5); contours (black) are in seconds (two-way traveltime) on the reflector I-I′ (Fig. 2B) projecting up to the Iapetus suture (from Soper et al., 1992). The contour interval is variable. B: A Silurian-Devonian (410 Ma) reconstruction of the Caledonian-Appalachian orogen shows the three-way closure of Laurentia and Baltica with the leading edge of Eastern Avalonia thrust under the Laurentian margin (from Soper, 1988). Long-dash line indicates approximate outer limit of Caledonian-Appalachian orogen and/or accreted terranes. GGF is Great Glen fault; NFLD. is Newfoundland.

ABSTRACT

After two decades of deep seismic reflection profiling, our understanding of dipping reflectors in the crust and upper mantle beneath old orogenic belts, and especially their relation across the crust-mantle boundary, remains incomplete. The Caledonian orogenic front (Moine thrust) and the Iapetus suture in Great Britain, two of the world's most studied compressional belts, show a consistent pattern of discrete dipping reflectors in the upper-to-middle crust, suggesting a "thick-skinned" structural style. These reflectors project downward into a pervasive zone of diffuse reflectivity in the lower crust. This zone of diffuse reflectivity corresponds to a theoretical depth interval of low strength that represents distributed shearing separating upper crustal and uppermost mantle layers of greater strength. Prominent dipping reflectors also occur within the high-strength uppermost mantle beneath the Caledonian orogen. Reflectors within the stronger upper-to-middle crust and upper mantle are not connected across the Moho discontinuity and thus seem kinematically distinct, although mantle reflectors in places appear to continue upward into the lowermost crust. Dipping crust and mantle reflectors probably originated from different geologic events: dipping reflectors in the crust first took form as thrusts during the early Paleozoic Caledonian orogeny, whereas those in the upper mantle

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GSA TODAY

April 1996
Vol. 6, No. 4

GSA TODAY (ISSN 1052-5173) is published monthly by The Geological Society of America, Inc., with offices at 3300 Penrose Place, Boulder, Colorado. Mailing address: P.O. Box 9140, Boulder, CO 80301-9140, U.S.A. Second-class postage paid at Boulder, Colorado, and at additional mailing offices. **Postmaster:** Send address changes to *GSA Today*, Membership Services, P.O. Box 9140, Boulder, CO 80301-9140.

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have an even older history associated with an as yet unrecognized episode of subduction or Late Proterozoic rifting of the Laurentian supercontinent. Crust and mantle reflectors were likely reactivated by Mesozoic and younger North Sea rifting, which may also have produced, or at least enhanced, the diffuse reflectivity in the low-strength lower crust.

INTRODUCTION

Since its inception in 1981, the British Institutions Reflection Profiling Syndicate (BIRPS) has been accumulating deep seismic reflection data over the offshore parts of the Caledonian orogen. To date, about 17,000 km of profiles have been recorded around the British Isles. The major crustal framework structures of the Caledonian orogen, namely the Caledonian orogenic front (locally Moine thrust) and the Iapetus suture, are arguably the best studied Paleozoic orogenic features in the world, particularly from the standpoint of deep reflection data. These two structures together effectively delimit compressional deformation resulting from the Caledonian orogeny (Silurian–Early Devonian) in Britain (Fig. 1A). The goal of this report is to summarize results of our recent work on the British Caledonides by focusing on the significance of dipping reflectors, features now considered to be characteristic of compressional orogens.

The greater Paleozoic Caledonide-Appalachian orogen continues to be the focus of studies of collisional tectonics, as illustrated by the recent debate over the relation of the early Paleozoic Argentine Precordillera and related terranes in South America to the North American Appalachians (e.g., Astini et al., 1995). The well-defined reflector patterns of the crust and upper mantle for the British Caledonides provide a guide to understanding terrane boundaries in Britain as well as elsewhere. The three main problems we address are: (1) Can dipping crustal reflectors beneath the Caledonides be unequivocally linked with compressional structures at the surface, and how are compressional structures distributed deeper within the crust? (2) Does dipping reflector structure in the upper mantle beneath the Caledonides have any relation to Paleozoic or younger features in the crust above it—what really are the admissible interpretations for upper mantle reflectors? (3) Finally, we argue that the crust and upper mantle were mechanically decoupled during Caledonian compression, and that crust and mantle deformation structures beneath the Caledonides have separate origins.

DIPPING CRUSTAL REFLECTORS

Moine Thrust

The Moine thrust (Fig. 1A) is the classic structure of the Caledonide-Appalachian system, and is probably analogous to the Taconian suture in the North American Appalachians. Where it crops out in mainland Scotland, the thrust floors a thick east-dipping mylonite zone that separates metamorphic rocks of the thrust belt to the east from the less deformed Precambrian foreland and cover sequence to the west (Barr et al., 1986). Deep seismic data over the offshore projection of the thrust reveal a thick wedge of east-dipping reflections in the middle-to-lower crust (Fig. 2A). This wedge is capped by a highly coherent reflection (Fig. 2A; M-M′) that correlates with the Moine thrust (McBride and England, 1994). The thrust separates an unreflective upper crust from a highly reflective crust below. The thrust can be projected into the lower crust on the basis of weaker collinear reflection segments and by the distinct change from the eastward-dipping fabric of the wedge to a westward-dipping set of reflections immediately to the east (W-W′).

Iapetus Suture

The Iapetus suture forms one arm of the Caledonian triple convergent “junc-

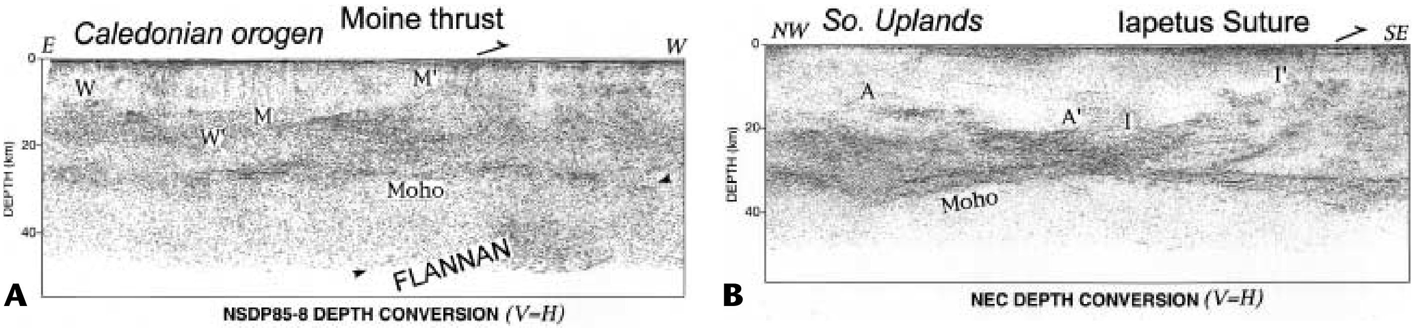

Figure 2. A: A 15° finite-difference time migration and depth conversion of Geco-Prakla NSDP85-8 seismic reflection profile (section displayed with east on left so seismic character can be directly compared to that in B). M-M′ is the interpreted Moine thrust reflector. W-W′ is an oppositely dipping reflector that appears to be cut off by M-M′. "Flannan" refers to dipping mantle reflector. B: A 15° finite-difference time migration and depth conversion of BIRPS NEC seismic reflection profile. I-I′ is a dipping reflector within the Iapetus suture. A-A′ is a weak set of subhorizontal reflectors. See Figure 1A for location. Data are displayed as variable area, no wiggle traces with no vertical exaggeration (V = H).

tion" of Laurentia, Baltica, and Gondwana (Fig. 1B). In mainland Britain, the suture separates the Eastern Avalonia terrane to the south from the Southern Uplands to the north (Fig. 1A), the farthest outboard of the Caledonian terranes accreted to Laurentia before the final closure of the Iapetus Ocean. Suturing is inferred to have been in the Middle Silurian and associated with northward subduction (Soper et al., 1992). Deep seismic profiles crossing the offshore projection of the Iapetus suture (NEC line in Fig. 1A) typically show two strong north-dipping reflectors spanning the middle crust (below and including I-I′ in Fig. 2B). The upper and northernmost reflector forms a boundary between reflective and unreflective crust. The seismic expression of the Iapetus suture is interpreted as the leading edge of Avalon crust (i.e., the footwall of the suture zone). A possible reversal of reflector dip appears farther northwest in the hanging wall of the suture zone (A-A′ in Fig. 2B), but the northwest-dipping pattern clearly dominates the crustal section and may slightly continue into the uppermost mantle, where it appears to either offset Moho reflections or merge with a northwest-dipping Moho.

Moine Thrust and Iapetus Suture Synthesis

A key point of our study is that the seismic signatures of the Moine thrust and Iapetus suture show significant similarities even though they appear to be quite different structures at the surface. Both crustal sections are dominated by a prominent dipping reflector that correlates with a metamorphic and/or terrane boundary and that divides the crust into a reflective lower section and a poorly reflective upper section. The dipping reflector acts as the leading edge of highly reflective crust which may be more widely deformed than poorly reflective crust. In each case, this dominant reflector appears to approach the Moho as a planar surface and to disrupt the Moho at intersection. The dominant and other associated dipping reflectors do not actually extend into the mantle. The continuation of the reflective wedge from the middle crust toward the Moho suggests a "thick-skinned" model for the Caledonian orogen, with thrusts imbricating the footwall rather than a single decollement separating upper and lower plates. If we interpret these observations in terms of deformation in a compressional zone, then the dominant reflector becomes a discrete thrust or shear zone, and the underlying reflectivity represents distributed and disordered deformation that continues to the base of the crust where it abruptly disappears. A principal difference between the crust beneath the Moine thrust and the Iapetus suture is the prominence of a "bivergent" (i.e., interpreted thrusts dipping in opposing directions) pattern of dipping reflectors in the Moine thrust section (Fig. 2A) compared with the relative absence of a bivergent pattern in the Iapetus suture section (Fig. 2B).

A finite-difference geodynamic model (Quinlan et al., 1993) formulated to explain dipping reflectors beneath orogens predicts a bivergent pattern that develops during a single deformation phase. This pattern forms above a stress discontinuity where the subducting crust bends downward as it detaches from its mantle (Fig. 3). Such models are potentially useful in linking observations of dipping crustal reflectors with mantle subduction polarity. Beneath the Moine thrust, a bivergent pattern similar to that in the model is observed (W-W′ and M-M′ in Fig. 2A). A problem is that this pattern may simply represent two distinct deformation episodes (W-W′, being older, is crosscut by the Moine thrust pattern). For the Moine thrust section where the dominant reflector dip is to the east, the model predicts that westward subduction occurred beneath Scotland (cf. Figs. 2A and 3). As yet, no such subduction has been inferred from surface geology (Barr et al., 1986). Near the Iapetus suture (I-I′ in Fig. 2B), no clear bivergence is observed, although the reflection data show one set of discordant reflectors (A-A′) that appears to intersect the dominant dipping Iapetus suture pattern. Following the model (Fig. 3), the predominance of northwest-dipping crustal reflectors would be associated with southeastward subduction; however, the available geologic evidence has been used to argue in favor of northward subduction (Soper et al., 1992).

In summary, the crustal sections underlying the two principal framework structures of the Caledonian orogen have a similar seismic signature. This similarity points toward a unified explanation in which both structures have a mainly thick-skinned deformation style modified by thrust imbrication. The thrust vergence directions inferred from the seismic data

Dipping Reflectors *continued on p. 4*

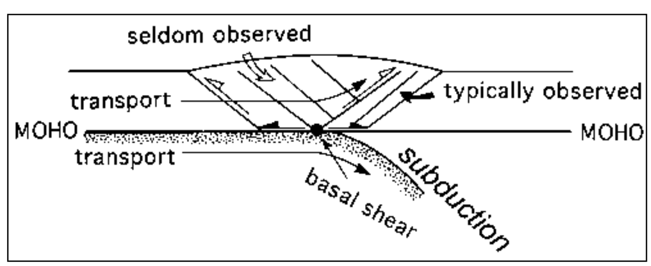

Figure 3. One-stage geodynamic model (from Quinlan et al., 1993) representing two domains of dipping crustal reflectors interpreted as thrust faults associated with subducting lithosphere. Only one domain is typically observed in the British Caledonides as indicated (see particularly Fig. 2B). As subduction proceeds to the right, mantle lithosphere is detached from the crust. The black circle gives the position on the top of the down-going plate where the mantle of the left plate detaches and is underthrust. The direction of the dominant thrust vergence is the same as that of material transport.

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indicate transport of crustal material away from the interior of the orogen (i.e., northwest for Moine thrust, southeast for Iapetus suture; Figs. 1A and 4). In summary, a single-phase geodynamic model correctly predicts key aspects of the seismic observations; however, linking the dipping reflector pattern in the crust to subduction in the mantle remains a problem. Our next step must be to intensify study of reflectivity in the upper mantle and show how it is, or is not, structurally linked with crustal reflectivity.

DIPPING MANTLE REFLECTORS

One of the world's most remarkable regions of reflective upper mantle (Fig. 1A) lies beneath the British Caledonides (Flack et al., 1990). New industry seismic profiles and reprocessed older profiles have recently improved our knowledge of the Flannan mantle reflectors (Fig. 5), better constraining their regional distribution and origin. We have pursued a working hypothesis that the northern Scottish mantle reflectors (currently mapped as an east-plunging antiform north of mainland Scotland and a synform west of Shetland; Fig. 1A) and the occasional reflectors from seismic lines north and west of Ireland (Fig. 1A) are correlative or at least closely related. Comparison of the sections in parts A and B of Figure 5 shows that the expression of this mantle reflector and its geometrical relation to the Moho vary considerably along strike. Northwest of the Scottish mainland (west end of section in Fig. 5A), the reflector continues from the uppermost mantle into the lower crust and marks a disruption or offset of the Moho. Although other workers have argued that this reflector is either a Mesozoic normal fault or a Caledonian thrust, it does not consistently follow either Mesozoic or younger normal fault trends, or Caledonian structural trends. On none of the available profiles can continuity of normal faults nor thrusts down into the upper mantle be seen, despite the fact that the Moine and other Caledonian thrusts, as well as major basin-bounding normal faults, commonly dip in the same direction as the mantle reflector.

The key point of our observations is that reflectors in the crust are discontinuous with and spatially unrelated to reflectors in the upper mantle and thus have distinct origins. We suggest that although the mantle reflectors were probably reactivated by Phanerozoic tectonism, they actually originate from a Precambrian tectono-thermal event. The complex shape of mantle reflectors in map view (Fig. 1A) may be related to subsequent deformation episodes. The multistrand nature of the reflection on some profiles (Fig. 5A) may express multistage reactivation of a zone of shearing. Two proposed explanations for a pre-Caledonian origin are that these reflectors represent (1) a relict subduction zone (Warner et al., 1996), or (2) extensional shearing within the upper mantle produced during Neoproterozoic rifting of the Laurentia-Baltica supercontinent (McBride et al., 1995). Support for pre-Caledonian subduction comes from the postulated accretion of at least one island arc onto the Laurentia-Baltica supercontinent at 1.8 Ga (Dickin, 1992). Alternatively, on the basis of parallelism between the trend of mantle reflectors and the old Laurentian margin (Fig. 1B), the mantle reflectors contoured in Figure 1A may be associated with Neoproterozoic rifting (McBride et al., 1995). Current models of continental rifting (e.g., Torske and Prestvik, 1991) predict the continuation of normal faults from the upper crust into the mantle as extensional shear zones that could be preserved as zones of high impedance contrast. It is difficult to favor conclusively either a subduction or a rifting hypothesis at this time, although both hypotheses postulate a zone of shearing or detachment in the mantle. Even though the Iapetus suture is associated with known subduction, no mantle reflectors have been observed anywhere on the profiles that cross it. Thus, it is clear that subduction need not produce mantle reflectors that are preserved for hundreds of millions of years after the event.

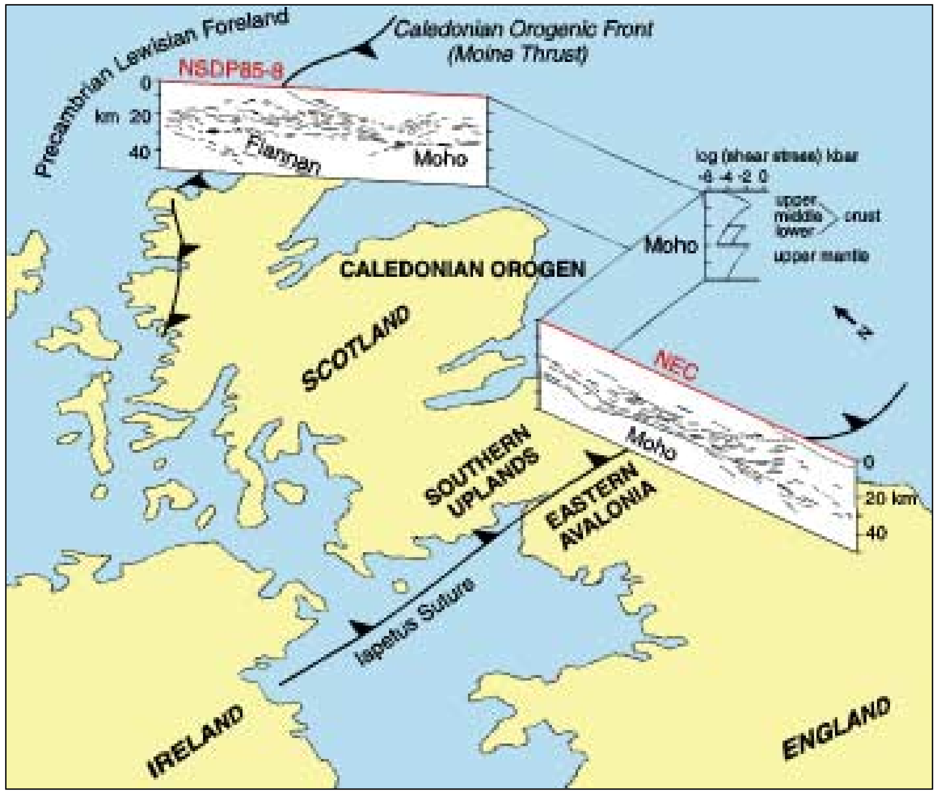
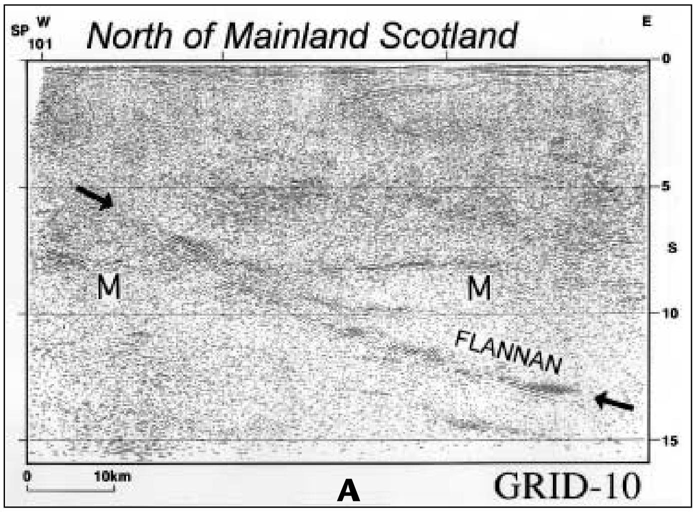


Figure 4. Simplified schematic drawings of NSDP85-8 and NEC seismic reflection profiles showing their positions relative to the surface traces of the Caledonian orogenic front (locally Moine thrust) and the Iapetus suture. Arrows on profiles indicate interpreted thrust vergence. The two seismic sections are shown referenced to a theoretical shear stress vs. depth curve for an idealized continental crust and mantle lithology (from Meissner and Kusznir, 1987) and a surface heat flow of 70 mW/m^2, typical for a Paleozoic orogen (alternative curve for lower crust assumes abrupt mid-crustal shift from acidic to dry mafic mineralogies).

STRAIN PARTITION IN CALEDONIAN LITHOSPHERE

The above discussion of crust and mantle structure, in which Caledonian-age thrusts and mantle reflectors are spatially unconnected, suggests distinct crust and upper mantle strain patterns. Rheological models of the crust and upper mantle, which assume an increasing mafic and decreasing quartz mineralogy with depth and a typical orogenic geotherm (e.g., Meissner and Kusznir, 1987), predict strength maxima in the mid-crust and just beneath the Moho for a constant applied stress (Fig. 4). Using these models, the low-strength zone in the lower crust corresponds to the zone of highest and most coherent reflectivity. This observation is consistent with interpreting these reflective zones as resulting from shear, and it provides an explanation for the concentration of deformation-related reflectivity in the middle and lower crust (cf. Kusznir and Matthews, 1988). With elevated temperature in the mid-to-lower crust, one would expect a partially ductile



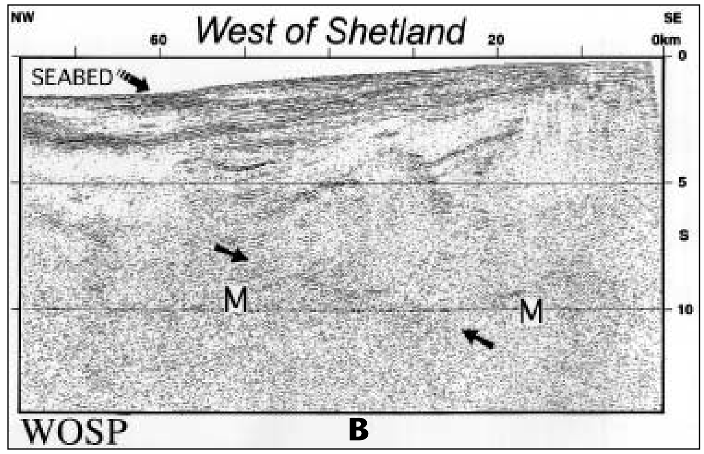


Figure 5. A 15° finite-difference time migration of BIRPS GRID-10 and the WOSP (West Of Shetland Profile) reflection seismic sections. See Figure 1A for location. Arrows indicate mantle reflectors (e.g., Flannan) shown as contours in Figure 1A. M is reflection from Moho discontinuity. Data are displayed as variable area, no wiggle trace sections with no vertical exaggeration for a time-depth conversion velocity of 6 km/s.

rheology, so that compressional deformation would develop as broad ductile shear zones rather than discrete brittle faults. The contrasting rock types necessary for the high-amplitude reflectivity could be produced either by deforming reflective material into elongated shapes that are optimum for strong reflection, juxtaposing layers with distinct impedance (seismic velocity and density), or creating a new high-reflectivity layer by internal deformation (e.g., mylonitization).

High-strength zones in the upper-to-middle crust and the uppermost mantle are characterized by a substantial decrease in reflectivity relative to the lower crust, almost to the point of being acoustically blank. Reflectivity, where it does exist within these zones, consists of a single bright reflection or narrow concentrations of reflections. The localization of shear stress maxima and minima around the Moho underscores the concept of mechanical decoupling accompanied by a change in deformation style near this boundary and is in harmony with the observation that dipping reflectors in the crust and mantle are discontinuous across the Moho. If the uppermost mantle is stronger than the crust (Fig. 4; Meissner and Kusznir, 1987; Cook and Varsek, 1994), stress-induced failure will occur at different times and rates in the crust and mantle. This means that the points of failure will not necessarily be linked, and that deformation structures will not match across the crust-mantle boundary.

CONCLUSIONS

The large set of reflection profiles from the Caledonide orogen around Britain reveals a "thick-skinned" structural style for the upper-to-middle crust. This style is expressed by a coherent planar reflector dipping toward the interior of the orogen which divides the crust into upper poorly reflective and lower highly reflective zones. Although a bivergent reflector pattern appears occasionally, as predicted by recent geodynamic models, a univergent reflector pattern best characterizes each side of the Caledonides. As such, dipping reflector patterns cannot yet be reliably linked to subduction polarity as suggested by the models. Univergent reflector patterns are also well developed in the upper mantle where they dip in the same direction as the Moine and other Caledonian-age thrusts. Because these mantle reflectors are unrelated to Phanerozoic deformation patterns, either in plan or cross-sectional view, we suggest a Precambrian origin for them. The complex mantle reflector contour pattern seen in Figure 1A probably arose from subsequent Caledonian compression or later extension associated with North Sea rifting that probably reactivated the mantle reflectors. A simple hypothetical Caledonian stress vs. depth relation indicates that discrete reflectors appear in strong upper and middle crustal and mantle layers, and that distributed reflectivity characterizes low-strength lower crust. The pronounced contrast of reflectivity across the crust-mantle boundary is consistent with this boundary acting as a detachment. Dipping reflectors in the crust and upper mantle are discontinuous across this boundary and must have had kinematically different origins.

ACKNOWLEDGMENTS

The British Institutions Reflection Profiling Syndicate (BIRPS) is supported by the Natural Environment Research Council and by BIRPS's Industrial Associates (Amerada Hess Limited, BP Exploration Co. Limited, British Gas plc, Chevron U.K. Limited, Conoco [U.K.] Limited, Lasmo North Sea PLC, Mobil North Sea Limited, Shell U.K. Exploration and Production, and Statoil [UK] Ltd.). Total Oil Marine provided technical assistance. The NSDP85-8 seismic section comes from a nonexclusive proprietary survey acquired by Geco-Prakla Exploration Services; we appreciate permission to use these data. We thank M. Hauck, S. M. Kay, D. R. Kolata, E. A. Latimer, E. M. Moores, E. I. Prussen, J. D. Treworgy, and an anonymous referee for helpful reviews of the manuscript, and S. Capon, J. L. Hannah, and D. R. Kolata for assistance with the illustrations. University of Cambridge Department of Earth Sciences contribution 4393.

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Geology and Geologists in the Former Soviet Union: Opportunities for Interaction

These three articles give us a glimpse of new possibilities for scientific interchange made possible by political change — the breakup of the Soviet Union

The Life of Geologists in the Former Soviet Union

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Geologists in the former Soviet Union are now having hard times. While the average salary of a geologist is less than US$100 per month, the prices for food, clothes, furniture, and housing are nearly the same as in the United States. Moreover, a helicopter is essential for field work in much of Russia, but chartering one costs about $1000 per hour, which is about the same as, or more than, in the United States. However, because they like their work and do it very well, Russian geologists continue to work, in spite of these difficulties.

There are various groups of geologists in Russia—geological survey scientists who deal with regional studies and perform geologic mapping, mining geologists, and geologists in academic institutes and universities. I have worked my entire life in academic institutes, but I have also taught at the universities and maintained close contacts with geologists from the geological survey. Thus, I know about the lives of all the groups of geologists in Russia.

I live and work in the town of Yakutsk, the capital of the Sakha Republic (Yakutia), a part of the Russian Federation. Yakutia is a vast area in northeast Siberia covering about 3.3 million km^2 and having a population of about 1 million. About 35% of the population are Yakuts and other native peoples; the remainder are Russians. The republic has its own president and government. Our republic spans several natural zones, including tundra along the shores of the Arctic Ocean, a mountainous eastern part, and a vast boggy lowland in the west. The main rivers flow into the Arctic Ocean and cross Yakutia from south to north; they are the primary routes for shipping. The Yakutian climate is very severe; winter lasts for 7–8 months, and temperatures reach minus 34 to minus 50 °C. Summer is brief (2–3 months) and hot (30–40 °C). Yakutsk is a city of about 200,000 and hosts governmental and cultural institutions, Yakut State University, and the Yakut Science Center of the Siberian Division of the Russian Academy of Sciences, which includes eight scientific institutes. I work in the Yakutian Institute of Geological Sciences and am concurrently a professor in the geology department of the university.

Russia, especially Siberia, is rich in mineral resources. There are numerous mineral deposits in Yakutia, discovered because of the work of many geologists. Most important are deposits of diamonds, gold, coal, rare earth elements (REEs), iron, natural gas, and oil on the Siberian platform, and gold, silver, tin, antimony, zinc, lead, coal, rare metals, REEs, and others in the Mesozoic orogenic belt in eastern Yakutia. It is possible that additional large deposits have yet to be discovered. Transportation and technology difficulties make most of these deposits, other than diamonds, unprofitable.

At present, geologic maps completed in the early 1970s, at a scale of 1:200,000, represent almost the entire territory of Russia. These maps have long been secret, and although many have now been issued, they remain unavailable to foreign geologists. This work would not have been accomplished without specialized schools and institutes, not only in Moscow and Leningrad, but also in most of the large cities of Siberia and the Russian Far East. In the course of this work, a whole generation of specialists in regional geology grew. A representative of that generation was Lev Zonenshain. He devoted much of his life to geologic mapping of various regions of the former USSR and developed into a scientist well-known even in America.

During the mapping in the 1950s and 1960s, the major tectonic structures were interpreted and large mineral deposits were discovered; for example, oil and gas fields in western Siberia, and diamonds in Yakutia. The theoretical basis of geologic investigations during that time was the geosynclinal concept. It was within this framework that the geology was interpreted and many great discoveries were made; this explains, in part, why the concept is still supported by many Russian geologists. But the main reason for the conservatism of Russian workers is intellectual isolation. For decades under Soviet power, science in the former USSR, including geology, was forcibly isolated from the rest of the world. Many of the new scientific ideas that appeared in the West were ignored as being bourgeois and alien to progressive Soviet science. Great efforts were made to develop something of our own that differed from western ideas. For this reason, the orthodox fixist interpretation of the geosynclinal concept remains popular among Russian geologists. An example of such ideas is the “deep fault” concept, which was incomprehensible to western geologists. Lev Zonenshain did much to popularize plate tectonics in the former Soviet Union, but it is still not generally accepted.

In the early 1970s, it was decided to compile a geologic map of the entire USSR at a scale of 1:50,000. This was to begin a new stage in the geologic study of the country and to lead to new discoveries. Maps at this scale are now available for most of the country, but most of them are simply enlarged copies of the earlier 1:200,000 maps; the hoped-for advances in geology did not occur. I believe that the reason for this lack of progress was, again,

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Dipping Reflectors *continued from p.5*

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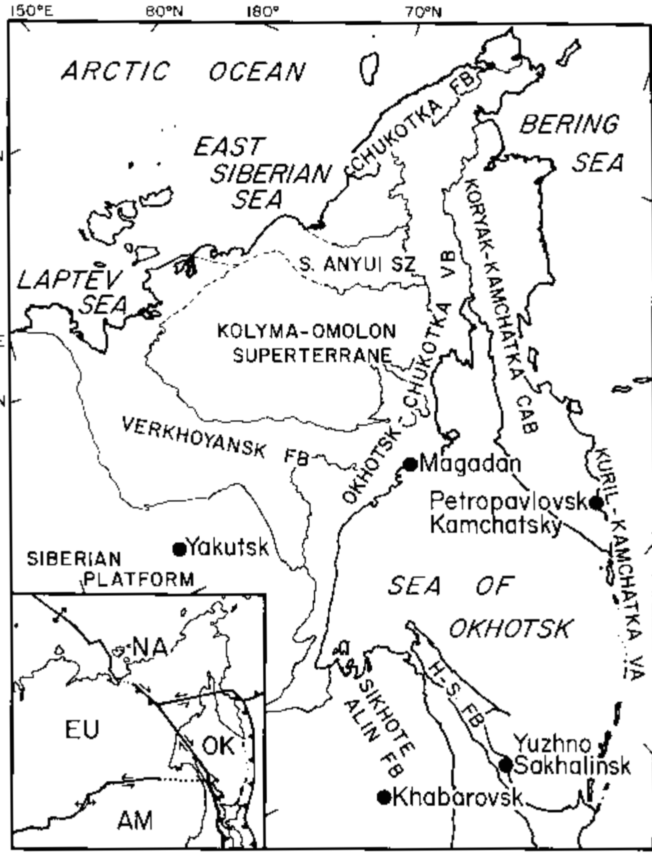

Figure 1. Regional tectonic zones of eastern Russia. FB—fold-belt (primarily Mesozoic); CAB—Cenozoic accretionary belt; VA—volcanic arc (Quaternary); SZ—suture zone (late Mesozoic); VB—volcanic belt (late Mesozoic); H-S FB—Hokkaido-Sakhalin fold belt (Mesozoic to Cenozoic). The Kolyma-Omolon superterrane consists of numerous terranes that were amalgamated and then accreted to Siberia in the Mesozoic. The inset shows present-day plate and major block boundaries: NA—North America, EU—Eurasia; OK—Okhotsk; and AM— Amur (north China). Boundaries are dotted where uncertain. The arrows show strike-slip motions; diverging arrows denote ridges; and teeth are on the upper plate of convergent boundaries. Figure by K. Fujita.

the isolation of the Russian geological community from the rest of the world. The late 1970s and 1980s were marked in the West by great advances in the study of deformation, sedimentology, isotopic dating of rocks, etc. The concept of terranes became very effective in the regional study of orogenic belts of different ages. All of these achievements remained unknown to Russian geologists, especially those who worked in the field and conducted geological surveys.

In order to improve the skill of survey geologists, so-called "geodynamic testing grounds" were set up in the 1980s in different areas of the former USSR, where new methods for geologic mapping were developed using plate tectonic concepts. Leading specialists from the Academy of Sciences contributed to this work, and attempts were made to involve foreign experts as well.

In 1990, such a testing ground was set up (on my initiative) in the Chersky Range of eastern Yakutia where a Yakutian expedition conducts geologic mapping at a scale of 1:50,000. The area is a highland, is well exposed, and has a wide variety of geologic structures. Shelf and slope deposits, mainly carbonates, of early Paleozoic age form deformed tectonic sheets which are thrust over deep-water Mesozoic clastic rocks. Ophiolites, metamorphic rocks of various ages, and Cretaceous collisional granites are also present. There are large deposits of tin and gold, as well as silver, copper, and complex and other ores. Our task is to study the focus areas thoroughly, using a combination of geological and geophysical methods, and to use it in the future as a training ground for young geologists.

At present, Russian geologists need, first and foremost, informal communication with their foreign colleagues, not at the level of high-ranking persons, but at the level of ordinary geologists involved in field work, analysis, and data acquisition. The North American Cordillera and northeast Asia represent different sectors of the same orogenic belt, and our cooperation in studying them, which was impossible until a few years ago, will undoubtedly contribute to better understanding of their structures, histories, and distribution of mineral deposits.

I know from experience that informal cooperation can yield excellent results and can benefit both Russian and American geologists. For five consecutive years, we have worked together with the Geophysical Institute of the University of Alaska on paleomagnetic, structural, and geochronological studies, and with Michigan State University on present-day tectonics and seismicity. We have also compiled a circum-Pacific terrane map with the U.S. Geological Survey which is now being used as part of the basis for a metallogenic and tectonic analysis of the territory, and new digital seismic stations are being deployed.

Russian and North American geologists can cooperate in various ways. In particular: (1) joint scientific projects involving synthesis of available data; (2) joint scientific projects involving the gathering of new geological, geophysical, and other data; this requires joint field work, mainly in Russia; (3) training of young Russian geologists at American universities and research centers.

In 1994, the Academy of Sciences of the Sakha Republic (Yakutia) was organized independently of the Russian Academy of Sciences to combine the efforts of all Yakutian scientists dealing with regional problems. Our academy includes several scientific institutes and has close contacts with Yakut State University, attended by some 7500 students. One of the main tasks of our academy is to organize direct contacts with foreign scientists, initially with those in the western United States.

A large number of geologists are affiliated with geological surveys and scientific institutes in the larger cities of Siberia and the Russian Far East, such as Magadan, Yakutsk, Petropavlovsk-Kamchatsky, Yuzhno Sakhalinsk, Khabarovsk, and Vladivostok. I meet with them often, and I find that we are all in favor of direct contacts with our American colleagues without the participation of intermediaries in Moscow. Moscow is far away from Yakutsk, about 6000 km (7 hours by air). The opening of direct flights and the development of electronic mail have made contacts between those of us in eastern Russia and the United States easier. All of us would like to enter into cooperative projects; please contact us directly! ■

Volcanoes in Kamchatka

William D. Romey, Department of Geography, St. Lawrence University, Canton, NY 13617

Eruption of Klyuchyevskoy, a 4750 m volcano on the Kamchatka peninsula, Russia, in July 1993. Note huge black plume of ash rising from the summit crater. Photo, by W. D. Romey, taken from a helicopter flying at approximately 4000 m.

In July 1993, 23 American geology teachers attended a volcanology field conference in Kamchatka, Russia, sponsored by the National Association of Geology Teachers and hosted by the Institute of Volcanic Geochemistry and Geology (IVGG) of the Russian Academy of Sciences Far Eastern Branch, headquartered in Pyetropavlovsk-Kamchatskiy (Fig. 1). Kamchatka is a 1200-km-long peninsula that juts south from near the Bering Strait, separating the Pacific Ocean from the Sea of Okhotsk (Fig. 1). Like the Aleutians and Alaska peninsula, it is a land of volcanoes—29 currently active cones and several hundred dormant or extinct ones (Fyedotov, 1991). The group visited Ksudach and Karymskiy volcanoes. Ksudach covers an area 18 by 22 km at its base, with elevation ranging from 900 to 1000 m. It consists of a large seven-part caldera complex with four principal eruptive phases ranging in age from early Pleistocene to Holocene; the last eruption occurred in 1907. Karymskiy is one of the most highly active volcanoes in Kamchatka, having erupted 21 times since 1771, the most recent eruption occurring in 1996 (January 1). Eruptions have been principally Vulcanian, with some Strombolian-Vulcanian activity (Ivanov et al., 1991; Simkin et al., 1981). The trip from Ksudach to Karymskiy (Fig. 1) a spectacular six-hour helicopter ride, took us past several active volcanoes, including 4750-m-high Klyuchyevskoy volcano. Klyuchyevskoy, the most active volcano in Kamchatka, erupted at least 70 times between 1697 and 1980 (Simkin et al., 1981), producing half of all the juvenile ejecta of the entire Kurile-Kamchatka arc (Khryenov et al., 1991). Klyuchyevskoy was erupting as the group went past. Another notable volcano, Byezymyannyy produced a little-known Mount St. Helens–size eruption on March 30, 1956, and continues to erupt one to two times per year.

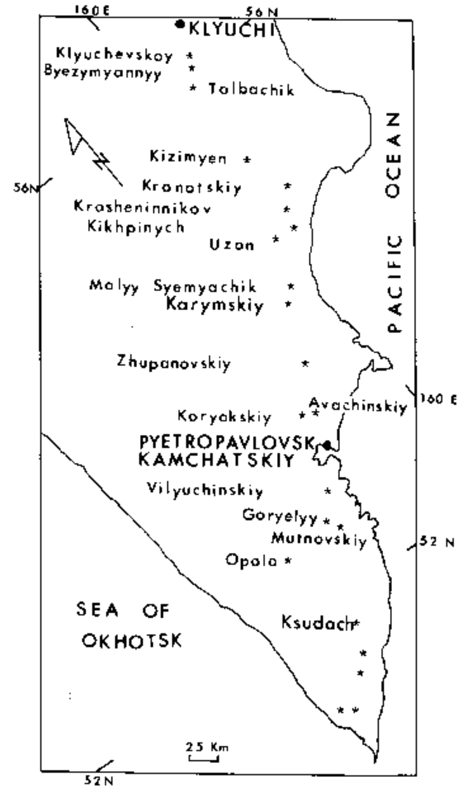

Figure 1. Locations of volcanoes (asterisks) in Kamchatka, Russia.

This was the first large group of western geologists permitted to enter this formerly closed region. A second group toured the same region in 1994. Dorothy L. Stout was the principal organizer of the trip.

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Republic of Kazakhstan: Environmental Restoration at a Nuclear Weapons Testing Complex

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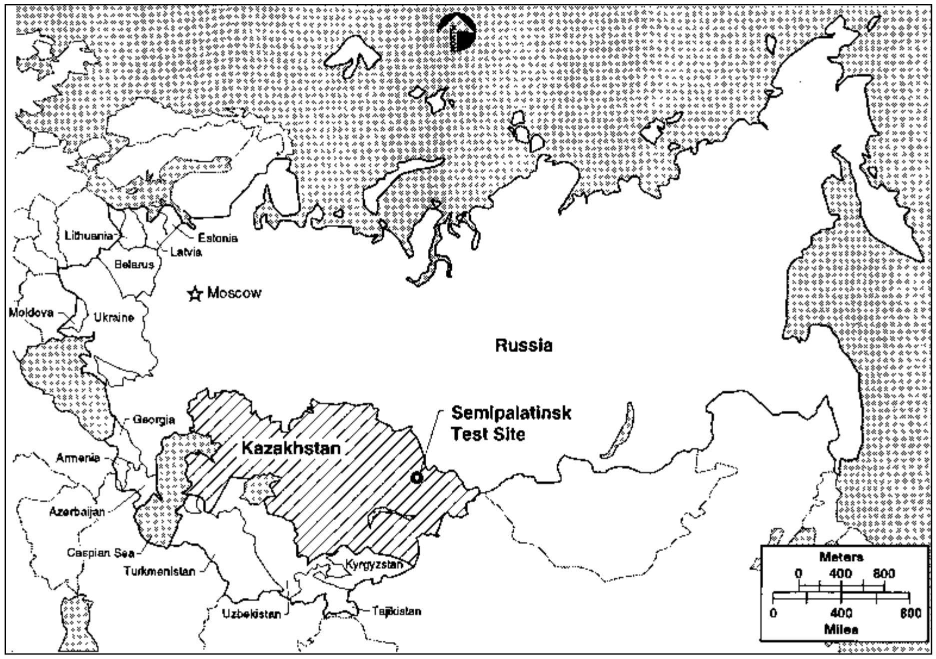

Figure 1. Location of Kazakhstan within the former Soviet Union.

Introduction

Kazakhstan, a newly established central Asian country, was one of the 15 republics of the former Soviet Union (Fig. 1). This fledgling, independent state hosts environmental problems as a result of its role supporting the former Soviet Union's military efforts and use (including mining and smelting) of its basic natural resources. Because of its remoteness and limited population, Kazakhstan was selected as a major testing ground for Soviet nuclear weapons development for more than 40 years. With the demise of the Soviet Union in December 1991, many of the ethnic Russian weapons scientists and engineers returned to Russia from Kazakhstan, leaving the state to deal with the legacy of nuclear weapons testing at the Semipalatinsk Test Site in northeast Kazakhstan. As in most, if not all, of the republics of the former Soviet Union, the transition from a controlled, Communist government to an independent democratic government with a capitalist-based economy has not been easy or straightforward. The loss of economic vitality led to a significant decrease in the standard of living for most Kazakh citizens and great pressure on the government to make progress in meeting basic needs of its citizens.

Despite this economic decline, the Kazakh people have used their new-found freedom to express their long-standing concerns about the inherent dangers and environmental consequences of the nuclear testing program. Furthermore, the government of the Republic of Kazakhstan is seeking remedies to the resultant environmental contamination. One such approach is to retrain their remaining former weapons scientists and engineers, who are now underemployed, to apply their skills to environmental restoration. This leads to a conundrum: they have identified both a need for environmental restoration and a solution (retraining of Kazakh scientists and engineers); however, the funds, technology, and associated expertise are not available within the country.

Semipalatinsk Test Site

The Semipalatinsk Test Site, the most active of the five nuclear test sites in the former Soviet Union, is located in flat, treeless terrain of the Asian steppes of northeast Kazakhstan. It lies close to the intersection of Kazakhstan, China, Mongolia, and Siberia. Kurchatov, formerly a Soviet "Secret City," occupies the northeast corner of the test site along the Irtysh River, and serves as the administrative center for the site. The site is now under the administration of the National Nuclear Center of the Republic of Kazakhstan. Covering 18,000 km^2, the test site is five times larger than the Nevada Test Site, the U.S. nuclear test site.

The first explosive test of a Soviet Union nuclear device occurred at Semipalatinsk on August 29, 1949. Between then and 1989, when testing at Semipalatinsk was curtailed, more than 450 atmospheric and underground tests were conducted. Of those tests, 124 released contamination beyond the boundaries of the test site. Ironically, because of unfavorable weather conditions on August 29, 1949, the first Soviet Union nuclear test resulted in the largest amount of offsite radioactive contamination of any test conducted at Semipalatinsk. Strontium-90, cesium-129, and plutonium have been detected in surface soil samples collected from the test site, but the extent of this contamination both on and off site, and the presence of other radionuclides, have not been determined.

Of the underground nuclear tests conducted, an undetermined number of devices were detonated below the water table. It is unclear if any analyses have been made to determine the nature and extent of ground-water contamination, but it is reasonable to expect that at least some such contamination does exist.

The climate at Semipalatinsk is semiarid, the depth to ground water is at least 70 m, and no perennial streams traverse the site. In addition, population around the site is sparse; most villages are small and support cattle and sheep grazing. As a result of these natural and demographic features, the effects of radioactive contamination are probably less than would be expected in more populous areas in wetter climates. Nevertheless, thorough investigations have not been conducted to characterize the natural geologic and hydrogeologic conditions at the site; determine the nature and extent of contamination of ground water, soil, and vegetation; predict through computer modeling the fate and transport of any contaminants; identify potential ecological receptors (human, flora, and fauna); assess potential doses received by these receptors; or calculate potential adverse health effects. Environmental assessment of the Semipalatinsk Test Site is in its infancy, lagging by far the progress that has been made in the United States to characterize the contaminant risk and assess appropriate remedial actions at the Nevada Test Site.

Kazakh scientists and engineers have sufficient desire and formal training in science and engineering to address the environmental issues at Semipalatinsk, given the opportunity to receive proper

Kazakhstan *continued on p. 10*

PEPTALK

Barbara L. Mieras
Partners for Education Program Manager

PEP Members' Call to Denver 1996

PEP, the Partners for Education Program, is growing! In 1995, we increased our membership from about 800 to over 1200 members, and new volunteers continue to lend their support every day.

We had an outstanding number of PEP members at GSA's Annual Meeting in New Orleans, and we look forward to an even greater turnout in Denver this fall. We encourage each of our members to consider submitting an abstract to one of the K–16 educational theme sessions or technical sessions or to offer assistance with a workshop, field trip, or other event for K–12 educators and scientists.

In the winter 1995–1996 issue of *PEP News,* we mentioned several volunteer opportunities for our Partners. Please remember to contact your GSA Education Committee Section Representative if you'd like to contribute to your section's K–12 educational efforts. If you need help locating those individuals, please contact us:

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Kazakhstan *continued from p. 9*

training to effect career changes as many of us in the United States have done in the past 10 years. The Kazakhs badly need an opportunity to learn the field techniques of environmental investigation and remediation. They need to spend time with American or western European environmental scientists and engineers working at contaminated sites in America or western Europe, and to host those scientists and engineers to provide training at Semipalatinsk. The primary goal of such an environmental training program would be to bring the Kazakhs current with industry standards as quickly as possible, to help them avoid the long and arduous learning process that most of us have experienced in the environmental restoration industry here in the United States. A potential beneficial consequence of this pursuit for us would be knowledge gained to better understand the health risks posed by long-term exposure to low-level radiation. By applying such knowledge, we could produce more appropriate guidelines for remediation efforts in the United States, not only for radionuclides, but for other environmental contaminants as well.

The environmental studies in Kazakhstan of which I am aware, which have been recommended or initiated by traditionally trained scientists and engineers, lack the environmental systems approach and the risk-based prioritization that has recently become common in the United States. If the Kazakhs do not have to rediscover already known technology to conduct environmental programs, perhaps they will be more successful than the United States has been in bringing sites to closure.

Conclusions

Given the potentially serious consequences of exposure to both radioactive and hazardous chemical contamination from the Semipalatinsk Test Site, and the desire expressed by the government of Kazakhstan to remedy the situation, an important question arises: What role, if any, should the United States play in this environmental issue? No organization in the United States, either governmental or private, has taken a lead role in consolidating and coordinating environmental cleanup assistance, either financial or technical, for the Kazakhs. Only individual, sporadic, and disjointed efforts have been made in the past three or four years by the Department of State, Department of Defense, and Department of Energy to assist the Kazakhs in their environmental efforts by providing limited amounts of funding, technical consultation, and field sampling. The U.S. government and private industry have nearly 20 years of invaluable experience in environmental restoration gained at facilities throughout the United States where nuclear weapons were developed and tested. By sharing this experience with the citizens of Kazakhstan, the United States could help effect a more rapid and cost-effective environmental cleanup there.

Moreover, the United States would be rewarded by its own efforts. Our environmental restoration industry stands to gain useful information about appropriate remediation strategies. Experimental methods could be tested on serious, real-world problems. The potential business ventures for U.S. environmental restoration industries could augment our economy. The rewards from long-term investment in future business in a country with abundant natural resources could offer considerable financial returns over dozens of decades.

Acknowledgments

I thank my colleagues T. R. Koncher, Rebecca Failor, Penny Webster-Scholten, and William McConachie for their constructive technical review of a draft version of the text; Kim Heyward for preparing the figure; Janet Orloff for manuscript production;. and especially Penny Webster-Scholten for her valuable assistance in all aspects of preparation of the article and for handling the innumerable logistical details of this effort. The work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract W-7405-Eng-48. ■

SAGE REMARKS

Bruce Nelson, *Department of Environmental Sciences, University of Virginia.*

Geology Evolves to Thrive at UVA

In his article in the January issue of *GSA Today,* P. Geoffrey Feiss said that leaving the petty details of academic administration to others is hazardous to the health of academic geology programs, but not every geologist can (or should) want to be a dean. My observation from 15 years of university administrative experience is that deans and vice-presidents can prune or expand resources for departmental operations, but they cannot invent vital programming, exciting instruction, or creative research activity. The faculty do this. In good institutions the academic departments must define and execute their missions creatively, if the institution is to prosper. We need good models that show how academic geology departments can evolve to succeed in the changing environment of university education.

Because the University of Virginia has been cited as a place where "geology has disappeared," let us examine that situation more closely. First, a bit of history. By late in the 1960s, it became clear here that both the geology and geography programs had reached a point where new directions were needed, if those programs were to retain a competitive role as the university moved to achieve academic excellence. The administration implemented reviews of the programs to seek future directions for them, but it was clear that strong programs already existed in other state institutions, especially in geology. In the end, two associate professors—one a geologist, the other a geographer—proposed that the two programs combine and focus on the environmental sciences. These two young faculty members perceived the new interdisciplinary trend, conceived an organized response, and convinced the dean to support it. Yes, the departments of geology and geography disappeared in 1970, but for 25 years both disciplines have prospered within the Department of Environmental Sciences!

What is meant by environmental sciences at Virginia? Our core disciplines are: geology or geosciences, ecology, hydrology, and atmospheric sciences. We offer a core course in each at the second- or third-year level, and undergraduates must include them in their majors. Afterwards, they may specialize in one core area, or they may take a variety of advanced courses and become generalists. Graduate students take at least one graduate level course in each core area, but they must achieve competence for research by specializing.

In geology, we offer some standard upper-level courses, such as in mineralogy, petrology, structure, geomorphology, and coastal processes, but the curriculum of standard courses evolves as the faculty and their interests change. When one faculty member retired, we dropped courses in paleontology and stratigraphy. These no longer seemed essential to our central purpose. Instead, we recently introduced three synthesizing courses, in earth surface processes, geochemistry, and geodynamics. We hope they will become the core of the geoscience program, in time. Our real objective is to forge linkages with other core subjects,—i.e., with hydrology, atmospheric sciences, and ecology, so that our students will become interdisciplinary in their thinking and training.

We have about 25 faculty positions, and 10 are geoscientists. Five call themselves geologists; the others identify their fields as: geochemistry, environmental chemistry, geomorphology, coastal environments, and paleoclimatology. These variants reflect the fact that the geoscientists try to bridge the gaps between geology and the other disciplines. This leads to interdisciplinary cooperation in teaching and research. We also have the resources of 14 research faculty—fully supported by grants—who enrich the overall research effort and who often serve on thesis and dissertation committees. Finally, there are joint appointments with chemistry and biology, and one of our faculty is a full-time administrator.

Virginia did rethink the way geology and geography were doing things 25 years ago, and some very hard decisions were made along the way. Is the program successful? What is the demand? How do we compare with the other sciences? Some statistics tell the tale. During the past five years we have counted an average of 230 majors and graduated an average of 77 per year (although the number of graduates has been increasing during this period). Of course, these are not all geologists—but they have all had geology courses! Many of our graduates are employed directly after graduation, a large number go to law school or to other professional programs, and about 20% pursue graduate work in one of the disciplines. Our graduate enrollment of 85 is the same as in physics, nearly 70% larger than in biology, 50% larger than in mathematics, but 18% less than in chemistry. We have produced 14–15 master's degrees and 5 doctoral degrees per year during this period. Most of these graduates have found employment in their fields. In terms of dollar support for research, we rank second or third among the departments above. This suggests that the overall quality of research in the department is competitive.

Are we viable? Yes. Are we expensive? About average. Are we expendable? Possibly, but that would be expensive to the university in terms of instructional effort and the overhead income we generate! Are we central to the university? Surely not, as long as the models of what a university should be derive from the classics.

On the other hand, in the terms Geoffrey Feiss defined, consider the following. We have popular courses and active research in "global change," marine science, environmental science, and geographic information systems—and more! We have linkages to evolutionary biology (a joint appointment with biology), and public policy (with the planning program in the School of Architecture). Our efforts at interdisciplinary instruction and research are real, and our external review committees have provided the administration with supportive reports.

Our administration has begun to recognize that the Department of Environmental Sciences is the most vital example of interdisciplinary instruction and cooperative research in the university, although this recognition develops slowly here and elsewhere! We would like to see our model of interdisciplinary instruction and research organized within a single academic unit duplicated elsewhere. But few other institutions have done so. We go unrecognized where the relative merits of disciplinary departments are discussed. Some believe that "geology has disappeared or been given the fright of its life" at the University of Virginia and that "Virginia is a very dangerous place for us to practice our profession." Au contraire! Geology has been given new life here that has sustained itself for a quarter century! Virginia is for lovers—of geology! ■

CORRECTION

Dinofest International, to be held April 18–21, 1996, will be at Arizona State University in Tempe, NOT at the University of Arizona. The event is mentioned in the March issue of *GSA Today* on p. 38 and p. 44.

FORUM

Bruce F. Molnia

Forum is a regular feature of *GSA Today* in which many sides of an issue or question of interest to the geological community are explored. Selection of future Forum topics and participants is the responsibility of the Forum Editor. Suggestions for future Forum topics are welcome and should be sent to: Bruce F. Molnia, Forum Editor, U.S. Geological Survey, 917 National Center, Reston, VA 22092, (703) 648-4120, fax 703-648-4227, E-mail: bmolnia@usgs.gov.

Politics and Economics: Geological Research Bridging the Gulf—The Near-Term Future—Part 2

This Forum attempts to examine how geology fits into the larger fabric of society, especially in light of recent societal changes. The interconnections between the geosciences and current political, economic, and environmental movements is analyzed in light of anticipated changes in the business market and education. Last month, Forum presented the first half of this topic, which is drawn from the Institute for Environmental Education Annual Forum at the GSA Annual Meeting in New Orleans. This month, we present three additional perspectives on the subject.

PERSPECTIVE 4:
Changes in Federal Government Agencies—Implications for Academics and Industry

Gordon Eaton,
Director, U.S. Geological Survey, Reston, VA

Introduction

New thinking in Washington and across the country is having a profound impact on future directions and support for science in our nation. The actions now being taken, which include abolishing the Congressional Office of Technology Assessment and the U.S. Bureau of Mines, modifying the former Soil Conservation Service, and cutting spending on fossil energy in the Department of Energy, will affect us well into the 21st century.

These actions reflect societal changes over the past few years, including:

- the end of the Cold War,
- the desire of the nation to reduce significantly the federal budget deficit,
- the actions of the Administration to reinvent our federal government,
- the actions of the 104th Congress to reduce substantially the size of the federal government, and
- the identification of a host of national challenges, such as crime, welfare reform, racism, and economic competitiveness, that do not call directly upon science for their solution.

In order to continue the quest for scientific excellence and minimize the negative impacts of these profound changes, scientists and scientific establishments must regroup. We must seize the initiative to demonstrate clearly the value of science to society. We have taken the Congress and the tax-paying public they represent for granted, for too long, resting smugly on our accomplishments and our laurels.

To regain the initiative, scientists must demonstrate this relevance to societal issues by producing outcomes that address the nation's most pressing needs. We must explain the benefits of science in language that all can comprehend, and we must cease our ineffectual habit of talking exclusively to our fellow scientists. We must define and focus our work, while being ever more creative with the diminishing resources at our disposal. Science can and should address key societal problems more effectively than ever before—while simultaneously pushing back the frontiers of fundamental understanding.

As federal science agencies respond to the new order in Washington, we must vigorously embrace the changes and see them as an opportunity, not merely as the reduction or destruction of long-established institutions. We must move forward rapidly and aggressively, influencing and setting national policy and seeking new ways to address critical societal issues. To do this effectively, we must: demonstrate our relevance to the solving of societal problems; plan for a prolonged period of limited financial and human resources; and develop innovative relations with the public, the wider academic community, and industry.

Virtually all federal scientific agencies will be smaller in the coming years. They will also be more sharply focused on key mission goals, establishing new priorities and new paradigms that should ultimately strengthen our nation's scientific endeavors.

The Need for Demonstrable Relevance

One of the most consistent themes in Washington over the past three years has been the admonition to balance basic and applied research so as to demonstrate clear relevance to national issues. The social environment that supports science has changed fundamentally from that described 50 years ago by Vannevar Bush in his report *Science, the Endless Frontier.* We no longer can expect the public to support scientific endeavors simply because one or more of the results might possibly be beneficial to society in the long term, if they will only keep the faith. We—and I mean all of us, practicing scientists, as well as managers and administrators—must show the public that their hard-earned dollars are being used to address issues that mean something to them. Our anecdotal list of specific contributions that science has made to the common good since 1940 has begun to wear a bit thin.

The public has come to realize that a lot of the work funded through their tax dollars during the past 50 years did not, in fact, provide much in the way of direct or demonstrable societal benefits, although clearly much did. In the earth sciences this new focus means practical efforts, for example, to protect the public from the effects of geologic and hydrologic hazards such as coastal erosion, earthquakes, floods, volcanic eruptions, and landslides. We need to assure the public that adequate clean water will be available for a growing population. We need to continue activities, such as our participation in the Federal Geographic Data Committee, to facilitate rapid access to all geographically referenced data sets, in the private sector as well as in the government.

Just how we communicate the results of our research to our clients and customers—the public and the Congress—is as important today as the results themselves. Most of this nation's citizens are not scientifically educated or inclined. We must greatly improve our efforts to educate the public about the need to understand Earth processes. And they need to know why they need to know. To achieve this goal, we must produce many more nontechnical publications than we have in the past—publications that are understandable to the lay public and are formatted in a manner that meets the customers' expectations and needs. Our methods of disseminating information must change, too. In the USGS, the EarthFax fax-on-demand system and our home page on the Internet are two of the nontraditional ways we have adopted to get our work to the audiences that can use it. CD-ROMs are a growing part of our publications program, as well.

Implications of Change for Academics and Industry

One way in which federal science agencies can become more relevant is by

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developing more interdisciplinary studies involving nontraditional colleagues. As our ability to hire and retain a large permanent staff is significantly constrained by limited resources, we will have to make greater use of the university community to accomplish our mission. We will need to form stronger internal and external partnerships in all that we do: partnerships with universities, with other government agencies (federal, state, and local), and with the private sector.

By forming partnerships, such agencies can avoid tying up scarce resources in the salaries of permanent staff, and they will be able to work with their partners to leverage both financial and human resources to produce outcomes that neither party, acting independently, could produce. Such partnerships allow for the flexibility needed to respond to changing national needs and priorities and to adopt new disciplines and new technologies.

To facilitate opportunities with industry, the USGS has formed a Business Enterprise Council, which seeks to work ethically and productively with industry to identify potential industry client groups and to develop and promote bureau partnerships with industry. Through mechanisms such as Cooperative Research and Development Agreements (CRADAs), we at the USGS can export our scientific expertise while taking advantage of the production and marketing abilities of the private sector. CRADAs are becoming increasingly important in transferring technology via licensing agreements for both domestic and international applications.

Looking Ahead

Federal science agencies face an uncertain future. At first, and even second, glance, the requirement for societal relevance in our work and the prospect of continued downsizing seem to limit what we can do. Yet the need for sound earth-science information is growing, as the world's population increases and the demand for water and minerals and safe places to live expands. The only way to meet this increasing need in the face of our diminishing resources is to reach outward, to develop partnerships with other agencies in federal, state, and local government, with academia, and with industry. If we use our partnerships to leverage our investment of people and money, both our science and our society will reap the ultimate benefits.

PERSPECTIVE 5:

From Site Investigations to Site Remediation: Implications for Hydrogeology

John A. Cherry,
University of Waterloo, Ontario, Canada

The modern commercial era of hydrogeology, which is founded on problems of contamination by industrial chemicals, began in 1980 with the passage of the first Superfund legislation and implementation of the Resource Conservation and Recovery Act (RCRA). For many years thereafter the number of practicing hydrogeologists and monitoring wells increased rapidly. The number of hydrogeologists in North America rose from about 2000 in 1975 to more than 20,000 in 1995, most of the growth occurring in the 1980s. In the Superfund and RCRA process and equivalent state programs, site investigations normally take many years or even a decade to complete for each site. It has been necessary to investigate extensively and according to prescribed procedures and methods the nature and extent of contamination before major decisions on remediation are made. The hydrogeology profession owes most of its growth to the demands of the site investigation process, and also to the regulation-bound and litigation-driven inefficiencies, inherent in the process, that have made the investigations take much longer and cost much more than warranted by scientific and technical factors.

For the first time in two decades, there is major uncertainty regarding the long-term employment trend in hydrogeology and the role that hydrogeologists will play in the field of ground water. Growth in the profession has ended, perhaps temporarily, and shrinkage may occur for a few years. On one side it is argued that the era in which the hydrogeologist was an important player in contaminated site investigations and remediation is over, as the emphasis switches from standard site investigations to routine site-remediation engineering that may be executed with minimal geologic insight. Defenders of hydrogeology argue that even more hydrogeologic insight will be needed in the future because most industrial sites where ground-water contamination occurs have not yet been investigated in any detail and because possibilities for success in remediation at nearly all sites depend on recognition of the influences of and limitations imposed by complexities caused by geologic factors. The future

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About People

GSA Fellow **Fred A. Donath**, San Clemente, California, recently received the University of Minnesota Outstanding Achievement Award; he was the founding director of the GSA Institute for Environmental Education, and he and his wife, Mavis, established the GSA Young Scientist Award.

Fellow **R. Michael Easton**, Ontario Geological Survey, has been elected chair of the North American Commission on Stratigraphic Nomenclature for 1995-1996.

The Archaeological Institute of America has presented its Pomerance Science Award to GSA Fellow **Norman Herz**, University of Georgia, Athens, for his work in determining sources of marble in ancient statuary and buildings.

Fellow **Naresh Kumar**, Richardson, Texas, has founded Growth Oil and Gas Company, an exploration and consulting firm; he is also a vice-president of Axis Resources, Inc.

Member **George Lindahl III**, Fort Worth, Texas, has been appointed executive vice- president, Operations, for Union Pacific Resources Company.

Member **Jereld E. McQueen**, Kingwood, Texas, has established McQueen & McQueen, an energy advisory and management firm.

Texas Tech University has honored GSA Fellow **Grover E. Murray**, Lubbock, Texas, by establishing the Grover E. Murray Distinguished Professorship at its Health Sciences Center; Murray is a former Texas Tech president and Health Sciences Center president.

Fellow **James A. Peterson**, University of Montana (Missoula) and U.S. Geological Survey, received the University of Minnesota's Outstanding Achievement Award recently, for his research in petroleum resource assessment and disposal of high-level nuclear waste.

Fellow **William A. S. Sarjeant**, University of Saskatchewan, has been elected to fellowship in the Royal Society of Canada.

Fellow **Daniel J. Stanley**, U.S. National Museum of Natural History, Smithsonian Institution, Washington, D.C., has been named an honorary professor by the East China Normal University in Shanghai.

Fellow **Robert C. Whisonant**, Radford University, has been elected chair of the Virginia Board for Geology; the board regulates the practice of geology in the state.

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of hydrogeology will depend to a major degree on how the hydrogeology profession responds to this new situation.

The rapid growth in the 1980s of investigations in ground-water contamination was unanticipated by academia and the ground-water profession. Therefore, many of the professionals in this field have little specialized education for this work, because university programs took many years to adapt to the new demand and because employment opportunities were so plentiful that specialized education or experience was not a prerequisite for employment. The profession of ground-water scientists and engineers is populated mostly by persons educated initially in geology or civil engineering; only a small minority comes from other educational disciplines such as biology and chemistry. Few undergraduate programs in geoscience or engineering have provided training specific to ground-water environments.

The ground-water profession has been the source of employment for most geologists entering professional ranks since the early 1980s when the petroleum and mining industries began downsizing. Even with graduate degrees, many—if not most—of the geoscientists working in the ground-water field are deficient in some of the quantitative and formal problem-solving training that engineers have received, and many engineers are commonly deficient in knowledge of geologic environments, especially insight relating to the nature, causes, and implications of subsurface complexity and heterogeneity. Each of these disciplines is generally sparse in education that prepares ground-water professionals for interpreting subsurface data in situations where the interpretation must integrate information from geology, geophysics, inorganic and organic geochemistry, and subsurface flow of multiple phases (gas, water, and immiscible organic liquids). The common approach in the ground-water profession is to attempt to accomplish the task of data interpretation by using a team of specialists, each of which knows much about one type of data (such as geology or geophysics or organic geochemistry) and little about the other data types. Although at first glance this would seem to be a logical approach, it is akin to assembling a team of medical specialists to examine an ill patient without benefit of involvement of an experienced general practitioner, or other persons particularly capable in the area of general diagnostics. The formulation of site-specific conceptual models for complex situations (nearly all contaminated industrial sites are relatively complex) depends on the successful integration of diverse types of information and effective hypothesis testing. One of the reasons site investigations have been excessively expensive and have taken so long is that the integrative and hypothesis testing steps have often confounded the teams of investigative specialists in which no one person sees clearly the "big picture" all the way from site conditions to remediations. When confusion strikes, the team resorts to acquiring more data, often not the critical data needed for hypothesis testing and conceptual modeling. Of course, persons with specialist knowledge are essential in the site investigation-remediation field, but their value is greatly diminished when the experienced generalist is absent.

One of the advantages that should be expected from a geoscience approach is use of the method of multiple working hypotheses, with ultimate selection of the preferred hypothesis by elimination of other hypotheses through interpretations of diverse and complex data sets. This approach has been the foundation of the observational approach in the geological sciences for more than a century, but it is generally underused and often ignored in contaminated site investigations. Thus, hydrologists are presented with much opportunity, if they can fully use and demonstrate the advantage of this approach.

Many options are becoming available for site remediation; however, selection of the most appropriate option should depend on the form and clarity of the conceptual model for the site. The design and intensity of the remediation effort should be reassessed as the initial performance is evaluated and the conceptual model refined. At many sites, the initial performance is a test of the site hypotheses, because much uncertainty in site conditions normally exists even after appropriate site investigations. Much of this uncertainty is usually due to geologic factors that cause complexity in contaminant distributions and in the flow paths of water, air, or heat used in the remediation.

Investigations of contaminated sites were rather chaotic in the first half of the 1980s as the growing profession scrambled to adjust to the unprecedented demands. Deficiencies in quality assurance and quality control were severe in the early years, resulting in the imposition by regulatory agencies and by litigation needs of standardized, conventional methods for nearly all subsurface data acquisition and for remediation. Excessive regulation resulted in minimal innovation in the 1980s. After a period of dependence on conventional drilling and use of standard monitoring wells for site investigations, the 1990s have seen rapid introduction of many new subsurface investigation technologies.

Many new types of downhole probes and sampling tools that do not require a well have been developed. Also, whereas vapor extraction for remediating soil and pump-and-treat for aquifers were the remediation methods of choice at nearly all significant remediation sites in the 1980s, many new in-situ remediation technologies have emerged for consideration in the 1990s. Although these new technologies will eventually produce more effective remediation at some sites, their existence greatly complicated professional practice. Many questions regarding the amount and type of subsurface information needed to properly select a remedial technology are difficult to answer because of the paucity of real world experience with these technologies.

The profession is moving rapidly from an era when much of the subsurface information at contaminated industrial sites was acquired regardless of whether it was essential for risk assessment, or for selection of remediation technology, to an era where there is little tolerance for the acquisition of data that will probably not have direct bearing on risk or remediation decisions. The new challenge is not just to acquire high-quality data but to acquire high-quality data that are necessary to a streamlined and cost-conscious decision-making process. Thus, geoscientists must be knowledgeable not only about the geoscience aspects of the site problems but also about the factors and processes critical to risk assessments and remediation engineering.

At most contaminated sites, geologic features or complexities such as faults, fractures, permeable channels, or low-permeability stagnant zones determine the critical subsurface contaminant pathways to receptors and also govern remediation performance. Thus, the hydrogeologic components of the problem are key elements around which much of the decision-making process should revolve. Accommodation to this reality has been slow at the administrative levels in government or executive levels in industry, where the important decisions are made.

Progress in this current decade will depend on how the hydrogeologic profession performs scientifically and technically and how it exerts influence in the decision-making process. Possibilities for the hydrogeology profession to perform well will be strongly dependent on the response of universities to the need for broadening curricula and modernizing of course content and to the continuing-education offerings of universities, professional societies, and many other organizations. Progress will also depend on the production of advance knowledge, which must come primarily from research. At this time, when the need is greatest, the belief at the political level that research provides useful dividends is faltering, and, as a consequence, research funding is decreasing. Doing more with less is the current challenge. Ultimately, the performance of hydrogeologists and other professionals in the ground-water field will be judged by the long-term benefits to the environment and to human health of the remedial actions undertaken at the thousands of contaminated sites across the continent.

PERSPECTIVE 6:
Universities: Confronting the Challenge of Change

Franklin W. Schwartz,
Department of Geological Sciences,
Ohio State University, Columbus, OH

Geoscience departments must face challenges as they confront the changes that are rocking academe. Driving these changes are fundamental, and probably permanent, shifts in the "academic" paradigm that governs the ebb and flow of academic life, teaching and research, and the historical relationship between geoscience departments and federal granting agencies. In an instructive book, *Paradigms—The Business of Discovering the Future,* published in 1993 (Harper Collins Publishers Inc.), Joel Barker defines a paradigm as "the set of rules or regulations … that establishes or defines boundaries, and tells us how to behave within these boundaries to succeed." This definition is not the typical usage of the term, but it provides an interesting vantage point to view life in universities.

Most readers will have already been affected by change in the academic paradigm in one form or another. It used to be that graduating doctoral students in virtually all specialties could expect to find a university position where they could begin to establish a research program, and to embark on an interesting and active research career. External funding was more or less a given, along with a corps of enthusiastic graduate students, who themselves went off to join the system. Now, however, things are different. There is little prospect of students finding an academic position in many geologic specialties. Those that join universities often find it harder than ever to begin a conventional academic career. Much more emphasis is being placed on the quality (and quantity) of teaching. Further, it is becoming increasingly difficult to fund research and to attract graduate students.

For those already established in universities, the waning interest in some specialties, along with departmental downsizing, means that teaching duties are shifting toward high-enrollment introductory courses.

A number of factors have contributed to the deterioration of academic life. The most important is a lack of employment prospects for geoscience graduates, which has had a substantial impact on student numbers, particularly in traditional areas of geology. The petroleum industry continues to downsize in a manner that one colleague has described as "corporate anorexia." The opportunities for employment are limited in the minerals industry and soft in the environmentally related areas. Making matters worse is a substantial reduction in the government research enterprise (e.g., U.S. Geological Survey, Department of Energy, and our national laboratories). Try as one might, it is not possible for a department to prosper over the long term without students.

Another factor limiting the opportunities for geoscience departments has been what D. I. Goodstein, in his 1995 article "After the Big Crunch," published by the Woodrow Wilson International Center for Scholars in *The Wilson Quarterly,* considers as natural limits to growth. He argues that exponential growth in science perhaps can be maintained for limited periods, but eventually expansion must stop—his so-called "big crunch." He concludes that physics stopped growing in the early 1970s. Geoscience growth, at least in most traditional areas, probably stopped about the same time. When a field stops growing, professors need to replicate themselves only once in an academic career to maintain the supply of appropriately educated individuals in doctoral-level research institutions. This desperate employment situation cannot be called upon to sustain the hopes and dreams of graduate students. Goodstein argues that to a significant extent, physics professors have ignored this problem of employment opportunities by creating new but temporary postdoctoral opportunities and by relying on foreign students, many of whom will return to their home countries. I would add that the situation within the geosciences seems very similar.

Confronted by dwindling university budgets, an increasingly competitive environment for research funding, and waning student interest in many specialties, departments are examining the possibilities for change. This process of reflection and renewal is especially difficult in universities because of a predilection to "paradigm paralysis" and a consensual management style with little individual accountability.

Barker has defined paradigm paralysis as "a terminal disease of certainty." Paradigm paralysis explains why some individuals will cling forever to the model of geological education that brought them success and power.

Once this kind of paradigm is in place, "any suggested alternative has to be wrong." Barker's logic explains, for example, why a faculty member may have been content to sit for more than a decade wait-

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ing for "the oil patch to come back," or even to deny the existence of fundamental problems in employment and research opportunities.

In all too many cases, a lack of understanding of the scope of change contributes to simplistic remedies to problems. In departments, feeble steps forward (or occasionally in other directions)—such as changing the department name, adding a hydrogeologist, including an environmentally oriented course in the undergraduate program, and so on—are often perceived by faculty to be revolutionary in scope. Popular articles muse on more general solutions, such as limiting the number of postgraduate students (most effectively applied to departments other than one's own), programs to offer dual master's degrees (designed to provide students with a greater scientific repertoire), or changing employment expectations for Ph.D.s (put your Ph.D. to work in sales!). The reality is that there will be no easy, across-the-board fix for the problems ailing the geosciences.

Here are my views on the direction of change in the academic game. Universities are being dragged, kicking and screaming, to the realization that their main raison d'être is education. Professors are or will be held to increasing standards of quality, innovation, and productivity in teaching with the integration of new technologies. The research mission of many universities will continue, except that research opportunities will decline along with the reduction in funding sources. It is likely that an increasing share of research dollars will come from industry and other nontraditional sources. For this reason, there will be an increasing proportion of what can be viewed as applied science. Many departments will become polarized in their distribution of graduate students and resources.

My advice would be not to underestimate the severity of the present problems in the earth sciences. Weak departments, specialties, and faculty will wither in the face of others who can adapt to changing times. As has always been the case, success in an academic sense will continue to be governed by the survival of the fittest. Now, however, with the present academic climate, success will come to fewer individuals. As a consequence, one should be willing to consider radical changes that are appropriate to one's time and place. The starting point would be an objective self-assessment, individually and collectively. A straightforward initial step would be to make many small improvements in teaching and research activities. The more difficult step to improve the competitiveness of individual programs will require rethinking of directions, retraining, or even more revolutionary changes. Such changes might include some emphasis on competency-based learning and a concerted effort to win back traditional "turf" that is being ceded to departments in agriculture, engineering, and urban and regional planning.

For individual faculty, one hallmark of success will be the unequivocal demonstration of viable and innovative educational opportunities for students at the graduate level. As in all tough fights, there will be casualties. For faculty unwilling to understand the issues at stake or to improve their academic performance, their most important contribution will be to retire.

An initial first step for departments would be to concentrate on substantive improvements in teaching, to coordinate and to improve the delivery of academic services, and to accept opportunities for innovation. Departments will compete with other departments and universities mostly on the quality of their educational offerings, and to a lesser extent on student numbers. Thus, one important measure of quality of an institution will lie in its ability to maintain robust and energetic programs at the graduate and undergraduate level. The old medicine and warmed-over solutions from the 1970s and 1980s are not likely to be strong enough to shake the malaise that has afflicted many of our number. ■

CALL FOR NOMINATIONS

To reward and encourage **teaching excellence** in beginning professors of earth science at the college level, the Geological Society of America announces:

THE FIFTH ANNUAL Biggs Award

For Excellence In Earth Science Teaching For Beginning Professors

ELIGIBILITY: All earth science instructors and faculty at 2- and 4-year colleges who have been teaching full time for 10 years or less. (Part-time teaching is not counted in the 10 years.)

AWARD AMOUNT: An award of $500 is made possible as a result of support from the Donald and Carolyn Biggs Fund.

NOMINATION PROCEDURE: For nomination forms write to Edward E. Geary, Coordinator for Educational Programs, Geological Society of America, P.O. Box 9140, Boulder, CO 80301.

DEADLINE: Nominations and support materials for the 1996 Biggs Earth Science Teaching Award must be **received by June 30, 1996.**

EARTH SYSTEM SUMMIT

Denver

Geological Society of America

1996 Annual Meeting

Denver, Colorado • October 28–31

Sunset at the Great Sand Dunes National Monument, Colorado. Photo by John Karachewski.

- **Abstracts:** Due July 9
  For a paper copy of the abstract form, E-mail: ncarlson@geosociety.org
  For the electronic form, http://www.geosociety.org
- **Preregistration:** Due September 20
- **Information:** (303) 447-2020 or 1-800-472-1988; fax 303-447-0648
  E-mail: meetings@geosociety.org
  World Wide Web: http://www.geosociety.org
- **Registration and Full Details:** June issue of *GSA Today*

Call For Papers

Theme Statement for the 1996 Annual Meeting

The scientific theme for the 1996 Annual Meeting in the mile-high city of Denver is *Earth System Summit.* As with previous themes for annual meetings, this one can be interpreted in several ways. We particularly wish to emphasize that Earth is a complete system whose processes are complexly interrelated at a variety of scales. In addition, the theme emphasizes that we are all inhabitants of this complex system; our actions can significantly impact, or be impacted by, its dynamic behavior. Of course, we can view the gathering of scientists and engineers of the Society, GSA divisions, and the associated societies as an intellectual summit focusing on the Earth System. Finally, the theme emphasizes our connection with the rugged peaks of the nearby Rocky Mountains.

—1996 Annual Meeting Committee

Associated Societies

Association for Women Geoscientists • Association of Engineering Geologists • Association of American State Geologists • Association of Geoscientists for International Development • Cushman Foundation • Geochemical Society • Geoscience Information Society • Mineralogical Society of America • National Association for Black Geologists and Geophysicists • National Association of Geoscience Teachers • National Earth Science Teachers Association • Paleontological Research Institution • Paleontological Society • Sigma Gamma Epsilon • Society of Economic Geologists • Society of Vertebrate Paleontology

Co-sponsors

Colorado Scientific Society • Rocky Mountain Association of Geologists

Daily technical session schedule appears: September issue of* GSA Today *and on the World Wide Web: http//www. geosociety.org

If you are not a GSA member, please call, fax, or write us, and we will gladly send you the schedule after September 1.

GSA's Institute for Environmental Education

IEE's fifth Annual Environmental Forum, entitled Prospects for the Future: Gold and Water in the Earth System, will be held on Sunday, October 27. Gold and water—the most valuable natural resources in the American West—are intimately connected in the Earth System through the human activity of mining, which creates economic benefit while putting stress on water resources, and raises complex and difficult questions about how society can meet short-term economic objectives without sacrificing long-term resource needs. This IEE Forum will investigate connections between gold and water that range from the geochemical and hydrological effects of gold mining on surface and ground water, to the political and technical challenges of balancing economic incentives and environmental protection, to the geopolitical dynamics that shape the mining industry in the international marketplace. Geology is a common thread in all of these issues, and society will continue to depend upon geologists for the exploitation, protection, and remediation of natural resources in the Earth system.

In addition to this Forum, IEE will sponsor or cosponsor several symposia and theme sessions in the technical program, as indicated on the following pages .

Joint Technical Program Committee: August 9–10

The JTPC selects abstracts and determines the final session schedule. Speakers will be notified by August 24. This should be much sooner for abstracts submitted electronically. The JTPC consists of representatives from each of the associated societies and GSA divisions participating in the technical program. The JTPC chairs, nominated by the Denver Annual Meeting Committee and approved by the GSA Council, also serve a four-year term on GSA's ongoing Program Committee, which oversees all technical program activities.

NEW FOR '96—Submit Abstracts via the WWWeb

Starting on or about May 1, abstracts for this year's Annual Meeting in Denver can be sent to GSA via the World Wide Web (Web). At that time, our new electronic system for abstract submission will be available, to be used at first for Annual Meeting abstracts only. In development for more than a year, the system has been tested extensively. Note that you can send abstracts to GSA only via the Web. They may ***not*** be sent by ordinary E-mail.

For the present, this system will accept only abstracts containing pure ASCII content; no graphics, tables, symbols, Greek, superscripts, etc. may be included. If you must use any of that in your abstract, use the paper form for now. We hope to be able to include non-ASCII material in the future, but for most users the technology for that is not yet in place.

However, if your entire content—title, addresses, and abstract body—is pure ASCII and you have access to the Web, the new system will make life much easier by eliminating the more onerous tasks usually connected with preparation of paper forms: scrambling for blank forms; printing and reprinting, then cutting and pasting to fit boxes; making multiple copies to send; and often paying a heavy toll for express-service delivery to meet the deadline.

We recommend that you compose your abstract in your favorite word processor. When you have finished, "save" it as "text." This will convert your data into pure ASCII. Then copy and paste this into the appropriate fields of the GSA Web form. Complete the personal information on the form, and you'll be ready to send it. We've included instructions, pull-down lists, and helpful hints on the Web form to save you time and confusion. There's even an error checker to make certain you include all the information we must have.

The best part is that it takes only a few seconds to send an abstract, and even less to get feedback from GSA. There will be no more mystery about whether we received your submission. You'll receive an *immediate* confirmation of receipt from GSA, with an abstract number assigned, while you're still on the Web.

The new system will not yet replace the familiar paper version of GSA's abstract form. Rather, the two systems will operate in parallel for another year, or until it is clear that most authors prefer the electronic method. Paper forms already have been distributed for 1996, and still can be obtained from GSA's Abstracts Coordinator (E-mail: ncarlson@geosociety.org).

About March 1, you will be able to test our new system, strictly on a "get acquainted" basis. *Nothing* you send via this form before May 1 will be saved at GSA or considered by GSA for any meeting. Although you will receive an acknowledgment of receipt on any test abstracts you send, that is just part of the test, too, and is meaningless.

To get acquainted with the form from March 1 to May 1, go to GSA's Home Page on the Web (http://www.geosociety.org). There you'll find the link, "TEST DRIVE GSA's Web Abstract Form." Just follow the instructions from there. If you discover any glitches in our system during a test, please send a detailed E-mail message to: pubs@geosociety.org. Please include your telephone number so we can call if more details are needed.

On or about May 1, the TEST DRIVE link will change to "SUBMIT an Abstract." When you see that message, you'll know we're in live mode, ready to take your abstract for Denver.

The success of this new system will determine whether, and how soon, it may be used for meetings of GSA Sections, as well. Watch this publication for further announcements.

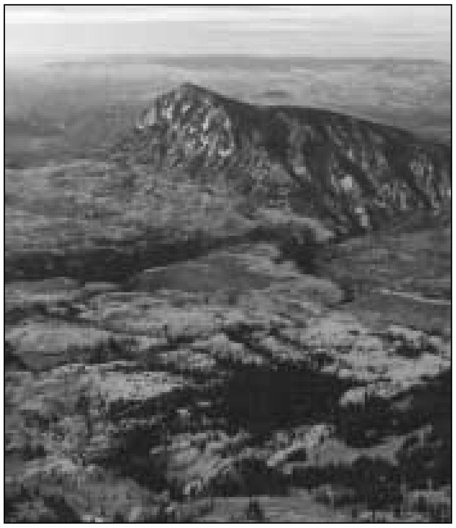
OR—Use Paper Abstract Forms Available From:

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

Please submit only one copy of your abstract — either electronic or paper.

Only ONE Volunteered Abstract May Be Submitted

Please submit only one volunteered abstract as *speaker or poster presenter* in discipline and/or theme sessions. Multiple submissions as speaker-presenter may result in rejection of ***all*** abstracts. Note that this limitation does not apply to, nor does it include, invited contributions to symposia.



Marcellena Mountain. Photo by Kenneth Kolm.

Abstract Submittal Guidelines

Abstract Deadline: July 9

Presentation Modes

Oral Mode—This is a verbal presentation before a seated audience. The normal length of an oral presentation is 15 minutes, including time for discussion. Projection equipment consists of two 35 mm projectors, one overhead projector, and two screens. Requests for video projection and computer display will be addressed on a case-by-case basis.

Poster Mode—*New format:* each poster session speaker is provided with ***two*** horizontal, free-standing display boards approximately 8' wide and 4' high. Precise measurements will appear in the Speaker Kit. The speaker must be present for at least two of the four presentation hours.

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

Symposia (Invited Papers)

NEW for 1996. **All invited abstracts (electronic and paper) are to be sent to GSA. The abstracts will be forwarded by GSA to the conveners for review.**

S1. **GSA Keynote Symposium: Linkages Among Dynamic Processes of Oceans, Continents, and Atmosphere.** *1996 GSA Annual Meeting Committee.* E-an Zen and Karen Prestegaard, University of Maryland.

Global events that result from coupled oceanic, atmospheric, and terrestrial processes are found in different types of stratigraphic records. For the recent past, we can examine ice cores, deep and shallow marine cores, soils, and other land records. For most of Earth's history, however, the preserved record is mainly shallow marine sedimentary rocks. What tools, individually and collectively, are available to study these linked processes, and how does the choice of tools bias our view of the record? The symposium aims to survey the tools, models, and interpretations, and bring them to bear on the nature of the dynamic linkages, thereby to stimulate questions and help to predict areas of future excitement.

S2. **Geologic Development of the Southern Rocky Mountains.** *1996 GSA Annual Meeting Committee.* Eric Nelson, Colorado School of Mines.

S3. **Dinosaurs, Asteroids, Spotted Owls and Humanity: An Evolving View of Ecosystems and the Role of Science in Their Management.** *1996 GSA Annual Meeting Committee and Institute for Environmental Education.* Cathleen L. May, U.S. Department of Agriculture, Forest Service, Denver; Kenneth Kolm, Colorado School of Mines.

S4. **Earth System Processes at the Last Glacial Maximum.** *1996 GSA Annual Meeting Committee.* Robert S. Webb, National Oceanic and Atmospheric Administration, Boulder; Benjamin Felzer, National Center for Atmospheric Research, Boulder.

S5. **Dimensional Scaling and the Stratigraphic Record of Episodic and Periodic Forcing.** *Sedimentary Geology Division.* Carl N. Drummond, Indiana University/Purdue University, Fort Wayne; Bruce H. Wilkinson, University of Michigan.

S6. **Interdisciplinary Strategies for Teaching About Earth as a System.** *Geoscience Education Division.* Ellen Metzger, San Jose State University.

S7. **Coalbed Methane—From Micropore to Pipeline.** *Coal Geology Division.* James R. Staub, Southern Illinois University at Carbondale; Thomas Demchuk, Amoco Exploration and Production Technology, Houston, Texas.

S8. **The Geoarchaeology of Caves and Cave Sediments.** *Archaeological Geology Division.* E. James Dixon, Denver Museum of Natural History.

S9. **IEE Annual Environmental Forum: Prospects for the Future: Gold and Water in the Earth System.** *Institute for Environmental Education.* Daniel Sarewitz, Geological Society of America.

S10. **Earth Systems Education: K–16.** *National Earth Science Teachers Association.* Victor J. Mayer and Rosanne W. Fortner, Ohio State University.

S11. **Recent Advances in Plate Tectonics—What Students Should Know.** *National Association of Geoscience Teachers.* Barbara Tewksbury, Hamilton College.

S12. **Geochemical Constraints on Seawater Composition and the Coupled Ocean-Atmosphere System: The Precambrian Revisited.** *Geochemical Society.* Timothy W. Lyons, University of Missouri; Tracy D. Frank, University of Michigan.

S13. **Organic Geochemistry—Linking the Biosphere and Geosphere.** *Organic Geochemistry Division of the Geochemical Society.* Keith A. Kvenvolden, U.S. Geological Survey, Menlo Park; Michael D. Lewan, U.S. Geological Survey, Denver; Joseph A. Curiale, Unocal Corporation, Sugarland, Texas.

S14. **Engineering Geology Applications of Geologic Maps.** *Engineering Geology Division.* Helen Delano, Pennsylvania Geological Survey.

S15. **Farvolden Hydrogeology Symposium.** *Hydrogeology Division.* John A. Cherry, University of Waterloo.

S16. **Perspectives on Soil-Based Information for Investigating Earth Surface Processes.** *Quaternary Geology and Geomorphology Division.* Eric V. McDonald, Los Alamos National Laboratory; Bruce Harrison, New Mexico Institute of Mining and Technology; Les McFadden, University of New Mexico.

S17. **Planets as Complex Systems.** *Planetary Geology Division.* James R. Zimbelman, Center for Earth and Planetary Studies, National Air and Space Museum, Washington, D.C.

S18. **Expanding Boundaries: Geoscience Information for Earth System Science.** *Geoscience Information Society.* Barbara DeFelice, Dartmouth College; Barbara Haner, University of California, Los Angeles.

S19. **Seismic Investigations Along the Western Margin and Cordillera of North America: Tectonic Implications.** *Geophysics Division.* G. Randy Keller, University of Texas at El Paso; Alan Levander, Rice University.

S20. **Active Tectonics of Intracontinental Mountain Belts with Implications for Ancient Systems.** *Structural Geology and Tectonics Division.* Michael Hamburger, Indiana University; Richard Allmendinger, Cornell University; Terry Pavlis, University of New Orleans.

S21. **Sigma Gamma Epsilon Student Research.** *Sigma Gamma Epsilon.* Charles J. Mankin, Oklahoma Geological Survey; James C. Walters, University of Northern Iowa. POSTER.

S22. **Alteration Geochemistry: Genetic and Exploration Perspectives.** *Society of Economic Geologists.* Terry Cookro, PCI, Inc., Denver, Colorado.

S23. **Geoscience Information for Tomorrow's Markets: What Is Wrong with the Present Products.** *Institute for Environmental Education, International Division,* and *Commission on the Management and Application of Geoscience Information.* A. Keith Turner, Colorado School of Mines.

S24. **Tectonic Evolution of the Urals and Surrounding Basins.** *International Division.* James H. Knapp, Institute for Study of the Continents, Cornell University.

S25. **Earth Science–Environmental Justice Summit.** *GSA Committee on Public Policy, Institute for Environmental Education, GSA Committee on Minorities and Women in the Geosciences,* and *National Association for Black Geologists and Geophysicists.* Wes Ward, U.S. Geological Survey, Flagstaff; Daniel Sarewitz, Geological Society of America.

S26. **Environmental Mineralogy: Science and Politics.** *Mineralogical Society of America* and *Clay Minerals Society.* George D. Guthrie and David L. Bish, Los Alamos National Laboratory.

S27. **The Role of Preferential Flow in the Unsaturated Zone.** *Hydrogeology Division.* Scott W. Tyler, Desert Research Institute, University of Nevada, Reno; Bridget R. Scanlon, University of Texas at Austin.

S28. **Biology of the Foraminiferida: Applications in Paleoceanography, Paleobiology, and the Environmental Sciences.** *Cushman Foundation.* Susan T. Goldstein, University of Georgia; Joan Bernhard, Wadsworth Center Labs & Research, Albany, New York.

S29. **Evolutionary Paleoecology.** *Paleontological Society.* Warren Allmon, Paleontological Research Institution, Ithaca, New York; David Bottjer, University of Southern California.

Kite Lake, Mosquito Range, Colorado. Photo by John Karachewski.

S30. **Impact of the Western Surveys.** *History of Geology Division.* William R. Brice, University of Pittsburgh at Johnstown.

S31. **Applications of Reactive Transport Modeling to Natural Systems.** *Mineralogical Society of America.* Carl I. Steefel, University of South Florida; Peter C. Lichtner, Southwestern Research Institute, San Antonio, Texas; Eric H. Oelkers, Université Paul Sabatier, Toulouse, France.

Volunteered Papers

Discipline Sessions

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

Theme Sessions

Papers are submitted to a specific *pre-announced* title and to ONE scientific category. Theme sessions are interdisciplinary; each theme may have as many as three categories from which authors may choose ONE. After each theme description below, the categories are identified by name and number as they appear on the 1996 Abstract Form. PLEASE SUBMIT ONLY IN THE MODE INDICATED in the description (oral or poster). An abstract submitted in the incorrect mode will be transferred automatically to a discipline session.

Theme submissions must include: *(Example)*

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

Role of theme advocate

Each theme session has been proposed by an advocate. *Advocates may not invite speakers; however, they may encourage colleagues to submit abstracts, with the understanding that there is no guarantee of acceptance. JTPC* representatives, in consultation with the theme advocates, will organize theme sessions by August 10.

Theme Topics

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

T1. **The U.S. Atlantic Passive Margin: Tectonics, Eustasy, and Sedimentation—A Memorial to James Patrick Owens.** *Sedimentary Geology Division.* Kenneth G. Miller, Rutgers University; Frank J. Pazzaglia, University of New Mexico.

James Patrick Owens was a pioneer in understanding the effects of tectonics, eustasy, and sediment supply as recorded in the Coastal Plain stratigraphy of the U.S. Atlantic passive margin, where the complex interactions among subtle tectonics, flexural isostasy, climate change, eustasy, and sedimentation are slowly being unraveled. This memorial session will integrate geomorphic, stratigraphic, sedimentologic, geophysical, geochemical, paleontologic, palynologic, and quaternary geochronologic studies of the best understood passive margins. ORAL and POSTER.

Marine Geology (14), Quaternary Geology/ Geomorphology (26), Sediments, Clastic (29).

T2. **History of the Equatorial Atlantic.** Mary Anne Holmes, University of Nebraska; Francisca Oboh, University of Missouri, Rolla.

The central equatorial Atlantic has been a critical region of the world's oceanic system since its opening in the mid-Cretaceous as a series of transform basins. This session will include results from Ocean Drilling Program Leg 159 at the Côte d'Ivoire and Ghana margin, as well as related studies from both conjugate margins and the ocean system. POSTER.

Marine Geology (14), Paleoceanography/Paleoclimatology (17), Tectonics (32).

T3. **High-Resolution Glacial Records from Marine and Lacustrine Basins.** *Quaternary Geology and Geomorphology Division.* Ellen A. Cowan, Appalachian State University; James P. M. Syvitski, Institute for Alpine and Arctic Research, University of Colorado, Boulder.

The history of glaciated continents is preserved in the sedimentary record of ocean basins and high-latitude lakes. This record, interpreted from cores and acoustic surveys, can be used to infer basin climatology and hydrology and the extent of glacial cover on scales from one to thousands of years. These case studies provide the necessary linkage to develop models that better describe the Earth's glacial systems. ORAL.

Paleoceanography/Paleoclimatology (17), Quaternary Geology/Geomorphology (26), Sediments, Clastic (29).

T4. **Application of Soil-Based Information for Understanding Earth Surface Processes.** *Quaternary Geology and Geomorphology Division* and *Institute for Environmental Eductaion.* Eric McDonald, Los Alamos National Lab; Bruce Harrison, New Mexico Institute of Mining and Technology; Les McFadden, University of New Mexico.

Soil-based information is being increasingly applied to a variety of issues in the Earth sciences. We seek papers that utilize soil information to address issues ranging from soil-water interactions to processes involving entire landscapes. Possible subjects include stable isotopes, micromorphology, surface hydrology, hillslope processes, climate change, neotectonics, environmental geology, remote sensing. ORAL.

Environmental Geology (6), Paleoceanography/Paleoclimatology (17), Quaternary Geology/Geomorphology (26).

T5. **Cretaceous of the Western Interior Seaway, North America.** Paul R. Krutak, Fort Hays State University; Michael Arthur, Pennsylvania State University, University Park.

Cretaceous rocks of the Interior Seaway of North America furnish models for eustatically generated cyclic sedimentation and provide superb examples of sequence and seismic stratigraphy. We solicit stratigraphic and facies studies that illustrate the accumulation of commercial hydrocarbons and coals in these rocks, as well as papers concerning evolution of their biotas. ORAL.

Coal Geology (2), Petroleum Geology (19), Stratigraphy (30).

T6. **The Rockies Across the Southern Border.** José F. Longoría, Florida International University; Dante Moran-Zenteno, Universidad Nacional Autónoma de México; Rogelio Monreal, Universidad de Sonora.

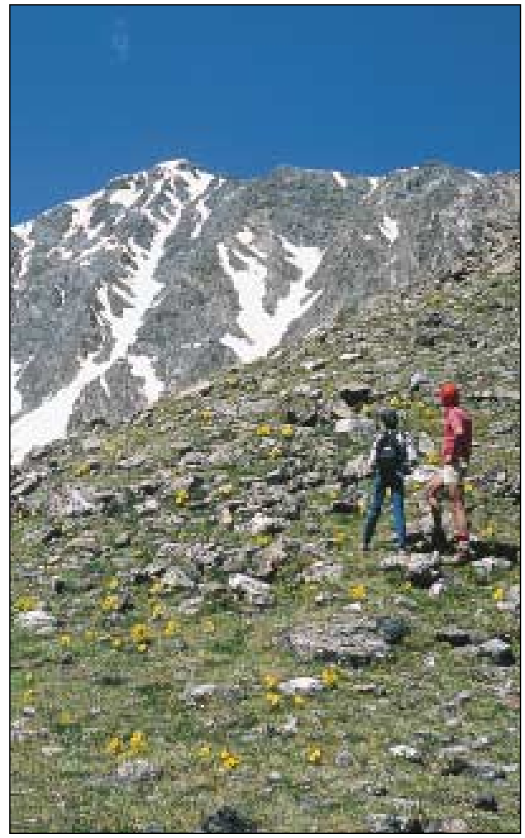
A multidisciplinary session of talks related to the geology of the "Mexican Rockies." Participants from both sides of the border will have an opportunity to present their results on problems related to the stratigraphy, paleontology, tectonics, and paleogeographic development of the Rocky Mountains south of the border. ORAL.

Paleontology/Paleobotany (18), Stratigraphy (30), Tectonics (32).

T7. **Paleozoic and Mesozoic Tectonic History of Central Asia.** Marc S. Hendrix, University of Montana; David B. Rowley, University of Chicago.

Much of the Asian continent was assembled during the Paleozoic and Mesozoic Eras. The record of this tectonic amalgamation is complicated by multiple phases of deformation. This session will provide an opportunity for geoscientists with a variety of specialties to address the Paleozoic and Mesozoic tectonic history of central Asia. ORAL.

Stratigraphy (30), Structural Geology (31), Tectonics (32).



Courtesy of Denver Metro Convention and Visitors Bureau.

T8. **Tectonic Evolution of the Urals and Surrounding Basins.** *International Division.* James H. Knapp, Cornell University.

The Ural orogen of central Russia, tectonic boundary of Europe and Asia, is the only intact example of a major continental collision of Paleozoic age. Rich in mineral resources, and associated with several of the world's largest oil and gas basins, the Urals are a world-class target, both scientifically and economically. POSTER.

Geophysics/Tectonophysics (10), Petroleum Geology (19), Tectonics (32).

T9. **Neotectonics of the Northern Caribbean Plate-Boundary Zone.** William R. McCann, Consultant, Broomfield, Colorado.

The Caribbean and North American plates are separated by a 2000-km-long, 200-km-wide zone of deformation. Understanding the neotectonics, dynamics, and kinematics of that zone are key to understanding the neotectonics and recent development of the Caribbean plate. ORAL.

Geophysics/Tectonophysics (10), Marine Geology (14), Tectonics (32).

T10. **Appalachian and Cordilleran Melanges: Comparisons and Contrasts.** *Northeastern, Southeastern, and Cordilleran Sections of GSA.* Stephen Pollock, University of Southern Maine.

Melanges of diverse origins and histories are significant components of both the Appalachian and Cordilleran orogens. This session will compare, contrast, and discuss recent advances as they pertain to the understanding of the origin, structural history, sedimentology and petrology of melanges from eastern and western North America. ORAL.

Sediments, Clastic (29), Structural Geology (31), Tectonics (32).

T11. **Laramide Sedimentation and Tectonics in the Rocky Mountains.** Eric A. Erslev, Colorado State University; Romeo M. Flores, U.S. Geological Survey, Denver.

Integration of sedimentologic and structural observations provide important keys to the Laramide evolution of basement-involved structures in the Rocky Mountains. Studies of synorogenic strata, palynology, and provenance combined with the delineation of basin geometries and deformation patterns promise to unravel the timing and paleogeography of the Laramide orogen. ORAL.

Sediments, Clastic (29), Structural Geology (31), Tectonics (32).

T12. **History of Recurrent Basement Faulting in Cratonic North America and Its Orogenic Margins.** Christopher Schmidt, Western Michigan University; Donald S. Stone, Consultant, Littleton, Colorado; William A. Thomas, University of Kentucky.

This session will address the role of recurrent movement on old basement faults in the tectonic evolution of the North American craton and the bordering Appalachian-Ouachita and Cordilleran–Rocky Mountain orogenic belts. Particularly encouraged are abstracts that describe previously unpublished work, synthesize the recurrent fault activity of large regions or major fault systems, or apply new research methods (particularly geophysical) or a variety of old methods to the task of identifying recurrently active basement faults. ORAL and POSTER.

Geophysics/Tectonophysics (10), Structural Geology (31), Tectonics (32).

T13. **Geologic and Hydrologic Studies of Fluid Flow in Faults.** Gary G. Gray, Exxon Production Research Company, Houston, Texas.

This theme session will present a range of studies that focus on evidence for the interaction between fluids and faults through time, and at different scales of investigation. Brittle faulting within the upper few kilometers is the primary focus. Contributions are invited on topics as diverse as petroleum exploration, water resources, waste disposal, and earthquake triggering mechanisms. ORAL.

Hydrogeology (13), Petroleum Geology (19), Structural Geology (31).

T14. **Evolution of the Neogene Strain Field in the Southeastern Great Basin: Roles of Faults, Folds, and Magmatism.** Robert B. Scott and Ernie Anderson, U.S. Geological Survey, Denver.

Neogene deformation and magmatism in the southeastern Great Basin produced an extraordinarily complex strain field, including extensional and other types of faulting, diverse fold orientation and style, and magmatic doming and related collapse and slide structures. This session encompasses these topics, as well as papers that elucidate three-dimensional aspects of the strain field and its temporal evolution. ORAL and POSTER.

Structural Geology (31), Tectonics (32), Volcanology (33).

T15. **Neogene and Quaternary Geology of the Yucca Mountain Region, Nevada, and Its Relevance to Long-Term Nuclear Waste Isolation.** *Institute for Environmental Education.* Dennis O'Leary and John W. Whitney, U.S. Geological Survey, Denver.

Yucca Mountain is a potential nuclear waste repository site. Studies of the mountain and its geologic setting pertaining to waste isolation include topics in tectonics, seismicity, volcanism, geochronology, structure, stratigraphy, hydrology, and geomorphology. This session will summarize results of multidisciplinary research and its relevance to environmental hazard and geologic synthesis. ORAL.

Geophysics/Tectonophysics (10), Quaternary Geology/Geomorphology (26), Structural Geology (31).

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

T16. **Seismic Investigations Along the Western Margin and Cordillera of North America: Data and Earth Models.** *Geophysics Division.* Gary Fuis, U.S. Geological Survey, Menlo Park; Ron Clowes, University of British Columbia.

In the past decade, U.S. and Canadian scientists have undertaken ambitious seismic investigations that have provided high-resolution images of the lithosphere for all of the strike-slip and subduction boundaries from southern California to the Aleutians. This theme session, coordinated with symposium S19, highlights the data sets and Earth models resulting from these investigations. POSTER.

Geophysics/Tectonophysics (10), Tectonics (32).

T17. **Cenozoic Uplift of the Western United States.** *Geophysics Division.* Paul Morgan, Northern Arizona University; Clement Chase, University of Arizona.

Most of the western United States is significantly uplifted—typical province mean elevations are about 1.75 km or higher. The region was last at or near sea level in pre-Laramide time, but the timing, modes, and mechanisms of uplift of different provinces in this region are problematical. Contributions are invited on all aspects of western U.S. uplift. ORAL.

Geophysics/Tectonophysics (10), Quaternary Geology/Geomorphology (26), Tectonics (32).

T18. **Precambrian Lithosphere I: Proterozoic Tectonics—Modification of Archean Cratons and Additions of Juvenile Crust.** Kevin Chamberlain and B. Ron Frost, University of Wyoming.

This session will feature comparison of Proterozoic belts that remobilize Archean terranes, such as the Trans-Hudson, Aldan, and southern Wyoming provinces, with Proterozoic accreted terranes, such as the Yavapai and Mazatzal in the southwestern United States. Papers concerned with such topics as the evolution of Proterozoic lithosphere, tectonics, isotopic evolution of continental crust, and petrogenesis are encouraged. ORAL.

Geochemistry, Other (8), Precambrian Geology (24), Tectonics (31).

T19. **Precambrian Lithosphere II: Mid-Proterozoic Magmatism and Tectonics of Western North America.** Carol Frost, University of Wyoming; Matt Nyman, University of New Mexico.

Western North America includes significant volumes of mid-Proterozoic igneous rocks, including the "anorogenic" granites of the southwestern and mid-continent United States, anorthosite complexes, and basaltic magmatism in the Belt Supergroup and elsewhere. This session will explore both the igneous rocks produced and the tectonic environment in which they formed. ORAL.

Petrology, Igneous (21), Precambrian Geology (24), Tectonics (32).

T20. **Precambrian Lithosphere III: Middle Crustal Processes.** Karl E. Karlstrom, University of New Mexico; Michael Williams, University of Massachusetts.

Photo by Bill Cronin.

The Rocky Mountain region provides an unparalleled field laboratory for understanding middle crustal orogenic processes. Exposed rocks record tectonism that took place at depths of 10–20 km in the crust. This session will concentrate on the interactions of deformation, metamorphism, and plutonism during tectonism, with examples from Precambrian as well as younger orogens. ORAL.

Precambrian Geology (24), Structural Geology (31), Tectonics (32).

T21. **Volcanism, Tectonism, and Sedimentation in the Rio Grande Rift and Its Margins in New Mexico and Colorado.** David Sawyer and Ren Thompson, U.S. Geological Survey, Denver; Scott Baldridge, Los Alamos National Laboratory.

This session will address evolution of the Rio Grande Rift in New Mexico and Colorado during the past 30 m.y. Suggested topics include seismological, petrologic-geochemical, geochronologic, and paleomagnetic evidence for active volcanism and tectonism; rift basin sedimentology, stratigraphy, and hydrogeology; geophysical expression of rift basins; and coeval rift-margin volcanism (e.g., San Juan volcanic field). ORAL and POSTER.

Sediments, Clastic (29), Tectonics (32), Volcanology (33).

T22. **Magma Generation and Evolution at Convergent Margins.** Robert J. Stern, University of Texas at Dallas; Mark Feigenson, Rutgers University.

Our understanding of igneous activity at convergent margins impacts a wide range of scientific questions and societal issues. This theme session is intended for those interested in discussing how magmas are generated in and above subduction zones, how these melts ascend and interact with the mantle and crust, and how they fractionate. Emphasis will be on understanding processes, rates, and budgets of magma evolution. ORAL.

Geochemistry, Other (8), Petrology, Igneous (21), Volcanology (33).

T23. **High and Ultrahigh Strain Rate Processes in the Earth and Planetary Sciences.** John Spray, University of New Brunswick.

The aim is to assemble scientists from diverse backgrounds who share an interest in working on geologically short-lived, high-energy processes in the fields of (1) impact geology (shock metamorphism and shock melting), (2) friction melting and coseismically generated fault rocks, (3) caldera development (catastrophic volcanic activity), and (4) landslides (especially large, high-energy examples). ORAL.

Planetary Geology (23), Structural Geology (31), Volcanology (33).

Precambrian gneiss. Photo by John Karachewski.

T24. **Mapping Other Worlds.** *Planetary Geology Division.* James R. Zimbelman, Center for Earth and Planetary Studies, National Air and Space Museum, Washington, D.C.

Maps represent our primary source for documenting the spatial relation between terrains, whether on Earth or other planets. Geologic, tectonic, and geomorphic maps of the planets, along with newly explored places on Earth, are encouraged. The synergy of displaying these maps together should provide for lively discussion. POSTER.

Planetary Geology (23), Quaternary Geology/Geomorphology (26), Stratigraphy (30).

T25. **Jupiter: Solar System Exploration Continues.** *Planetary Geology Division.* Larry Crumpler and James W. Head, Brown University.

The Galileo spacecraft is now making new observations of discovery in the system of satellites about Jupiter. This session will draw together new studies of the Galilean satellites and will present some preliminary findings from new observations by the Galileo spacecraft. ORAL.

Planetary Geology (23), Quaternary Geology/Geomorphology (26), Remote Sensing (27).

T26. **Application of Reactive Transport Modeling to Natural Systems.** *Mineralogical Society of America.* Carl I. Steefel, University of South Florida; Peter C. Lichtner, Southwest Research Institute, San Antonio, Texas; Eric H. Oelkers, Université Paul Sabatier, Toulouse, France.

This theme session, held in conjunction with an MSA short course, will examine how coupled geochemical and biogeochemical reaction-transport models can be used to interpret complex phenomena occurring in natural environments. Contributions are welcomed from researchers investigating such processes as the transport and containment of toxic wastes, diagenesis of sediments, the migration of petroleum, metasomatism in metamorphic environments, chemical weathering, and hydrothermal ore deposits. ORAL.

Geochemistry, Aqueous/Organic (7), Hydrogeology (13), Mineralogy/Crystallography (16).

T27. **Mineralogy of Planetary Surfaces Using In-Situ Analysis and Remote Sensing.** *Mineralogical Society of America* and *Planetary Division.* Bradley L. Jolliff, Washington University.

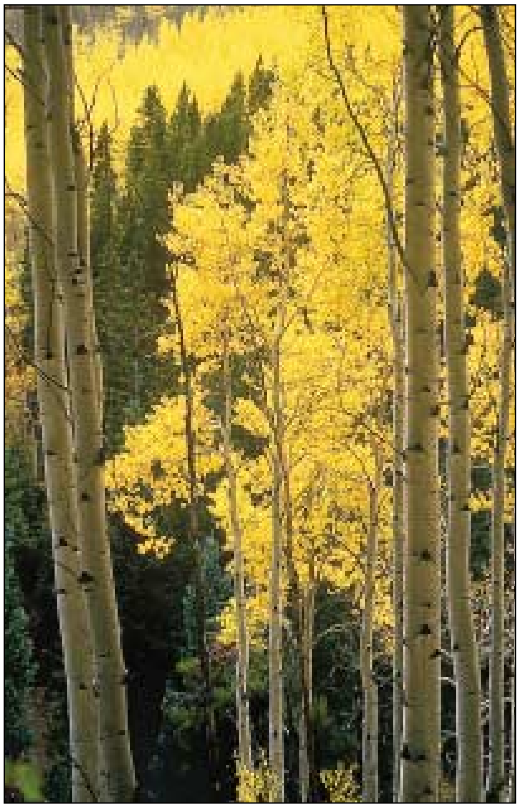
This session will focus on applications of current and developing technologies for automated mineralogical investigations of planetary surfaces, emphasizing Moon, Mars, and Earth. We will consider a broad range of applications such as (but not limited to) reflectance, vibrational, and Mossbauer spectroscopies; X-ray methods; thermal analyzers; and resulting petrologic investigations. ORAL.

Photo by Bill Cronin.

Mineralogy/Crystallography (16), Planetary Geology (23), Remote Sensing (27).

T28. **Environmental Mineralogy.** *Mineralogical Society of America* and *Clay Minerals Society.* George D. Guthrie and David L. Bish, Los Alamos National Laboratory.

This session will address mineralogical aspects of a variety of environmental



Golden aspen, Vail, Colorado. Photo by John Karachewski.

problems. Subject areas range from the health effects of minerals, to mine tailings and wastes, to mineralogical solutions to environmental problems. This is a follow-on to an MSA symposium on environmental mineralogy. ORAL.

Environmental Geology (6), Geochemistry, Aqueous/Organic (7), Mineralogy/Crystallography (16).

T29. **Hydrogeology of Confining Units I: Sampling, Analysis, and Interpretation.** *Hydrogeology Division* and *Society for Sedimentary Geology.* Paul A. Thayer, University of North Carolina, Wilmington; Mary K. Harris, Westinghouse Savannah River Co., Aiken, South Carolina.

This session will focus on water and sediment sampling techniques and analytical methods for studying the samples. It will address how this information can be applied along with sedimentology to the formulation of comprehensive, multiple-unit hydrogeological models. ORAL.

Computers (3), Hydrogeology (13), Sediments, Clastic (29).

T30. **Hydrogeology of Confining Units II: Physical and Biogeochemical Processes.** *Hydrogeology Division* and *Society for Sedimentary Geology.* William W. Simpkins, Iowa State University; C. Kent Keller, Washington State University.

Despite their crucial role in the protection and storage of water resources, fine-grained sediment units and their distinctive physical and biogeochemical environments remain a frontier area for hydrogeological research. This session will present research into basic processes, including topics such as aquitard hydraulics and mechanics, fracture and multiphase flow and transport, diffuse transport, and biogeochemistry. ORAL.

Geochemistry, Aqueous/Organic (7), Hydrogeology (13), Quaternary Geology/Geomorphology (26).

T31. **Field-Scale Investigations of Biodegradation.** *Hydrogeology Division.* Hedeff Essaid, U.S. Geological Survey, Menlo Park; Isabelle Cozzarelli, U.S. Geological Survey, Reston.

Many toxic contaminants commonly found in the subsurface can be degraded by microorganisms. A thorough understanding of field-scale processes in natural and altered environments is necessary for the successful development and implementation of bioremediation technologies. This session will focus on field-scale biodegradation processes and rate estimates, their relation to laboratory-scale processes and rates, and mass-balance estimates of contaminant removal at field sites. ORAL and POSTER.

Environmental Geology (6), Geochemistry, Aqueous/Organic (7), Hydrogeology (13).

T32. **Scale Effects of Fluid Flow and Fractures.** Randall Marrett, University of Texas, Austin.

Fracture-associated fluid flow is important in many contexts, including hydrocarbon recovery, waste management, ground-water flow, and hydrothermal mineralization. Quantitative studies of fracture attributes and fluid flow over a wide range of scales will be the focus of this session, which will highlight the scaling of and the relations between fractures and fluid flow. ORAL.

Hydrogeology (13), Petroleum Geology (19), Structural Geology (31).

T33. **Geofluids: The Role of Fluids in Crustal Processes.** Mark Person, New Mexico Institute of Mining and Technology; Emi Ito, University of Minnesota.

Fluid circulation, composition, interaction, and history are of fundamental importance in understanding dynamic processes of Earth's crustal system as diverse as the evolution of mid-ocean ridges, basin formation, collision tectonics, climate change, ocean history, paleolimnology, and sediment transport. ORAL and POSTER.

Geochemistry, Aqueous/Organic (7), Hydrogeology (13), Sediments, Clastic (29).

T34. **Applications of Isotopes for Understanding Hydrologic Systems.** *Hydrogeology Division.* James M. Thomas, U.S. Geological Survey, Carson City, Nevada; John Hess, Desert Research Institute, Las Vegas.

Isotopes can be extremely powerful tools for understanding how the forces that drive hydrologic systems work. Many different isotopes have been used in different combinations for a variety of hydrologic purposes. This session aims to bring together different and innovative studies that explore new and established isotope applications in the hydrologic sciences. ORAL.

Environmental Geology (6), Geochemistry, Aqueous/Organic (7), Hydrogeology (13).

T35. **High Plains Hydrogeology.** *Hydrogeology Division.* Alan E. Fryar, University of Kentucky; Allan R. Dutton, University of Texas at Austin.

This session is intended to integrate hydrologic and geologic studies of the High Plains. Suggested topics include ground-water recharge and vadose-zone hydrology; flow and chemical evolution in regional aquifers; paleoclimate; hydrostratigraphy; surface-water hydrology; landform and soil development; agricultural impacts on water resources; and case studies of contamination and ground-water depletion. ORAL.

Hydrogeology (13), Quaternary Geology/Geomorphology (26), Sediments, Clastic (29).

T36. **Physical and Chemical Heterogeneity: Impact on Reactive Transport.** *Hydrogeology Division.* Janet S. Herman, University of Virginia; John L. Wilson, New Mexico Institute of Mining and Technology.

Concern about quality of water resources and the influence of environmental contamination and remediation motivates our need to better understand how potential contaminants are transported in ground-water systems. This session will focus on how characterization of physical and chemical heterogeneities in aquifers yields insight into migration of solutes, inorganic colloids, and microorganisms in ground water. ORAL.

Geochemistry, Aqueous/Organic (7), Hydrogeology (13).

T37. **Innovations and Applications of Inverse Ground-water Models.** *Hydrogeology Division.* Eileen Poeter, Colorado School of Mines; Mary Hill, U.S. Geological Survey, Denver.

Inverse models help take full advantage of the insight available from ground-water models through calculated sensitivities and statistics such as correlation between estimated parameters. This session focuses on applications demonstrating the value of using inverse models, and new approaches and techniques that advance the area of inverse modeling. ORAL.

Computers (3), Hydrogeology (13).

T38. **Evaporite Karst: Origins, Processes, Landforms, Examples, and Impacts.** *Hydrogeology Division* and *Engineering Geology Division.* Kenneth S. Johnson, Oklahoma Geological Survey; James T. Neal, Sandia National Laboratory.

Evaporite rocks, such as gypsum and halite, are highly soluble and can be dissolved rapidly to form karstic features similar to those in carbonate rocks. This session will deal with the origins, processes, landforms, examples, and impacts of natural and human-induced evaporite karst. ORAL.

Engineering Geology (5), Environmental Geology (6), Hydrogeology (13).

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

T39. **The Death Valley Hydrogeologic System.** Frank A. D'Agnese and Claudia C. Faunt, U.S. Geological Survey, Denver; A. Keith Turner, Colorado School of Mines.

The Death Valley hydrogeologic system reflects some of the most complex geologic, hydrologic, and ecologic features within North America. Numerous multidisciplinary approaches have described and quantified this system's resources. Investigators involved in stratigraphic, structural, hydrogeological, hydrogeochemical, geomorphological, and Quaternary studies in the Death Valley region are encouraged to participate. ORAL.

Environmental Geology (6), Hydrogeology (13), Quaternary Geology/Geomorphology (26).

T40. **Physical and Chemical Heterogeneity: Impact on Samples and Measurements at Wells.** *Hydrogeology Division.* Thomas E. Reilly, U.S. Geological Survey, Reston; Dennis R. LeBlanc, U.S. Geological Survey, Marlborough, Massachusetts.

Wells provide access to the subsurface to allow observations on the occurrence and movement of water and solutes in ground water and the unsaturated zone. The heterogeneous nature of the deposits and solute distributions affect these observations. Researchers will explain their techniques in measuring this heterogeneity and assessing its effect on observations made at wells. ORAL.

Geochemistry, Aqueous/Organic (7), Geophysics/Tectonophysics (10), Hydrogeology (13).

T41. **Diagenetic Processes at Waste-Disposal Sites.** *Hydrogeology Division.* Peter J. Hutchinson, University of Pittsburgh.

Municipal solid waste is subjected to biogeochemical and settling processes in a waste-disposal facility. Alteration of the waste mass and adjacent soils after disposal may be analogous to certain geologic processes. The purpose of this session is to explore taphonomic modifications to the waste mass and diagenesis of adjacent materials. ORAL.

Geochemistry, Aqueous/Organic (7), Hydrogeology (13), Sediments, Clastic (29).

T42. **Global Impacts of Mining and Urbanization on Fluvial and Coastal Systems.** *Institute for Environmental Education.* Robert A. Morton, University of Texas, Austin; Waite R. Osterkamp, U.S. Geological Survey, Tucson, Arizona.

Extraction and emplacement of surficial materials are modifying geomorphic processes and landscapes worldwide. These activities translocate sediments and associated chemical contaminants, alter channels, and increase flooding and erosion. Case studies and models are needed to describe and forecast the impacts of material distributed relative to industrial expansion and population growth. ORAL.

Environmental Geology (6), Public Policy (25), Sediments, Clastic (29).

T43. **Environmental Geology: The Voice of Reason.** *Institute for Environmental Education.* Paul R. Pinet, Colgate University; Daniel Sarewitz, Geological Society of America.

Geoscientists understand the complex underpinnings of Earth systems from both a short- and long-term perspective. This unique outlook is vital for informing nonscientists about the political, economic, and ethical implications of environmental policies. This session will explore how geologists can apprise others of the social ramifications of their research findings. ORAL.

Environmental Geology (6), Geology Education (9), Public Policy (25).

T44. **Clean-up at Rocky Flats, a Former Nuclear Weapons Plant: Application of Science to Site Remediation Plans.** *Institute for Environmental Education.* Barry Roberts, Rocky Flats Environmental Technology Site; Daniel Sarewitz, Geological Society of America.

Scientific characterization of the Rocky Flats site has been going on for more than 20 years, in disciplines ranging from geohydrology and geochemistry to soil ecology, radioecology, and epidemiology. This session explores how current knowledge about the unique combination of environmental problems, ranging from plutonium in surficial soils to organic solvents in the subsurface at Rocky Flats, can be applied to future clean-up efforts at the site. ORAL.

Engineering Geology (5), Environmental Geology (6), Public Policy (25).

T45. **Integrated Site Characterization for Waste Disposal.** *Institute for Environmental Education.* Daniel J. Soeder, U.S. Geological Survey, Las Vegas; Richard Quittmeyer, Woodward Clyde Federal Services, Las Vegas, Nevada.

Understanding the geology of potential hazardous waste disposal sites is critically important for accurate hydrologic models of ground-water flow, and hydrologic studies are needed for determining the geochemical transport paths of haz-

Roxborough Park. Photo by Kenneth Kolm.

ardous materials. The integration of multidisciplinary studies is a requirement for the proper characterization and performance assessment of any site being considered for the long-term storage of hazardous chemical or radioactive waste. ORAL.

Environmental Geology (6), Hydrogeology (13), Public Policy (25).

Spelunker, Fulford Cave, White River National Forest, Colorado. Photo by John Karachewski.

T46. **Interpretation of Continental Sedimentation Patterns Using Surface and Subsurface Data.** Debra Hanneman, Whitehall Geogroup, Inc., Whitehall, Montana; Charles J. Wideman, Montana Tech of the University of Montana.

The geological interpretation of continental sedimentation patterns is best accomplished by integrating surface and subsurface data. This session will focus on the integration of surface and subsurface continental-sedimentaion data sets collected by means of various geological and geophysical techniques and the interpretation of these data sets. ORAL.

Environmental Geology (6), Geophysics/Tectonophysics (10), Stratigraphy (30).

T47. **The Impact of Geologic Heterogeneities on Characterization, Transport, and Remediation of Non-Aqueous Phase Liquids (NAPLs) at Hazardous Waste Sites.** *Institute for Environmental Education.* John A. Karachewski, OHM Remediation Services Corp., Pleasanton, California; Mark K. Levorsen, ERM—Rocky Mountain, Inc., Greenwood Village, Colorado.

Successful characterization, transport modeling, and remediation of NAPLs in the vadose zone and aquifers requires a multidisciplinary approach. This session will explore the impact of geologic heterogeneities on hydrologic, chemical, biological, and engineering processes, which span variable spatial and time scales. Case histories will illustrate field, laboratory, and modeling projects. ORAL and POSTER.

Environmental Geology (6), Hydrogeology (13).

T48. **Rates of Geologic Processes in the Holocene.** *Institute for Environmental Education.* Thure E. Cerling, University of Utah.

The earth sciences have a critical role in assessing environmental issues of societal concern (e.g., waste disposal, climate change, natural hazards). This session will focus on methods for measuring rates of Holocene processes that occur at or near Earth's surface on time scales from less than one to more than 1000 years. ORAL.

Environmental Geology (6), Geochemistry, Other (8), Quaternary Geology/Geomorphology (26).

T49. **Mechanics of the Riverbed I: Hydrology.** Paul A. Washington, Northeast Louisiana University.

This session will consider the mechanical environment of the riverbed; of particular interest are the dynamic interactions between the surface water and ground water, but contributions to the nature of the surface water flow or the ground water system at or adjacent to the boundary are welcomed. ORAL.

Engineering Geology (5), Hydrogeology (13).

T50. **Mechanics of the Riverbed II: Sedimentology.** Leonard M. Young, Northeast Louisiana University.

This session will consider the mechanics of sediment movement along riverbeds and at the base of similar flowing fluids. Contributions are sought concerning the mechanics of entrainment, transport, and deposition at any scale. ORAL.

Hydrogeology (13), Sediments, Clastic (29).

T51. **Mechanics of the Riverbed III: Geomorphic Consequences.** Rene A. DeHon, Northeast Louisiana University.

This session will consider the mechanics and dynamics of fluvial systems from a geomorphic perspective. Of particular interest are contributions concerning erosion and deposition along rivers and the evolution of fluvial systems. For this session, rivers are interpreted in their broadest context to include all fluvial systems from rills to deltas. ORAL.

Engineering Geology (5), Hydrogeology (13), Quaternary Geology/Geomorphology (26).

T52. **Integrated Digital Databases in Tectonics and Geomorphology.** Dogan Seber, Cornell University; Eric J. Fielding, Jet Propulsion Lab, California Institute of Technology.

This session will focus on the application of geographic information systems (GIS) to effectively utilize geophysics and geology databases, digital elevation models (DEMs), satellite imagery, and 3D visualization for analyzing tectonics and geomorphic problems. Papers that integrate a variety of disciplines into a GIS (or similarly organized system) are welcome. ORAL and POSTER.

Computers (3), Quaternary Geology/Geomorphology (25), Tectonics (32).

T53. **Geographic Information System Technology and Geoscience Applications: Present Applications and Future Directions.** Robert J. Krumm, Illinois Geological Survey.

Geographic information systems (GIS) technology is being used by geologists in many organizations to compile and analyze data, to produce maps and graphics, to access and use remotely sensed images, and to integrate GIS capabilities with specialized modeling routines. This session will feature current GIS applications as well as the future directions of this innovative and useful technology. ORAL.

Computers (3), Public Policy (25), Remote Sensing (27).

T54. **Improving Geoscience Courses Through the Use of the Internet and the World Wide Web.** *National Association of Geoscience Teachers.* Dave Mogk, National Science Foundation.

This session will illustrate creative uses of the Internet and the World Wide Web. We seek presenters who will focus on improvements in courses and in student learning that arise from integrating Internet and World Wide Web activities into courses. ORAL.

Computers (3), Geology Education (9).

T55. **Roles of Multiple Intelligences and Creativity in Teaching, Learning, and Doing Geoscience.** Barbara L. Mieras, Geological Society of America.

What implications do multiple intelligences and creativity have in the teaching, learning, and doing of geoscience? How do our educational and professional development systems interact with individuals' multiple intelligences to affect who pursues scientific interests and who is successful in geoscience careers? How does personal creativity affect who does geoscience? ORAL.

Geology Education (9)

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

T56. **When Plates and People Collide—Teaching About Human-Tectonics Interactions.** *National Association of Geoscience Teachers.* Barbara Tewksbury, Hamilton College.

This session will focus on creative ways of linking plate tectonics and human events in order to help students understand the underlying influence, both positive and negative, of tectonic processes on human events. This session is linked to the symposium, "Recent Advances in Plate Tectonics—What Students Should Know." ORAL.

Geology Education (9), Tectonics (32).

T57. **National Parks as Classrooms for Geoscience Education.** *National Association of Geoscience Teachers.* Duncan Foley, Pacific Lutheran University; Paul and Heidi Doss, Colby College.

This session will explore the opportunities, challenges, and diverse audiences that national parks present for geoscience education. Geologists are involved with the education of students, the public, and park service interpreters. Papers that focus on the use of parks as classrooms and laboratories are invited from geologists and park service personnel. ORAL.

Environmental Geology (6), Geology Education (9).

T58. **The Role of Geology Field Camp in the Geology Curriculum: An Appraisal.** David McConnell and Verne Friberg, University of Akron; Kevin Stewart, University of North Carolina.

This session will discuss changes in content and/or organization of geology field camp programs. It will examine how programs have adapted as geology curricula have changed and how traditional field camp courses have reorganized to meet the needs of changing student populations. ORAL.

Geology Education (9), Stratigraphy (29), Structural Geology (31).

T59. **Geology Field Camp Exercises in the Rocky Mountains.** David McConnell, University of Akron.

This session will be a forum for those who run geology field camp programs to share information and ideas on the region's best field camp exercises. It will provide an opportunity to review the types of exercises that instructors have found most effective and to learn about alternative locations that may introduce variety to field camp programs. POSTER.

Geology Education (9), Stratigraphy (30), Structural Geology (31).

T60. **Linking Natural and Social Systems in Geoscience Education: Pedagogy, Content, and Context.** *National Association of Geoscience Teachers* and *Institute for Environmental Education.* Lauret E. Savoy, Mount Holyoke College; Margaret N. Rees, University of Nevada, Las Vegas; Jill S. Schneiderman, Vassar College.

Interdisciplinary approaches to teaching and conducting research in the geosciences which explore the historical, cultural, and social contexts of scientific knowledge and the study of earth systems can provide students with a more complete understanding of science's linkage to the world. We invite abstracts from a range of disciplines, within and beyond the geosciences, that describe interdisciplinary approaches to curricular and research endeavors in the earth and environmental sciences and related fields. ORAL and POSTER.

Environmental Geology (6), Geology Education (9).

T61. **Organics-Ore Interactions in the Field and Laboratory.** *Society of Economic Geologists* and *International Geological Correlation Program, Project 357—Organics and Mineral Deposits.* Thomas H. Giordano, New Mexico State University.

This session will examine ore-organics interactions using field and experimental studies, including the use of organics for exploration. Included topics are organically mediated precipitation mechanisms and organic controls on metal and sulfur at sources and in fluids. Analytical and field studies will examine organic-ore links in terms of timing, spatial relations, alteration, and applications to prospecting. ORAL.

Economic Geology (4), Geochemistry, Aqueous/Organic (7), Petroleum Geology (19).

T62. **The Magmatic-Hydrothermal-Epithermal Transition and Associated Alteration and Mineralization.** *Society of Economic Geologists.* Mark Bloom, PTI Environmental Services, Boulder, Colorado.

Mineralization and alteration associated with high-level porphyry copper systems, and the relations between low- and high-sulfidation epithermal deposits, have become topics of exploration and research interest. The complex environment of magmatic-hydrothermal-epithermal transitions will be examined. Geological and geochemical case studies will be presented and occurrence models discussed. ORAL.

Economic Geology (4), Geochemistry, Aqueous/Organic (7).

T63. **Quantifying the Environmental Impacts of Mining.** *Society of Economic Geologists.* Andrew Nicholson, PTI Environmental Services, Boulder, Colorado.

While the potential impacts of mining on the environment are well known, and the processes that create these impacts are generally well understood, the quantitative characterization and prediction of these impacts is an area that needs further development. These issues are critical in evaluating the long-term impacts and liabilities of mine development. ORAL.

Economic Geology (4), Geochemistry, Aqueous/Organic (7), Hydrogeology (13).

T64. **Conservation Geology: Preserving and Protecting the Natural Resources of Ecosystem Earth.** *Institute for Environmental Education.* Russell G. Shepherd, U.S. Department of Agriculture, Natural Resources Conservation Service, Ft. Collins, Colorado.

This session will present research results and case studies from environmental geology, geomorphology, hydrogeology, and engineering geology, emphasizing conservation rather than exploration of resources. Topics will include conservation and restoration of wetlands, surface- and ground-water quality protection, agricultural watershed non–point-source pollution and erosion control, urban resource conservation, stream restoration, and GIS methods in conservation geology. ORAL.

Environmental Geology (6), Hydrogeology (13), Quaternary Geology/Geomorphology (26).

HOT TOPICS AT NOON:

Popular Scientific Debates for Everyone.

Monday through Thursday, October 28–31, 12:15 to 1:15 p.m., Colorado Convention Center.

Life's New Twist: The Precambrian/ Cambrian Radiation. Moderator: Jere Lipps, University of California, Berkeley.

Chicxulub: How Did It Do It?—The K-T Boundary, Mass Extinction, and the Post-Chicxulub Era. Moderator: Philippe Claeys, Museum für Naturkunde, Berlin, Germany.

Bald Uprights from the Pleistocene: Paleoclimate Influence on Human Evolution. Moderator: Craig Feibel, Rutgers University.

Federal Collecting Laws for Fossils and Minerals: Boon or Bane for Professionals? Moderator: Richard Stuckey, Denver Museum of Natural History.

Field Trips

The theme of the 1996 Annual Meeting, *Earth System Summit,* reflects both the complex interrelation of Earth system processes and the synergy of human adaptation to and effect upon Earth's dynamic systems. Field trips build on this theme, offering a plethora of opportunities to observe and discuss complex geologic and hydrologic relations in the West, with special emphasis on the Rocky Mountains, High Plains, and Colorado Plateau–southern Great Basin regions. Many geologic disciplines and specialties are represented, and the proximity to Denver of wide-ranging geologic terrain ensures something of interest to everyone.

All pre- and postmeeting field trips are technical in nature, one to five days in duration, and led by active field researchers. Professionals and students are strongly encouraged to take advantage of these offerings; lower airfares on Saturday night stay-over flights can reduce the costs associated with field trip participation significantly. **All trips begin and end in Denver unless otherwise indicated.**

The following list of trips and estimated costs is tentative and subject to change. Further details will be given when registration begins in June. If you register for a field trip only, you must pay a $35 nonregistrant fee in addition to the field trip fee. This fee may be applied toward meeting registration if you decide to attend the meeting. Weather will be a factor in many of the trips. Several half-day trips concurrent with the meeting will be described in the June issue of *GSA Today.*

For further information, contact the trip leader or the 1996 Field Trip Co-Chairs Charles L. Pillmore and Ren A. Thompson, U.S. Geological Survey, Box 25046, Federal Center, MS 913, Denver, CO 80225-0046, (303) 236-1240 or (303) 236-0929, E-mail: cpillmor@ardneh.cr.usgs.gov; or rathomps@usgs.gov, fax 303-236-0214.

Garden of the Gods. Courtesy of Denver Metro Convention and Vistors Bureau.

Premeeting

Geology of the Western San Juan Mountains and a Tour of the San Juan Skyway, Southwestern Colorado. Friday, October 25 and Saturday, October 26. Robert W. Blair, Jr., Dept. of Geology, Fort Lewis College, Durango, CO 81301, (970) 247-7263; Jack Campbell, Jack Ellingson, and Doug Brew. Starts and ends in Durango, Colorado. Maximum: 40. Cost: $165.

Permian-Triassic Deposystems, Paleogeography, Paleoclimate, and Hydrocarbon Resources in Canyonlands and Monument Valley, Southeastern Utah. Wednesday, October 23 through Sunday, October 27. Russ Dubiel, U.S. Geological Survey, Box 25046, MS 972, Federal Center, Denver, CO 80225, (303) 236-1540; Jacqueline Huntoon, and John Stanesco. Maximum: 24. Cost: $280.

Hayden's Lakes Revisited: The Origin and New Stratigraphic Interpretations of the White River Sequence, South Dakota, Nebraska, and Wyoming. Friday, October 25 through Sunday, October 27. Emmett Evanoff, University of Colorado Museum, Campus Box 315, Boulder, CO 80309-0315, (303) 492-8069; Rachael Benton, Dennis Terry, and Hannan Lagary. Maximum: 24. Cost: $190.

Kinematics of the Slumgullion Landslide, Lake City, Colorado. Saturday, October 26 and Sunday, October 27. Robert Fleming and Bill Savage, U.S. Geological Survey, Box 25046, MS 972, Federal Center, Denver, CO 80225, (303) 273-8603. Maximum: 24. Cost: $125.

Proterozoic Magmatism in Southeastern Wyoming: Evidence for the Cogenetic Relationship Between Anorthosites and Rapakivi Granites, Laramie Mountains, South-Central Wyoming. Thursday, October 24 through Sunday, October 27. Ronald Frost, Dept. of Geology and Geophysics, University of Wyoming, Laramie, WY 82071-3006, (307) 766-4290; Carol D. Frost, Ken Chamberlain, Donald H. Lindsley, and James S. Scoates. Maximum: 24. Cost $225.

Geology of El Solitario Dome, Laccolith, and Caldera System, Southern Texas. Thursday, October 24 through Sunday, October 27. Chris Henry, Nevada Bureau of Mines and Geology, University of Nevada, MS 178, Reno, NV 89557-0088, (702) 784-6691; William Muehlberger, University of Texas at Austin. This trip originates and ends in El Paso, Texas. Maximum: 40. Cost: $390 (including airfare from El Paso to Denver).

Sequence Stratigraphy of the Muddy Sandstone and Equivalent Rocks from North-Central Colorado to Northeastern New Mexico. Thursday, October 24 through Saturday, October 26. John Holbrook, Dept. of Geosciences, Southeast Missouri State University, Cape Girardeau, MO 63701, (314) 651-2348; Frank Ethridge, Colorado State University, Fort Collins. Maximum: 24. Cost: $220.

Geology and Geologic Hazards of the Glenwood Springs Area, Central Colorado. Friday, October 25 through Sunday, October 27. Robert Kirkham, Colorado Geological Survey, 1313 Sherman St., Denver, CO 80203, (303) 866-3293; Bruce Bryant, and Ralph Shroba. Maximum: 30. Cost: $175.

The Absaroka Range: A Fifty-Million-Year Fascination with Gravity, North-Central Wyoming. Wednesday, October 23 through Saturday, October 26. David Malone, Dept. of Geography-Geology, Illinois State University, Normal, IL 61790-4400, (309) 438-2692; Kent Sundell, and Thomas Hauge. This trip originates and ends in Cody, Wyoming. Maximum: 24. Cost: $350.

Synchronous Oligocene and Miocene Extension and Magmatism in the Vicinity of Caldera Complexes in Southeastern Nevada. Friday, October 25 through Sunday, October 27. Robert Scott, U.S. Geological Survey, Box 25046, MS 913, Federal Center, Denver, CO 80225, (303) 236-1230; Peter Rowley, Lawrence Snee, Ernest Anderson, Anne Harding, Daniel Unruh, David Nealey, and Dawna Ferris. One night camping. This trip originates and ends in Las Vegas, Nevada. Maximum: 24. Cost: $280.

A New Look at the Laramide Orogeny in the Seminoe and Shirley Mountains, Freezeout Hills, and Hanna Basin, South-Central Wyoming. Thursday, October 24 through Saturday, October 26. Arthur Snoke and Jason Lillegraven, Dept. of Geology and Geophysics, University of Wyoming, Laramie, WY 82071-3006, (307) 766-5457. Maximum: 24. Cost $225.

Neogene Geology of South-Central Colorado and North-Central New Mexico and the Volcanic Geology of Los Mogotes and San Luis Hills, Northern New Mexico. Friday, October 25 through Sunday, October 27. Alan Wallace, U.S. Geological Survey, Box 25046, MS 905, Federal Center, Denver, CO 80225, (303) 236-5648; Ken Hon, Tom Steven, and Ren Thompson. Maximum: 34. Cost: $185.

The Petroleum System, Sequence Stratigraphy and Reservoir Compartmentalization, Central Denver Basin, Colorado. Saturday, October 26. Bob Weimer, Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401-1887, (303) 273-3818; Stephen A. Sonnenberg. Maximum: 40. Cost: $60.

Laramide Orogeny and Cenozoic Erosional History, Front Range and Denver Basin, Colorado. Sunday, October 27. Bob Weimer, Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401-1887, (303) 273-3818. Maximum: 43. Cost: $60.

Postmeeting

Evidence for Early Proterozoic Reworking of Archean Rocks in the Central Laramie Range, South-Central Wyoming. Thursday, October 31 through Saturday, November 2. Robert Bauer, 101 Geological Sciences, University of Missouri, Columbia, MO 65211, (314) 882-3729; Kevin Chamberlin, Art Snoke, and Ron Frost. Maximum: 22. Cost: $215.

Soil-Geomorphic Relationships Near Rocky Flats, Boulder and Golden, Colorado Area, With a Stop at the Pre–Fountain Formation Paleosol of Wahlstrom (1948). Friday, November 1. Peter Birkeland, Dept. of Geological Sciences, University of Colorado, Boulder, CO 80304, (303) 492-8141; Ralph Shroba, Dan Miller, and Penny Petterson. Maximum: 36. Cost: $55.

Upper Cretaceous Coals of the Western Interior Seaway, Northwestern Colorado. Thursday, October 31 through Saturday, November 2. Mick Brownfield and Mark Kirschbaum, U.S. Geological Survey, Box 25046, MS 972, Federal Center, Denver, CO 80225, (303) 236-7767. Maximum: 34. Cost: $185.

Oblique Laramide Convergence in the Northeastern Front Range of Colorado: Regional Implications from the Analysis of Minor Faults. Friday, November 1. Eric Erslev and Joe Gregson, Dept. of Earth Resources, Colorado State University, Fort Collins, CO 80523, (970) 491-6375. Maximum: 26. Cost: $65.

Depositional Environments of Codell–Juana Lopez Sandstones and Regional Structure and Stratigraphy of Cañon City and Huerfano Areas and Northern Raton Basin, South-Central Colorado. Thursday, October 31 through Saturday, November 2. Paul Krutak and Kenneth Neuhauser, Dept. of Geosciences, Fort Hays State University, 600 Park St., Hays, KS 67601-4099, (913) 628-5389. Maximum: 24. Cost: $175.

Sequence Stratigraphic Relationships of Coeval Shallow Marine and Nonmarine Strata, Kaiparowitz Plateau, Eastern Arizona and Southern Utah. Thursday, October 31 through Monday, November 4. Peter McCabe, U.S. Geological Survey, Box 25046, MS 972, Federal Center, Denver, CO 80225, (303) 236-7550; Keith Shanley, Shell Development Co. This trip originates and ends in Grand Junction, Colorado. Maximum: 24. Cost: $290.

Hydrogeology of the San Luis Valley and Summitville Mine, South-Central Colorado. Thursday, October 31 through Saturday, November 2. Isobel McGowan, Shepherd Miller, Inc., 2460 W. 26th Ave., Denver, CO 80211, (303) 477-5338; Doug Cain, Alan Davey, and Kathy Smith. Maximum: 24. Cost: $190.

Geology and Paleontology of the Gold Belt Back Country Byway: Garden Park Fossil Area and Florissant Fossil Beds. Friday, November 1 and Saturday, November 2. Herb Meyer, National Park Service, Florissant Fossil Beds National Monument, P.O. Box 185, Florissant, CO 80815, (719) 748-3253; Dan Grenard, Bureau of Land Management. Maximum: 35. Cost: $125.

Cretaceous-Tertiary Boundary in the Southern Peninsula of Haiti. Friday, November 1 through Sunday, November 3. Florentine Maurrasse and Gautam Sen, Dept. of Geology, Florida International University, Miami, FL 33199, (305) 348-2047. This trip will originate and end in Miami and will depend on the political conditions in Haiti at the time of the meeting. Maximum: 20. Cost: $500, including airfare.

Tertiary Intrusive Rocks of the Spanish Peaks and the Laramide Structure of the Western Margin of the Raton Basin, South-Central Colorado. Friday, November 1 and Saturday, November 2. Brian Penn, Colorado School of Mines, 15 Mines Park, Golden, CO 80401, (303) 278-2750; Dave Lindsey, U.S. Geological Survey, Box 25036, Federal Center, Denver, CO 80225, (303) 236-6482. Maximum: 24. Cost: $140.

Jemez Volcanic Field and Valles Caldera–Middle Rio Grande Rift. Thursday, October 31 through Sunday, November 3. Dave Sawyer and Ren Thompson, U.S. Geological Survey, Box 25046, MS 913, Federal Center, Denver, CO 80225, (303) 236-1021; Fraser Goff, Steve Reneau, Jamie Gardner, Scott Baldridge, and Dave Broxton, Los Alamos National Laboratory. Maximum: 36. Cost: $315.

Precambrian Tectonics and Metallogeny of the Hartville Uplift, Wyoming. Friday, November 1 and Saturday, November 2. Paul Sims, U.S. Geological Survey, Box 25046, MS 905, Federal Center, Denver, CO 80225, (303) 236-5621; Warren Day, and Terry Klein. Maximum: 24. Cost: $185.

Dunes, Rivers, Lakes, and Wetlands: Tales from the Nebraska Sand Hills of Western Nebraska. Thursday, October 31 through Saturday, November 2. James Swinehart, 113 Nebraska Hall, University of Nebraska, Lincoln, NE 68588-0517, (402) 472-7529; David Loope, Dan Muhs, and Tom Winter. Maximum: 24. Cost: $190.

Capitol Peak, Snowmass Wilderness, Colorado. Photo by John Karachewski.

Field Workshop

Innovative Techniques for Shallow Soil and Ground-water Investigations. Saturday, October 26. William DiGuiseppi, CTE Engineers, 2750 Prosperity Ave., Suite 230, Fairfax, VA 22031, (703) 204-6346; Jeff Flanzenbaum. Maximum: 40. Cost: $50.

Sponsored by Society of Economic Geologists

Contact trip leaders for information.

State Line Kimberlite District, Colorado. Saturday, October 26. Howard Coopersmith, P.O. Box 1916, Ft. Collins, CO 80522, (970) 224-4943, fax 970-221-5280. Maximum: 40. Minimum: 20. Cost: $100.

Cresson Mine, Cripple Creek District, Colorado. Friday, November 1. Jeffrey Pontius, Pikes Peak Mining Company, P.O. Box 191, Victor, CO 80860, (719) 689-2977, fax 719-689-3254. Maximum: 40. Minimum: 20. Cost: $100.

Educational Programs

GSA-Sponsored Continuing Education Courses

Registration information and course descriptions will be published in **June** *GSA Today.* For additional information, contact Edna Collis, Continuing Education Coordinator, GSA headquarters, E-mail: ecollis@geosociety.org.

Fees will be approximately $150–$175 for the first day and $125–$150 for the second day. If you register for a GSA course *only,* you must pay a $35 nonregistrant fee in addition to the course fee. This fee may be applied toward meeting registration if you decide to attend the meeting. Students will receive a discount on all GSA courses.

Tax Deduction: Expenses for continuing education (including registration fees, travel, lodging, and meals) to maintain and improve professional skills are generally tax deductible in whole or in part (Treasury Reg. 1-162-5, Coughlin vs. Commissioner, 203F2d307). Please discuss this with a qualified accountant.

Geomorphic Expression of Active Tectonics. Saturday, October 26 and Sunday, October 27. Cosponsored by the *Structural Geology & Tectonics Division* and *Quaternary Geology and Geomorphology Division.* Frank J. Pazzaglia, University of New Mexico; Nicholas Pinter, Yale University. C.E.U. 1.6.

How To Do Anything with Mohr Circles (Except Fry an Egg): A Short Course About Tensors for Structural Geologists. Saturday, October 26 and Sunday, October 27. Cosponsored by *Structural Geology and Tectonics Division.* Winthrop D. Means, State University of New York at Albany. C.E.U. 1.2.

New Numerical Techniques for Sedimentary Data: Fractals and Nonlinear Dynamics. Saturday, October 26 and Sunday, October 27. Cosponsored by *Sedimentary Geology Division* and *Society for Sedimentary Geology (SEPM).* Gerard V. Middleton, McMaster University, Ontario; Roy E. Plotnick, University of Illinois; David M. Rubin, U.S. Geological Survey, Menlo Park. C.E.U. 1.6.

Applications of Environmental Isotopes to Solving Hydrologic and Geochemical Problems. Sunday, October 27. Cosponsored by *Hydrogeology Division.* Carol Kendall, U.S. Geological Survey, Menlo Park. C.E.U. 0.8.

Applications of GPS in the Earth Sciences. Sunday, October 27. Cosponsored by *Structural Geology and Tectonics Division.* Charles Meertens, University NAVSTAR Consortium, University Corporation for Atmospheric Research, Boulder; Roland Burgmann, University of California, Davis. C.E.U. 0.8.

Effective Teaching of Hydrogeology: How To Make Do with Scant *Real World* Data. Sunday, October 27. Cosponsored by *Hydrogeology Division* and *National Association of Geoscience Teachers.* Donald I. Siegel, Syracuse University. C.E.U. 0.8.

Recognition, Investigation, and Mitigation of Landslides. Sunday, October 27. Cosponsored by *Engineering Geology Division.* Jerome V. DeGraff, U.S. Forest Service, Clovis, California; Michael W. Hart, Consultant, San Diego; William R. Cotton, William Cotton & Associates, Inc., Los Gatos, California. C.E.U. 0.8.

Vadose Zone Hydrology: Introduction and Applications to Water and Solute Transport. Sunday, October 27. Cosponsored by *Hydrogeology Division.* Scott W. Tyler, Desert Research Institute and University of Nevada, Reno; Bridget Scanlon, Texas Bureau of Economic Geology, Austin. C.E.U. 0.8.

Other Courses and Workshops

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

Reactive Transport in Porous Media: General Principles and Application to Geochemical Processes. Friday, October 25 through Sunday, October 27. Sponsored by *Mineralogical Society of America.* For information: MSA Business Office, 1015 18th St., N.W., Suite 601, Washington, DC 20036, (202) 775-4344, fax 202-775-0018.

National Science Foundation—Undergraduate Faculty Enhancement Workshop on Innovative and Effective Techniques for Teaching Geoscience. Saturday, October 26. Sponsored by *National Science Foundation Undergraduate Faculty Enhancement Program, GSA SAGE Program,* and *National Association of Geoscience Teachers.* For information: R. Heather Macdonald, Dept. of Geology, College of William and Mary, Williamsburg, VA 23185, (804) 221-2469, fax 804-221-2464.

Systematics of Fluid Inclusions. Saturday, October 26 and Sunday, October 27. Sponsored by *SEPM (Society for Sedimentary Geology).* For information: Judy Tarpley, Education and Meetings Coordinator, SEPM, 1731 E. 71st St., Tulsa, OK 74136, (918) 493-3361, ext. 22, fax 918-493-2093, E-mail: cemeet@galstar.com.

Biology and Paleobiology of Corals. Sunday, October 27. Sponsored by *Paleontological Society.* For information: George D. Stanley, Dept. of Geology, University of Montana, Missoula, MT 59812, (406) 243-2341, fax 406-243-4028.

DataBase Forum. Sunday, October 27. Sponsored by *Geoscience Information Society.* For information: Vivienne Roumani-Denn, 230 McCone Hall, University of California, Berkeley, CA 94720, (510) 643-7041.

Preparing Successful Grant Proposals to Fund Curriculum Innovation in the Geosciences. Sunday, October 27. Sponsored by *National Association of Geoscience Teachers* and *National Science Foundation.* For information: David Mogk, Division of Undergraduate Education, National Science Foundation, Room 835, 4201 Wilson Blvd., Arlington, VA 22230, (703) 306-1669, fax 703-306-0445, E-mail: dmogk@nsf.gov.

GSA's SAGE Program for K–16

SAGE (Science Awareness through Geoscience Education) is five years old! We will celebrate in Denver by hosting an array of K–16 educational events for scientists and teachers. We'll begin with a premeeting gathering on Friday, October 25, including the fall conference of the Colorado Earth and Space Science Educators' Network (CESSEN), an event that draws K–12 teachers from across the state. We'll continue with hands-on workshops on the atmosphere, dinosaurs, planetary geology, and national and state science standards. With the support of our Partners for Education Program (PEP) and other divisions and societies, we will offer K–6 educators and PEP scientists the chance to learn interactively on all-day field trips. During the technical sessions, a selection of thought-provoking theme sessions, symposia, and forums will focus on K–16 educational issues. Everyone interested in geoscience education will want to attend the popular Share-A-Thon, the riotous Rock Raffle, and the Educators' Social Hour. We expect a hallmark year in Denver, and look forward to an interactive good time!

Special Programs

Geology and Public Policy Forum

Wednesday, October 30. The GSA Committee on Geology and Public Policy will conduct a forum, "Saving Our Science—Entering the Public Policy Debate."

Graduate School Information Forum

The forum will take place in the exhibit hall at the Colorado Convention Center in three sessions, from 9:00 a.m. to 5:00 p.m., Monday, October 28, through Wednesday, October 30.

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

Each school will be given use of a 4' × 8' poster board, a table, and four chairs. If your school is interested in participating, contact Matt Ball, GSA headquarters, E-mail: mball@geosociety.org. The reservation deadline is August 15.

Employment Interview Service

GSA will again be offering its Employment Interview Service. Each year, this program provides valuable job-matching opportunities in the geosciences. At last year's meeting in New Orleans, participating employers conducted nearly 400 interviews with nearly 350 applicants seeking employment!

As in the past, booths will be provided for employers to interview applicants registered with the Employment Service, and GSA staff will be on hand to coordinate the scheduling of interviews. In particular, students completing doctoral and master's theses during 1996 are encouraged to check the job offerings.

See the July 1996 issue of *GSA Today* for applicant and employer forms and further information, or contact T. Michael Moreland, Employment Service Manager, GSA headquarters, E-mail: tmorelan@geosociety.org. Information is also available on the World Wide Web. The URL is http://www.geosociety.org; check under the Membership section.

Evening Highlights

Denver Theatre and Dinner
Saturday, October 26

Microbrew Mania Pub Crawl
Saturday, October 26

Welcoming Party *(registration required)*
Sunday, October 27

GSA Presidential Address and Awards Ceremony
Monday, October 28

Alumni Receptions
Monday, October 28

Child Care Now Available!

The New Thomas Learning Centers of Colorado, approved and screened by the City and County of Denver, will provide a child care service in the Colorado Convention Center. This company is a Colorado-based, licensed, insured child care corporation with 19 years of experience. They employ thoroughly screened professionals to provide quality care to the children of convention attendees.

Your child will enjoy age-appropriate activities in a relaxed environment. Children can enjoy arts and crafts, story-telling, games, puzzles and toys. Security and safety procedures will be carefully observed.

Estimated cost will be $3.50 per hour. Preregistration will be required. For further information or registration materials, contact Kathy Ohmie Lynch, GSA headquarters, E-mail: klynch@geosociety.org. Parents are also welcome to contact Deanna Zerr at the New Thomas Learning Centers at (303) 639-6240.

Guest Program

GSA welcomes its guests to the Mile High City. A hospitality room will be provided for guests to meet, enjoy refreshments, and get information on Denver and surrounding areas. Formal and informal tour information will also be available. **Guest registration includes an exhibit hall pass, but does not give access to technical sessions.**

The Guest Program Committee wants your Denver visit to be most memorable. We welcome suggestions and participation in the guest program. Contact Kata McCarville at (303) 273-3448 or E-mail: kmccarvi@mines.edu.

Formal Tours
(Open to All GSA Registrants)

Mile High City Highlights
Bus tour of downtown Denver including State Capitol, Molly Brown's house, Ninth Street Park, Coors Field, and Larimer Square.

Bones and Tracks:
Dinosaur Ridge Family Field Trip
Cosponsored by *Association for Women Geoscientists* and *Friends of Dinosaur Ridge.* The Dinosaur Ridge hogback exposes Jurassic and Cretaceous rocks containing dinosaur bones, and dinosaur and crocodile footprints and trackways. We'll also have the opportunity to visit the new Visitor Center at the Ridge. Bring the kids!

"For the Birds" Field Trip
In cooperation with the Denver Audubon Society, the Field Ornithologists of Denver, and the Field Ornithologists of Colorado, we're planning a special treat for you GSA birds of a feather. Space will be limited.

An Art Affair
Tours of the Denver Art Museum and the Museum of Western Art followed by high tea served at the historic Brown Palace Hotel.

Beneath the Flatirons
Tour of Boulder including Celestial Seasonings Tea Company and the Pearl Street Mall.

Lowdown on LoDo
Walking tour of Denver's lower downtown area including galleries, bookstores, restaurants, Union Station, the Ice House, and Coors Field.

Fashions, Favors, and Fads
Shuttle bus to Cherry Creek mall, galleries, boutiques, specialty shops and the Tattered Cover bookstore.

Colorado Springs
Tour of U.S. Air Force Academy, Garden of the Gods, Old Colorado City and lunch at the Broadmoor Hotel.

Museum and Zoo Tour
Shuttle transportation to the Colorado Museum of Natural History and Denver Zoo, both located in City Park.

Informal Tours

In addition to the tours listed above, you might enjoy visiting Denver attractions with other guest attendees. Plan to sign up for these informal, self-guided tours in the Hospitality Room.

GSA Software Fair

Back by popular demand! An expanded and improved Software Fair is being organized for the Denver meeting, to promote the use of computers in all fields of geology. GSA is looking for developers of freeware, public domain, shareware, and commercial packages to give demonstrations. GSA supplies PC, Macintosh and Silicon Graphics computers with Internet connections. The Software Fair will be located in the exhibit hall in a high-traffic area between poster sessions and exhibits. A nominal fee of $100 will be charged to commercial vendors for one four-hour morning or afternoon presentation. Contact: Matt Ball, GSA headquarters, E-mail: mball@geosociety.org for information and application form. The deadline for receipt of completed applications is August 15, 1996. See GSA's World Wide Web site (http://www.geosociety.org/meetings/96/softfair/) for an on-line application form.

Internet Access Center

Computers connected to the Internet will be available free of charge for attendees to browse the World Wide Web or use Telnet to retrieve their E-mail.

Registration

Registration materials available in June *GSA Today!*

June GSA Today *will be the* only *complete registration issue.*

PREREGISTRATION DEADLINE:
SEPTEMBER 20, 1996

CANCELLATION DEADLINE:
SEPTEMBER 27, 1996

Make plans now to take advantage of the **June** registration opportunity! **Events will fill quickly.** There is considerable savings on registration fees if you register early. Registration is required for events. One-day registration is available on-site Sunday through Thursday.

Guest/Spouse registrations do not include technical session access.

GSA members will automatically receive registration information and forms during the first weeks of June. If you are not a member and would like registration forms and further information, please contact the GSA Registration Coordinator, GSA headquarters, E-mail: jphillip@geosociety.org.

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

Members Pay Less! Join Now!

If you are not yet a GSA member, **now** is the time to join. Nonmembers who become GSA members by October 1, 1996, can **pre**register at the member rate. You will save a substantial amount on your registration fee by paying the member rate—almost exactly the amount you would pay to join GSA. *That's like joining GSA for free!* For membership information, contact T. Michael Moreland at GSA headquarters, E-mail: tmorelan@geosociety.org.

Accessibility for Registrants with Special Needs

GSA is committed to making every event at the 1996 Annual Meeting accessible to all people interested in attending. If you have special requirements, such as an interpreter or wheelchair accessibility, there will be space to indicate this on the meeting registration form, or you can call Becky Martin, GSA headquarters, E-mail: bmartin@geosociety.org. If possible, please let us know your needs by September 27.

Abstracts with Programs

Purchase an advance copy through GSA Membership Services, Publication Sales, or pick up a copy on site in the registration area. The *Abstracts with Programs* is not part of your registration fee. For advance sales, contact Publication Sales, GSA headquarters, 1-800-472-1988. Cost: $24.

Estimated Registration Fees

	Advance Full Meeting	On-Site Full Meeting	One Day
Professional Member	$195	$235	$118
Professional Nonmember	$235	$275	$138
Student Associate Member	$ 70	$ 90	$ 45
Student Nonmember	$ 90	$110	$ 55
Guest or Spouse *(no technical session access)*	$ 80	$100	n/a
K-12 Professional	$ 25	$ 35	n/a
Cont. Ed./Field Trip Only Fee	$ 35	$ 35	n/a

Travel and Lodging

Travel

GSA's official travel agent, Travel King, has negotiated discounted airfares with United Airlines, Denver's primary carrier. Travel King is committed to obtaining the best possible fares for GSA Annual Meeting travelers.

Advance bookings with Saturday night stayovers are the best route to lowest fares. However, as with all airline reservations, please use caution regarding change and cancellation penalties that accompany low-fare tickets. This applies especially to field trip and continuing education participants, whose trip or course may be canceled after the September 20 preregistration deadline. Call Travel King at 1-800-458-6398 or E-mail: trvlking@indra.com, for a reservation or more information.

Airport shuttle services offer convenient transportation from Denver International Airport to the downtown hotels.

GSA Student Associate Member Travel Grants

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

South-Central
Rena Bonem, (817) 755-2361

Northeastern
Kenneth Weaver, (410) 554-5532

Southeastern
Harold Stowell, (205) 348-5098, http://www.geo.ua.edu/segsa/segsa.html

Lodging

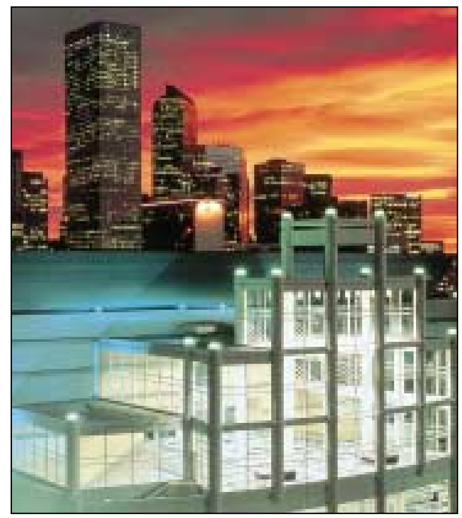
GSA has booked rooms at nine properties that offer special convention rates ranging from $67 to $119 single, and $77 to $136 double. A block of 500 rooms is reserved at the Marriott City Center, which, as headquarters, will host most social and business events. Other participating hotels include the Adams Mark Hotel, Hyatt Regency, Holiday Inn, Embassy Suites, Executive Tower Inn, Westin, Comfort Inn, and Brown Palace Hotel. In addition, several lower cost properties will be available to student registrants.

Activities will take place at the Colorado Convention Center, as well as GSA's headquarters hotel, the Marriott City Center, the Adams Mark, and Hyatt Regency.

The key to getting your first hotel choice is to make your reservation *early*. GSA will publish housing information and reservation forms in the **June** issue of *GSA Today*. All hotel reservations must be processed by the Denver Housing Bureau to obtain GSA special rates.

GSA Shuttle

Most downtown Denver hotels are a convenient walking distance from the Convention Center and from each other. Therefore, GSA will provide a limited, evening shuttle serving the GSA-selected hotels and the Convention Center.



Colorado Convention Center. Courtesy Denver Metro Convention and Visitors Bureau.

Exhibits

Exhibiting at GSA is a cost-effective way to reach a targeted buying audience of over 6000 geoscientists in only $3^1/_2$ days. The exhibition hall will be filled with more than 250 booths representing the latest: geological publications; geological software; scientific instrumentation; microanalysis and photographic equipment; geoscience educational supplies; gems, minerals, and fossils; resource information from environmental, national, and state agencies; field supplies and gear; and information on earth science programs at major institutions. Please visit GSA's World Wide Web address, http://www.geosociety.org, to browse an on-line product and services listing of current exhibitors. For information on becoming an exhibitor, please contact Matt Ball, GSA headquarters, E-mail: mball@geosociety.org.

Penrose Conference Report

Fine-grained Fault Rocks

Conveners
Jerry Magloughlin, *Department of Geology, University of Illinois, 1301 West Green St., 245 Natural History Building, Urbana, IL 61801*

Frederick M. Chester, *Department of Earth and Atmospheric Sciences, Saint Louis University, 3507 Laclede Ave., St. Louis, MO 63103*

John Spray, *Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3, Canada*

Tectonic processes commonly lead to concentrated deformation in the form of faults and shear zones that range from microscopic to megascopic in scale. The products of such focused deformation are typically fine grained, and consequently they can be difficult to study, identify, and interpret. Various fault rocks can be superficially similar, but may form under markedly different conditions of strain rate, pressure, temperature, fluid composition, and fluid pressure. Aside from problems of nomenclature, we need to improve our knowledge of fine-grained fault rocks in order to reveal the underlying controlling mechanisms operating in fault and shear zone systems. This is particularly the case for the seismogenic regime where there are clear socioeconomic and environmental implications.

Because of these and other problems, a Geological Society of America Penrose Conference was held August 31–September 4, 1995, in Leavenworth in the North Cascade Mountains of Washington state. The 78 participants included 30 attendees from 14 countries, as well as 12 graduate students. The conference was supported by the Geological Society of America, the National Science Foundation, and the U.S. Geological Survey Earthquake Hazards Reduction Program.

The objectives of the conference were: (1) to review existing field and laboratory data and discuss the application of these data to further our understanding of fault-rock genesis; (2) to discuss the importance of multidisciplinary studies, particularly with respect to fluid-rock interaction during faulting, and outline future research priorities for the investigation of fault-rock genesis and fault-zone properties, and (3) to facilitate the application of research results to societal needs. An additional goal was to bring together experts on all aspects of fault-rock studies. Research expertise included experimental rock mechanics, field studies, fluids in fault zones, deformation mechanisms involved in fault-rock generation, physical properties of fault rocks, petrology, and stable and radiogenic isotope analysis.

Specific questions posed were: (1) What can specific fault rocks reveal about the mechanical properties, and therefore the associated geological hazards, associated with a fault or shear zone? (2) What can be inferred about the timing, volume, and composition of fluids flowing though faults and shear zones? (3) What do the textures, particle size distributions, and operative deformation mechanisms observed in naturally and experimentally formed fault rocks reveal about temperature, stress, and strain rate? (4) Which fault rocks are amenable to geochronometric techniques? (5) What are the spatial, temporal, and genetic relations among the fine-grained fault rocks? (6) How can a multidisciplinary approach to fault-rock studies better elucidate the evolution of faults and shear zones? (7) Does the current classification scheme require modification, extension, or loosening? (8) Should fault-rock terminology be developed or modified for better application in the field?

On the first day of the conference, spent in the field, we observed a variety of fault rocks in a transect through part of the Nason terrane in the North Cascade Mountains. The fault rocks included ductilely deformed migmatite, gneiss, and mylonite, through rocks of a more brittle nature, pseudotachylyte and cataclasite, to faults and fault gouge representative of deformation at shallower crustal levels. We observed brittle and ductile features in the tonalites and mylonitic peridotites of the White River ultrabasic body, as well as pseudotachylytes and cataclasites in interlayered schists and gneisses of the Wenatchee Ridge Gneiss. The trip provided an excellent forum for viewing fault-related rocks from the brittle through to the ductile fields.

We devoted the following three days of the conference to oral and poster presentations covering field, experimental, theoretical, and analytical aspects of fine-grained fault rocks. More than 40 posters were displayed during the conference. Considerable time was dedicated to formal and informal discussion periods, and to the poster displays, so that all participants had the opportunity to share their ideas. Many participants commented that the group roundtable discussion was one of the highlights of the meeting. Most participants left the conference with the realization that significant progress had been made in our understanding of fault rocks and that the future will provide the opportunity for fruitful research.

MECHANISMS OF DEFORMATION AND RECOVERY

Fine-grained fault rocks form by a variety of grain-scale deformation mechanisms. Microstructures also reflect the operation of recovery processes, such as crack healing and dynamic recrystallization. In some cases, particularly for steady-state deformation, the recovery processes are as important as the deformation mechanism in producing microstructure and controlling flow behavior. Individual deformation and recovery processes are thermally activated and will be important over a restricted range of crustal conditions. Much of what we know about these mechanisms comes from laboratory experiments. Because of technological restrictions, experimentalists do not try to simulate crustal conditions, but rather impose conditions to activate the various deformation and recovery processes. The well-

Penrose *continued on p. 35*

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MICROTECTONICS TO GPS

C.W. PASSCHIER, University of Mainz, Germany, and
R.A.J. TROUW, Universidade Federal do Rio de Janeiro, Brazil

MICROTECTONICS

Microtectonics is the interpretation of small-scale deformation structures in rocks. Containing a wealth of information on the history and type of deformation and metamorphism in a given rock, microtectonics are used by geologists to obtain data for large-scale geological interpretations. This volume contains numerous photographs and explanatory drawings, special chapters on related techniques (including microgauges) and a simple, non-mathematical treatment of continuum mechanics in which special terms are explained in boxes throughout the text. This advanced textbook is ideally suited for use as a reference manual during optical studies on microstructures and as a manual for short courses.

1996/302 PP., 254 ILLUS./HARDCOVER/$39.00
ISBN 3-540-58713-6

H. KOBUS, B. BARCZEWSKI and **H.-P. KOSCHITZKY,** University of Stuttgart, Germany (eds.)

GROUNDWATER AND SUBSURFACE REMEDIATION

Research Strategies for In-Situ Technologies

This book illustrates the role large-scale experiments play in groundwater and subsurface remediation research. The refinement of existing techniques and the development of new approaches for in-situ remediation of contaminated aquifers and soils resulting from accidental spills, old waste deposits or abandoned industrial sites are challenging, multidisciplinary tasks. The material covered in this volume runs the gamut from basic process research to technology experiments and numerical systems simulation, as well as processes for the extraction, decomposition and immobilization of contaminants.

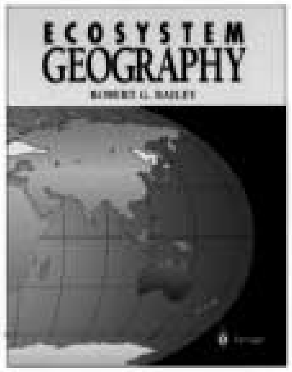
1996/APPROX. 400 PP., 149 ILLUS.
HARDCOVER $102.00 (TENTATIVE)
ISBN 3-540-60916-4
ENVIRONMENTAL ENGINEERING

W. JOHANNES, University of Hanover, Germany, and
F. HOLTZ, CNRS-CRSCM, Orléans, France

PETROGENESIS AND EXPERIMENTAL PETROLOGY OF GRANITIC ROCKS

This volume deals with the mineralogy and petrogenesis of granitic rocks and is the only work to emphasize experimental aspects. It summarizes and interprets the results obtained from experiments with both synthetic and natural rock systems. An important part of this book is that it reveals the significance water has in the formation, intrusion and crystallization of granitic magmas. Finally, the reader is provided with a complete review of the evolution of granites: the most important type of rock in the continental crust.

1996/APPROX. 306 PP., 182 ILLUS., 14 TABLES
HARDCOVER $129.00
ISBN 3-540-60416-2
MINERALS AND ROCKS VOLUME 22



R.G. BAILEY, US Forest Service, Fort Collins, CO

ECOSYSTEM GEOGRAPHY

"Bob Bailey [is] the man behind the ecosystem mapping of the world" — LINGUA FRANCA

"Bailey's work is a key element in a revolution-in-the-making among the four federal agencies that oversee our nation's public lands." — NATURE CONSERVANCY

"Bailey's maps and the hierarchy he developed may turn out to be the compass that points the way toward a common ground for the Forest Service and the National Parks Service." — AMERICAN FORESTS

The analysis and management of ecosystems rely increasingly on sound geographical knowledge. **Ecosystem Geography** is a landmark contribution which brings the geographers' tools — maps, scales, boundaries and units — to the study of ecosystems. The author, a senior geographer and program manager with the US Forest Service, has distilled more than two decades of research on ecosystem mapping and classification. His work has had a growing influence on how government and academic scientists are using ecological data to monitor biodiversity, manage land holdings and interpret the results of climatic change. **Ecosystem Geography** features spectacular graphics, including diagrams, photographs and abundant maps. It will be welcomed by ecologists, geographers, land and resource specialists, and anyone involved in the study or management of landscapes and ecosystems.

1996/216 PP., 122 ILLUS. (MANY 2-COLOR), 14 TABLES
ISBN 0-387-94586-5/SOFTCOVER $34.50
ISBN 0-387-94354-4/HARDCOVER $69.95
INCLUDES TWO FULL-COLOR MAPS IN BACK POCKET

For more information on Bailey's Ecosystem Geography visit http://www.springer-ny.com/catalog/bio-b149.html

Springer

http://www.springer-ny.com

M. BREUNIG, Institut für Informatik, Universität Bonn, Germany

INTEGRATION OF SPATIAL INFORMATION FOR GEO-INFORMATION SYSTEMS

In this volume Breunig presents a model for the integration of spatial information into three-dimensional Geo-Information Systems (3D-GISs). Previous Geo-Information Systems were restricted to two-dimensional space and executed the integration of spatial information by converting vector and raster representations. This led to conceptual difficulties because of totally different paradigms. The three-dimensional concept of space serves as a basis for a model that integrates spatial information by taking into account the geometry, metrics and topology of geo-optics. Breunig provides a thorough introduction to the history and architecture of Geo-Information Systems. He then discusses in detail the suitability of spatial representations in 2D and 3D space in 3D-GISs. This volume will prove invaluable to anyone interested in this burgeoning field.

1996/APPROX. 186 PP., 79 ILLUS., 20 TABLES
SOFTCOVER $59.95
ISBN 3-540-60856-7
LECTURE NOTES IN EARTH SCIENCES VOLUME 61

A. KLEUSBERG, University of New Brunswick, Fredericton, Canada, and **P.J.G. TEUNISSEN,** Delft University of Technology, The Netherlands (eds.)

GPS FOR GEODESY

This volume provides a detailed description of the theory and mathematical models behind the applications of the Global Positioning System (GPS) in geodesy and geodynamics. Contributions from leading experts in the field provide refreshing, unique points of view. The text is written so that, unlike a collection of disjointed papers, it provides a continuous flow of ideas and developments. The volume begins by developing mathematical models for GPS measurement and then gradually progresses into the exploration of GPS solutions for geodetic applications on local, regional and global scales. This volume is a worthy addition to the bookshelf of students and researchers in this dynamic field.

1996/APPROX. 416 PP., 86 ILLUS., 18 TABLES
SOFTCOVER $99.95
ISBN 3-540-60785-4
LECTURE NOTES IN EARTH SCIENCES

Penrose *continued from p. 33*

known technique of trading temperature for time is a method to activate processes in the laboratory time frame that would occur naturally over geologic time in the earth. The experimental work to date has largely focused on defining the flow laws and characteristic microstructures for each type of deformation and recovery process. Scaling and extrapolation of laboratory relations to nature are the two main difficulties, because experiments generally are done on small samples at high deformation rates.

Several participants presented observations of flow fabrics in gouge and cataclasite. In some cases the structures are remarkable, particularly the flow patterns about irregular contacts between wall rock and gouge, and gouge ponding, extrusion, and folding. These observations prompted some discussion of the extent to which gouge and ultracataclasite are fluidized during faulting. Although it is typically assumed that flow structures are associated with steady creeping behavior, the process of fluidization during seismic slip events also could produce flow structures. It is generally agreed that we have much to learn regarding mechanisms of deformation within the ultrafine-grained cataclastic rocks.

Considerable discussion pertained to a perceived division between the experimentalists and those working on natural rock systems. Experimentalists pointed out the dearth of information on the mechanical behavior of different lithologies at different rates of strain, and encouraged the other group to speculate on deformation mechanisms in their studies of natural deformation. Those working on natural rocks encouraged the experimentalists to more thoroughly explain how to apply experimental data to natural settings.

A major point was that in contrast to the Penrose Conference on mylonites, this one did not focus on terminology. Instead, it focused on processes, with many detailed descriptions of observations of both experimentally and naturally deformed rocks.

RHEOLOGY OF FINE-GRAINED FAULT ROCKS

Experimental work has helped not only to define deformation and recovery processes, but also to quantify mechanical behavior. We generally use a simple Coulomb failure criterion to describe fault behavior in the brittle, frictional regime. However, there is growing concern that this simple description of brittle failure may not be applicable in some mature faults, and it certainly is insufficient to explain brittle fault rock genesis and some aspects of faulting phenomena. The mechanical behaviors of brittle fault rocks containing phyllosilicates, and in settings where significant pressure solution processes have operated, are particularly important to constrain. Observations of deformation across the brittle-crystal plastic transition indicate that behavior in the transitional regime is pressure dependent (frictional) even though the microstructures may record significant crystal plasticity. Descriptions of rheology in the transitional flow regime are generally lacking. There is a fairly good consensus on the creep rheology of quartz and calcite, but other crustal minerals are less well understood. Characterization of the creep behavior of feldspars and phyllosilicates will be an important step in helping to quantify fault rock rheology. In addition, it will be important to investigate the behavior of polymineralic aggregates in experiments as well as by theoretical modeling.

Rheological behavior at very high strains is also an area of active research. Several participants described new testing machines or novel approaches to looking at high-strain behavior. In conventional experiments that can achieve only limited strains, constant-strength behavior is commonly achieved even though the microstructure continues to evolve. Many questions exist regarding the behavior in very high strain zones. An interesting preliminary finding is that the common assumption that flow by grain boundary sliding produces random crystallographic fabrics is not correct. In these discussions some attention was given to superplastic behavior. It was noted that superplasticity is not mechanism specific, but rather is phenomenological and defined by a creep law with a stress exponent of less than two. There is a real need to understand the mechanisms that lead to superplasticity in fine-grained fault rocks.

ROLE AND NATURE OF FLUIDS IN FAULT ROCKS, FAULTS, AND SHEAR ZONES

Circulation of fluids is important in some geodynamic settings, such as in subduction zones and in plutonic regions. It is well known that fault zones may serve as conduits or barriers to fluid flow. Depending on the geometry of the fluid-flow field and the geometry and permeability structure of faults, faults may serve to focus fluid flow and to establish local sources and sinks for fluids. There is much evidence for the involvement of fluids in faults, and the physical and chemical effects of fluids on fault rocks may be profound, particularly for the fine-grained component of fault zones. Not surprisingly, there was much interest at the conference in the role of fluids in the genesis of fine-grained fault rocks.

Some concepts upon which there was extensive agreement included the notion

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GSA ON THE WEB

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In the **Education** section, read about GSA's educational programs, including **PEP** (Partners for Education), and Project Earth S.E.E.D.

See our **Administration** section for information on Congressional contacts.

Our **Publications** section now offers a lot. Read the tables of contents and **abstracts of journal articles** each month for *GSA Bulletin* and *Geology.* You'll also find **information for authors** on preparation of articles for submission to GSA publications. There are 12 months of complete issues of *GSA Today,* in living color, that you can read or download. Check out our new ***Retrospective Electronic Index*** to GSA journal articles, books, maps, and transects (see p. 7, March *GSA Today*). Search this index on line, and copy and paste results into your text editor. We're now on line with our **Web Catalog of GSA Publications.** Search all GSA's nonperiodical titles in print, read descriptions and tables of contents (for books), or copy from it. The exciting news this month is our new **Web Abstracts system.** From now until May 1, test drive it; after May 1, you'll be able to submit real abstracts electronically for the 1996 GSA Annual Meeting in Denver. See p. 18.

ENVIRONMENT MATTERS

Institute for Environmental Education

Geology as a Social Science: Addressing the Complexity of Human Habits and Values in Water-Quality Conflicts

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In a previous Institute for Environmental Education (IEE) column (February 1996), Dan Sarewitz suggested that geology is becoming more and more a social science, one that must address the conflict between land use and conservation of natural resources. He identified a primary frustration of geoscientists: the public just does not seem to listen to or appreciate all the hard work that appears to solve many environmental conflicts. He also touches upon the vast differences between what geoscientists and mainstream society value. In environmental conflicts, geoscientists, in the role of the expert, value data and its interpretation, whereas mainstream society tends to value beauty, environmental aesthetics, natural resource utility (usability), and safety. These different value orientations create a competing set of emphases on the way we perceive and interpret information pertaining to environmental conflict. Often the result is poor communication and misunderstanding between the scientist and the community, which may lead to a distrust of scientists as a whole. This lack of trust is NOT simply a reflection of scientific illiteracy on the part of the community; it reflects as well a general inability of the scientist to listen to the concerns of the community. The solution is to enter into a dialogue with the community. What should this interaction look like? The ideas presented here are based on analysis of a water-quality conflict centering on Skaneateles Lake in central New York.

A PROBLEM

Nowhere does the problem of environmental conflict appear greater than in the arena of non–point-source pollution of water. Because water is visible and has many functions, it is one component of the environment on which most people have some strong opinions. Compare water quality to invisible radon or underground storage tank debates, and you begin to see the "perceptual psychology" of water conflicts. For this and other reasons, issues surrounding water quality often evolve into multiparty, multi-issue, multiagenda disputes. In the case of the Skaneateles Lake conflict, water-quality deterioration was an important issue because the lake is both a source of recreation (some great lake trout!) and the main source of water for the city of Syracuse, some 20 miles to the east. Some of the parties involved in the dispute include the U.S. Environmental Protection Agency, the New York State Department of Environment Conservation, the town of Skaneateles, three county governments, the city of Syracuse, part-time and year-round residents, tourists, farmers, golf courses, businesses, citizen groups, and other environmental action groups. Many of these groups use the lake or the surrounding land for purposes that substantially contribute to water-quality deterioration, yet few saw themselves as part of the problem. The sources of the pollution include animal waste runoff, pesticides, herbicides, fungicides, fertilizers, septic tank leakage, and gas spills from boats, all of which are linked to the standard practices and habits of the communities surrounding Skaneateles Lake. Individuals or groups were good at identifying what others did to pollute, but often did not recognize that their habits contributed to the problem as well. At stake was either a change in habits that would result in cleaner water, or the construction of a multimillion-dollar water-filtration plant

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that the upper crust is "wet" and undergoes episodic deformation, leading to fluctuating or cyclic processes, including changes in fluid pressure, porosity, and permeability. Also, it has become very clear that the fluid history is a vital factor for consideration in any complete study of a fault zone, owing to its effect on diffusive mass transfer, dissolution and precipitation, changes in the bulk chemistry of the rock, and its role in fracture propagation. Some major questions raised included the nature of the fracture-controlled plumbing system, evolution of the pathway and its degree of closure with time, volumes of and continuous vs. transient flow of fluids, the directions of flow, and the fluid sources and sinks. More information is needed on the permeability and porosity of gouge; in situ measurements may be required. Another complication is that fluids passing through fine-grained fault rocks may leave little or no record of their passage, at least as can be detected through the traditional analytical methods.

RELATION BETWEEN FINE-GRAINED FAULT ROCKS AND SEISMICITY

The relation of fine-grained fault rocks to the seismic cycle elicited much interest and discussion. An important question repeatedly mentioned is, How do we distinguish mode of slip in ancient fault zones on the basis of fault-rock structure? Is the presence of pseudotachylyte in faults the only indicator of seismic slip? It is important to clarify the definitions of seismic and aseismic slip, because these terms originated in the field of seismology. It appears that most crustal faults are seismic. The San Andreas fault in California is an important case, because it contains both seismic and aseismic segments. However, it should be noted that the aseismic, creeping sections of the fault are actually characterized by continuous generation of microseismic events. Thus, mesoscopic- and microscopic-scale samples may contain structures produced during microseismic events within faults that would be regarded by seismologists as aseismic. Seismologists also classify earthquakes on the basis of rates of slip and slip duration. Normal earthquakes have slip durations on the order of seconds, whereas longer duration and lower slip rates produce events referred to as "slow earthquakes," "quiet earthquakes," and, over the longest duration, creep events. Thus the real question regarding structural criteria in fault rocks for seismic vs. aseismic slip should be posed in terms of the rates of deformation that produce fault-rock structures.

The issue of seismic vs. aseismic criteria within fault zones was a frequent topic of discussion. Pseudotachylyte was cited as the only reliable indicator of seismic slip, but even this is complicated in unusual settings. Pseudotachylytes have been described from impact settings and landslides, as well as the typical "tectonic" setting. In impact settings, such as Vredefort and Sudbury, shock melting and frictional melting may both contribute melts to form "pseudotachylytes." However, in the tectonic setting, there was a call against the

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and other technological “fixes,” the cost of which would be disproportionately borne by the communities and individuals who use the lake.

TOP DOWN FAILURE

Currently, the resolution of most environmental conflicts, such as the Skaneateles Lake issue, is top down. Federal regulations guide the state agency in identifying a problem, and the state agency enforces the regulations by telling the violator to clean up its act. This style of conflict resolution works well in two instances. The first is when an individual or company is clearly to blame (point-source pollution). The second is when there is a simple solution under a compliance agreement or a readily implementable technological fix. The top-down style of conflict resolution fails, however, when the habits of the community as a *whole* cause large-scale water-quality deterioration (non–point-source pollution). In such a case, improvement of water quality is dependent on the cooperation of the community with the state agency. This cooperation requires a significant change in the community’s perceptions about itself and its relation to the natural resources upon which it depends. Such a shift in focus—from individual or group needs to the needs of the community as a whole—is required to change the habits of land and water use that result in pollution. Perceptual shifts change attitudes and the way people interpret their own behavior. Our behavior is the source of pollution, and addressing the source can resolve the problem. Water treatment, however, is a temporary fix to an unsolved problem.

The typical top-down approach breeds a variety of noxious reactions that often block the needed cooperation between the community and government agencies. We call these reactions the four Rs: regulation, resentment, resistance, and refusal. The perceived job of the government agencies is to regulate communities with little regard for their needs and points of view. Time and again, this insensitivity results in community resentment over power imbalances and competing political agendas. Resentment triggers a resistance to change in personal and community habits and values, as well as an inability or refusal of the regulated community to see their current habits and values as part of the problem. Furthermore, the community often begins to view the government and consulting scientists with skepticism, more as part of the “problem” than as a group of people working toward a solution. This perception stems from the general tendency that most scientists are rarely, if ever, required to be involved with the community as part of their job. In fact, many scientists may never work with non–physical scientists (social scientists, political scientists, economists, business people, community leaders) or even ever take a non-science course beyond the undergraduate level. The role of geoscientists in this case is only to analyze the data and remediate; they are the ultimate consultants.

Although we acknowledge the role of the consulting geoscientist as an important one (we’ve both played the role), this role must be expanded to encompass community education if we are to play a leading part in resolving environmental conflict. Scientists must begin to address the social realities of the water-quality issue, such as the relative value of water in farming practices and recreational enjoyment. In the role of educators, scientists become a resource to the community that is learning, through a process of ongoing dialogue, about the relations between water usage and water quality.

BOTTOM-UP POTENTIAL

How does one become such a resource? First, to avoid partiality, or even the appearance of partiality, one cannot become an advocate for any of the involved parties (e.g., state agency, the consulting firm, the city). This need for impartiality suggests that academic scientists may be able to play a large role because of their institutional freedom of association. Second, LISTEN, LISTEN, LISTEN. It is less important to spew all your hard-earned knowledge than it is to listen to the concerns of members of the community, and to use these perspectives and interpretations of the problem as the starting point in the search for a solution of the community’s own making. In this sense, you become a professional “aide” to the community and a facilitator of community dialogue. In the Skaneateles Lake conflict, this was accomplished by scientists attending or facilitating public meetings, engaging in personal contact

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use of “pseudotachylyte” as a general term for unidentified black veinlike rocks. It is also possible that pseudotachylyte zones may not be associated with typical seismic faulting, but perhaps only with the initiation of faulting in crystalline rocks, possibly because the subsequent availability of water in established faults could suppress continued frictional melting.

METHODS FOR STUDY OF FINE-GRAINED FAULT ROCKS

Because the conference focused on fine-grained fault rocks, advanced techniques for analysis at the microscopic scale were discussed. It is important to study these rocks at the grain and crystal lattice scales because the fundamental processes of deformation and recovery do not necessarily reveal themselves at the mesoscopic level. The value of imaging with electron microscopy has certainly been demonstrated and is an important technique when using modern microchemical and dating techniques. In many cases the most difficult aspect of such studies is sample preparation and characterization. There will always be the problem of relating microscale features to the larger tectonic picture, but the rewards of careful microstructural analysis can be great. This was well demonstrated by studies of fault gouge. Remarkably, even the finest grained clays can preserve isotopic signatures and microstructures of deformation events over geologic time. Observational and experimental studies of clays and other phyllosilicates would seem to be an area of fruitful research.

A continuing major difficulty in the study of fine-grained fault rocks is the lack of good pressure and temperature constraints. In high-grade rocks—e.g., ultramylonites—fine grain size can be a problem, but at low grades—e.g., in the case of gouge and cataclasites—there are commonly no applicable thermobarometers, and disequilibrium is likely a problem for traditional exchange thermometers.

Laser techniques were hailed as a major improvement over previous methodology for radiogenic, stable isotope, and bulk-chemical analysis for fine-grained fault rocks. The advantages of in situ analysis, small sample size, low blank, rapidity of analysis, and ability to vaporize chemically refractory phases offer great future promise.

A somewhat longer, though still incomplete, summary of the conference is available. For a copy of the extended summary, contact any of the conveners or retrieve it electronically from http://www.eas.slu.edu/publications.

ACKNOWLEDGMENTS

The Geological Society of America, the National Science Foundation, and the U.S. Geological Survey National Earthquake Hazards Reduction Program provided partial support of the meeting. We thank Ben van der Pluijm for assistance with the NSF grant; all of the participants, who contributed to a very productive meeting; and Lois Elms, the meeting coordinator, for her efficiency and hard work that helped to make this meeting successful. ■

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with disputants, and acting as information resources. Thus, geoscientists can help translate technical issues into larger socioenvironmental issues.

In order to be successful in this role, geoscientists must learn how the lay person views environmental conflicts. In the highly rational, exploratory field of earth science, we focus on data interpretation that adheres to logical scientific argument. Yet for each issue in an environmental dispute, the community may also interpret information at several levels of analysis other than data. Figure 1 diagrams this phenomenon. Scientists typically solve a problem starting with data—the knowledge that is most extrinsic and negotiable to the community (funny how scientists never think of data as negotiable!)—and work down. This is the typical, top-down approach used in most environmental conflict resolution. From the Skaneateles Lake experience, we have learned that not all groups involved in an environmental conflict think the same, and that each group enters the conflict with relatively intrinsic, nonnegotiable values, needs, and beliefs. From the standpoint of values, not data, each group develops positions to protect group interests (a bottom-up or individual, needs-based approach). Scientists are trained to think, however, that the rigorous, data-based, scientific method is nonnegotiable, and that this method is superior to the value-based perspectives of other groups. In such situations, scientists may further anger an already skeptical and irate public by calling for "more research" when faced with complex environmental disputes.

The skepticism that the community has of "the scientist" resides in the overwhelming tendency of scientists to derive values from facts, in violation of Hume's dictum that an "is" is not the same as an "ought." As scientists, we must remember that values are intrinsic to the community (and typically nonnegotiable); they cannot be *derived* from scientific facts. Thus, the role of technical "expert" in which scientists tell people *how* to value the environment as derived from the data is doomed to fail. In the role of educator, however, scientists can change *what* the community values by changing the community's perception of its relationship to the environment. This perceptual change should be our ultimate goal, rather than giving a community a blunt—and commonly short-term—technical solution. To paraphrase J. Baird Collicott, the end result of genuine environmental education is a complete reorientation of a community to its surroundings.

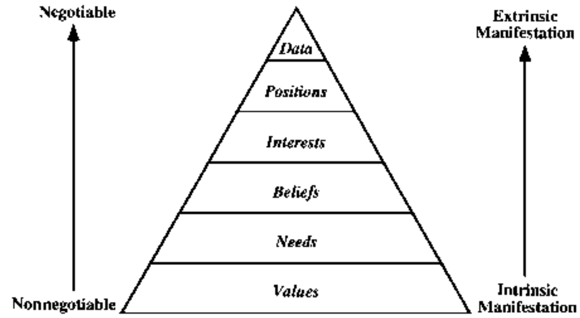

Figure 1. The bottom-up approach of the community to conflict. Scientists typically approach scientific problems from the top down.

APPLIED SOCIAL GEOLOGY

In a conflict-resolution dialogue, then, scientists should listen to the sometimes conflicting values and beliefs of community groups, and work with the community to develop a common ground, using data only as needed to address or answer questions. In essence, the scientist is no longer a technical expert but more appropriately a facilitator of dialogue and a conveyer of useful knowledge that the community can incorporate into its evolving solution. The most critical aspect of this dialogue is that the community must guide the discussion. Analysis of the Skaneateles Lake conflict shows that this approach may lead to several dead-end solutions that test the patience of the scientist (who "knows better"), but this path can result in the community taking control of its own destiny with a greater understanding of its role in both the problem and the solution, with the bonus of greater respect for the scientist. By allowing community participation and keeping the focus on collective decisions, the disputants are able to address the sources of pollution. In the case of Skaneateles Lake, one key result of this process was the allocation of funds to farmers for the construction of animal-waste containment systems that eliminated runoff into the lake.

We have also uncovered a few barriers in regard to this shift in the role of the geoscientist. If you are not willing to learn how people solve problems and work together, then you are not likely to be effective in this new role. Also, if you do not possess basic communication skills beyond simple articulation of ideas, then you may not succeed in making this role transformation. The ability to listen is only the first step; other skills are necessary. Oftentimes, establishing a sense of rapport or empathy is more important than letting people know that you heard their words. Those scientists we have seen as effective professional aides in the Skaneateles Lake negotiations are those who have an understanding not only of the scientific and technical factors but also of the human factor. They know the people they are working with and how basic human needs, values, and beliefs become intricate factors in resolving environmental disputes. Analysis of the Skaneateles Lake water conflict shows that the academic scientist who was also trained in group facilitation, mediation, and environmental negotiation had the greatest degree of success when facilitating meetings and when intervening with stakeholders.

In the end, we see the role of the geoscientist in public issues as evolving to that of "applied social geologist." We believe that applying some principles of the social sciences to the way geoscientists deal with the public will increase the value of our profession in the community. This will require fundamental changes both in the way geoscientists view complex, socioenvironmental problems and in the methods by which they solve these problems. The paradigm shift we envision may not make our work easier in terms of the normal practice of solving geological puzzles, but it certainly can improve the effectiveness of our participation in large-scale environmental disputes, and can put geoscientists in a leading role. Besides, this is what the public is telling us to do. It's about time we listened! ■

April and May IEE-sponsored Events

The Roy Shlemon Mentors in Applied Geology program offers undergraduate seniors and graduate students the opportunity to learn about professional and intellectual challenges of careers in a broad range of applied environmental geosciences. The first workshops under this program will be presented in April at the GSA Cordilleran Section and Rocky Mountain Section meetings, and in May at the North-Central Section meeting.

IEE is also sponsoring or cosponsoring technical program events at upcoming section meetings. ***Cordilleran Section:*** Geoscience Input in Water Resource Decision Making: Case Studies from Portland, Oregon (symposium); Site Characterization and On-site Remedial Solutions (theme session). ***North-Central Section:*** Applications of Hydrogeology in Agricultural Water-Quality Studies (symposium); Hydrogeology and Water Quality of the Walnut Creek Watershed (field trip); Hogs, Bogs, and Logs: Quaternary Deposits and Environmental Geology of the Des Moines Lobe (field trip).

For more information on these events, see section meeting announcements in the January and February issues of *GSA Today.* For information about the Institute for Environmental Education, or to become a member of IEE's Geology and Environment Public Outreach Program, contact Daniel Sarewitz, IEE Program Manager, P.O. Box 9140, Boulder, CO, 80301, (303) 447-2020; E-mail: iee@geosociety.org.

LETTER TO THE EDITOR

The U.S. Geological Survey's Reduction-In-Force

The November 1995 issue of *GSA Today* carried an unattributed account of the U.S. Geological Survey (USGS) reduction-in-force (RIF), apparently prepared by USGS managers. That account overstates the need for such a deep cut in scientific and technical staff and fails to describe the poor implementation and haphazard procedures employed in the RIF. Inadequacies in implementing the RIF resulted from three major factors: (1) an extremely short timeline that did not allow for careful execution of staffing and RIF procedures, (2) recategorizing scientists into ultra-narrow specialty groups just prior to the RIF, which violated substantive employee rights, and (3) giving responsibility for all of the major aspects of the RIF to lower level managers who had no overall plan on which to base their decisions. These factors resulted in an earth science program with significant gaps and a demoralized workforce, which will impair the ability of the USGS to provide quality earth science in the public interest.

Background—Two Agendas

The USGS initiated the RIF on August 11, 1995, and effected the RIF actions between October 7 and October 14, 1995. The Specific Reduction in Force Notice states, "This reduction is necessitated solely due to shortage of funds *and reorganization* of the Geologic Division within the U.S. Geological Survey" [emphasis added]. The reorganization of the Geologic Division, implemented October 1, 1995, was integral to the RIF, for it defined the jobs to be kept or abolished in the RIF. The reorganization was not mentioned as a reason for the RIF in the *GSA Today* article. Perhaps this was because a budget-driven RIF and a mission-driven reorganization are such obviously conflicting goals, and readers might wonder about the extremely short time frame allowed by USGS management for planning and implementation.

Immediately following election of a new U.S. Congress in November of 1994, the USGS appeared to be threatened with abolishment, as part of the "Contract with America." Well before March 9, when the general RIF Notice was issued, broad support for USGS had surfaced in press reports and in calls to Congress from the earth science community, local and state governments, and members of the general public. By May, abolishment was no longer an issue and the "worst case" scenario was a 20% budget cut for fiscal year 1996, requiring a reduction of about 600 employees.

To ease the apparent need for involuntary staff reductions, three buyout opportunities were offered to USGS employees between May 1994 and August 1, 1995. Together, the buyouts netted 405 retirements in the Geologic Division, and shrank its staff to ~2,200 (a 16% reduction). An additional 641 Geologic Division positions were to be abolished in the RIF, according to the staffing plan issued in May 1995. The USGS Director promised the House and Senate Appropriations Subcommittees responsible for the USGS budget that "if the financial situation improves" he would add back positions.

By August 1, 1995, the proposed USGS budget contained a small actual increase over the 1995 budget, and approximately $40 million of funding had been restored. Nonetheless, when the Chief Geologist released a list of add-backs on August 2, 1995, it contained only 100 positions, of which 84 were actually filled. Thus, between May of 1994 and October 14, 1995, the effective date of the RIF, the Geologic Division's staff was reduced 36% (to ~1,650) in response to a "worst case" 20% budget cut that has not materialized. (As of February 1996, the FY 1996 USGS budget had not been finalized).

The RIF Process[1]

Contrary to assertions of USGS managers, the 1995 RIF was as ill-planned and poorly managed as it was ill-timed. The short interval allowed for planning both the reorganization and the RIF provided no time for external review of internally set objectives, past/future programs, or staffing decisions. The staffing plan was devised *in camera* by lower level managers with little oversight. As a result, many staffing decisions can be traced to favoritism and retribution rather than to a basis in jobs required by programmatic priorities.

To implement the RIF, the Geologic Division devised a strategy that circumvented normal procedures and involved numerous personnel practices that are prohibited by law. For example, in the "first round" of a RIF, employees whose positions are abolished are allowed to compete for encumbered and vacant positions that have job descriptions similar to those of their own (i.e., jobs within their "competitive level"). The USGS RIF largely circumvented first-round competition and enabled the firing of almost any targeted individual. Here is how it was done.

Staffing Plans. In late March 1995, supposedly "unpopulated" generic Staffing Plans were developed for the Division under a reorganization plan by the Division's outgoing lower and middle managers (Branch and Office Chiefs). All of these managers were designated as "acting" and were to compete for scientific positions for the purpose of the RIF. The plans were prepared *in camera*, with no formal record of the process, and were finalized in late June 1995, at Reston, Virginia, in secret meetings that were followed, apparently, by destruction of records of the proceedings. The process was largely complete before appointment of the new Chief Geologist, and lacked oversight by the acting Chief who preceded him or by the Director. As a result, the Branch and Office Chiefs selected the individuals, rather than the jobs, to be retained. Some of these managers advised favored staff members how to modify their Position Descriptions to survive the RIF. Modifications of Position Descriptions included adding of detail not normally found in a Position Description to enhance "uniqueness." In some cases, false entries were made, such as duties not actually being performed. Falsification and certification of falsified Position Descriptions are criminal offenses.

A committee of Geologic Division scientists was assigned by the Acting Chief Geologist to review the staffing plan. This committee produced serious criticisms of the plan, noting:

> "The plan under review that will lead to a separation of several hundred employees of the Geologic Division is flawed by the lack of time and information to analyze lost capabilities, by the uncertain retention of our broadest, most productive, and entrepreneurial personnel, and by the lack of vision of what the Division should become."

> "The committee has a number of concerns ... not the least of which was the inability of the committee to see in some plans a clear link between the broad plans discussed and the positions to be preserved."

Management publicly praised the committee, but never openly discussed its conclusions. Perhaps not surprisingly, a final version of this report was never issued. Such a major reorganization would have profited from outside review. Given a reasonable amount of time, input from university, industry, and other federal scientists could have provided a more balanced review of proposed research and applied science activities with respect to overall scientific importance and appropri-

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[1] All assertions contained in the following commentary are documented by a number of independent requests under the Freedom of Information Act and by documents obtained in the discovery process of current appeals of the RIF.

CALENDAR

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

1996 Penrose Conferences

April

April 17–22, **Tectonic Evolution of the Gulf of California and Its Margins,** Loreto, Baja California Sur, Mexico. Information: Paul J. Umhoefer, Department of Geology, Box 4099, Northern Arizona University, Flagstaff, AZ 86011, (520) 523-6464, fax 520-523-9220, E-mail: pju@nauvax.ucc.nau.edu.

October

October 8–14, **Exhumation Processes: Normal Faulting, Ductile Flow, and Erosion,** Island of Crete. Information: Uwe Ring, Institut für Geowissenschaften, Universität Mainz Becherweg 21, D-55099 Mainz, Germany, 011-49-6131-392164, fax 011-49-6131-394769, E-mail: ring@mzdmza.zdv.uni-mainz.de.

1996 Meetings

May

May 18–24, **Natural and Anthropogenically Induced Hazards: Large Earthquakes in the Geological Record,** Corinth, Greece. Information: J. Hendekovic, European Science Foundation, 1 quai Lezay-Marnesia, 67080 Strasbourg Cedex, France, phone 33-88-767135, fax 33-88-366987, E-mail: eurescoesf.org, WWW: http://www.esf.org.

May 19, **Hubbert Quorum** Spring Meeting, Baltimore, Maryland. Information: Grant Garven, Johns Hopkins University, (410)516-8689, E-mail: garven@indigo.eps.jhu.edu; Jeff Raffensperger, University of Virginia, (804) 924-0581, E-mail: jpr2y@virginia.edu.

May 22–23, **Society of Petroleum Engineers Western Regional Meeting,** Anchorage, Alaska. Information: Mike Stover, Marathon Oil Co., (907) 564-6403.

July

July 11–14, **Nevada Petroleum Field Conference and Trip,** Cenozoic Structure and Stratigraphy of Central Nevada. Information: Wanda J. Taylor, Dept. of Geoscience, University of Nevada, Las Vegas, (702) 895-4615, E-mail: wjt@nevada.edu, or Joan E. Fryxell, Geology Dept. California State University at San Bernardino, (909) 880-5311, E-mail: jfryxell@wiley.csusb.edu.

September

September 27–28, **Great Lakes Section of SEPM Fall Field Conference,** The Silurian Dolomite Aquifer of the Door Peninsula: Sequence Stratigraphy, Facies, Porosity and Hydrogeology, Green Bay, Wisconsin. Information: Mark T. Harris, Geosciences Department, University of Wisconsin—Milwaukee, P.O. Box 413, Milwaukee, WI 53201, (414) 229-5777, fax 414-229-5452, E-mail: mtharris@csd.uwm.edu.

October

October 18–20, **New York State Geological Association,** Staten Island, New York, Information: Alan Benimoff or Anderson Ohan, Dept. of Applied Sciences, College of Staten Island, 2800 Victory Blvd., Staten Island, NY 10314, (718) 982-2835,-2829, E-mail: benimoff@postbox.csi.cuny.edu or ohan@postbox.csi.cuny.edu.

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

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ateness to a Federal research agency, and of the kind of qualifications needed. An open, documented process of staffing with external review would have gone far to eliminate the problems of egregious favoritism.

Competitive Levels. Competitive levels for Geologic Division personnel have been identified and coded for many years. Before the RIF, the competitive level codes (CLCs) for earth scientists and technicians were based on academic training, previous work experience, and current assignment, and represented broadly defined areas of expertise such as “regional bedrock geology,” “structural geology,” “mineralogy,” and “paleontology.” Those engaged in broadly similar work were assigned the same CLCs, and by practice were considered interchangeable. Scientific breadth, depth, and adaptability were hallmarks and strengths of the scientific staff.

Early in 1995, shortly after announcement of the RIF, USGS management completely revised the CLCs. Nearly every research position in the Geologic Division was allocated a separate and unique competitive level. For example, in Spring of 1995, shortly before this process began, 20 members of three Branches in the Menlo Park, California, office had the same CLC. After the revisions, this single CLC became 20 one-person CLCs, thus completely eliminating competition between those employees for the seven positions retained. Whereas the pre-RIF CLC descriptions were generic, the narrative descriptions for the new CLCs were excerpts from individual Position Descriptions, which had been rewritten by the incumbents for the purposes of the RIF.

In the Western Region, a seven-member committee had only two weeks to evaluate the rationale for establishing each unique, noninterchangeable CLC for every scientist and technician in the Western Region; other committees performed the same task independently for the Central and Eastern Regions. Contrary to management’s assertion that this evaluation was done with care and deliberation, these committees did not have time even to review the position descriptions, and were confused about the tasks to be performed. As recorded by one of the regional committees, “... information from the Division was either equivocal, contradictory, or too vague to be useful, and the limited time available for panel deliberations allowed only a cursory evaluation of the competitive level codes (CLC) and the *uniqueness* or *interchangeability* of positions.” In response to a question on procedures, the RIF Coordinator for CLC issues confessed to a group of Branch Representatives, “We’re making this up as we go.” Members of one of the regional committees “... found the experience to be confusing, frustrating, and discouraging. Certainly the experience did not inspire any confidence that the CLC validation and subsequent crucial steps in the RIF process would be taken any more thoroughly or comprehensively, given the very tight time line imposed by the Division.”

Fundamental questions about the CLCs were put to the RIF Coordinator by these committees (how is the work unique if the only substantive distinctions between two CLCs come down to experience of one geologic province versus another?), and the only answer they received was that these issues should be considered on a “case by case basis,” despite the lack of time to do so. Nevertheless, the largely unique CLCs were “validated” by a team containing some of the same managers who had established the staffing plan and had a vested interest in the use of unique CLCS.

The “second round” of a RIF is a complex process, called “bump and retreat,” in which employees whose jobs are abolished may “bump” other employees with less tenure or on the basis of veteran’s status, or “retreat” into positions they have previously held, similarly displacing the incumbent. Committees of scientists and Branch managers evaluated the qualifications of released employees to bump or retreat into certain positions. This part of the RIF process opened the way to further abuses and conflicts of interest.

The way the managers who created the Staffing Plan treated each other echoes the favoritism that dominated all RIF procedures. The top-heavy pre-RIF Geologic Division had about 75 managers, most of whose jobs were abolished in the restructuring. In a standard RIF, the incumbents of those jobs would have been separated. In the Geologic Division RIF, however, only one manager—a woman who had filed complaints—actually lost her job. Many of the managers had been away from science for many years, but nearly all now occupy newly created, “scientific,” positions, each with a unique CLC, in the restructured Division, and have retained their large administrative salaries. Whereas all other staff were evaluated strictly on the basis of current duties, managers’ position descriptions commonly cited duties performed years ago or functions no longer performed or needed. Also retained were the USGS employee-spouses of managers and nearly all senior assistants of the former managers.

The degree of influence of Branch Chiefs on the staffing plan and evaluation processes is easily demonstrated. Many excellent scientists and technicians were fired because they had disagreed with their supervisors personally or professionally, or in some cases politically. Whistleblowers were targeted. One Branch Chief kept all

Letter *continued on p. 41*

Letter *continued from p. 40*

who accepted his pet methodology and fired those who did not; another fired many of those who had protested a proposed move of duty station for their research group. In some branches the dominant survivors are co-located with the Branch Chiefs or have the same specialty whether or not those locations and specialties have relevance for the restructured Survey. Firings by specialty are otherwise inexplicable; for example, nearly all marine sedimentologists were retained, yet many dry-land ones were fired. The duties of some of those fired have been taken on by survivors despite the positions having been abolished. Staff for whole projects were fired and the functions transferred and reassigned without competition. Women scientists and technicians were fired in much higher proportions (38%) than their pre-RIF numbers (27%), and 50% of women in all jobs were separated. More than half of all support personnel were fired even though the ratio of technical support to research scientists was already so low as to impede operations.

Conclusions

The RIF procedure is not effective for downsizing scientific organizations, especially as it was run by the USGS. Complex and constantly changing assignments and specialties make it very difficult to categorize scientists according to traditional government methods. Earth scientists, especially, tend to be broadly trained and adaptable to many subdisciplines, in contradiction to the pigeonholing used in the RIF to avoid competition.

Conducting a RIF simultaneously with a major reorganization, and in the absence of a well-formed long-term plan, has proven especially foolish. A reorganization as complex as was needed in the Geologic Division required time for careful consideration, and needed objective oversight from both inside and outside the USGS. Some of the issues that could and should have been resolved before the downsizing are (1) How can the unbiased nature of federal earth science best be protected for the long-term interest of the Nation? (2) What "core" scientific capabilities should the USGS have in order to respond rapidly to short- and long-term local, State, and National needs? (3) What are the pressing and appropriate areas of long-term basic research for the USGS?

The losses to the USGS cited in the November *GSA Today* article—mostly holes left in particular functions—are not the most serious ones, although the dollar costs of restoring needed capabilities will be huge. The toll that the RIF has taken on those who remain as well as those who were "separated" is measured instead in morale, allegiance, and willingness to speak out on controversial issues. The fact that the actions taken by USGS management violated substantive rights of employees is not lost on the survivors or the larger earth science community. Stumbling in the Division's effort to reorganize has compounded the devastating effects of the RIF on morale. No good for science came from this RIF, and the prospects for survival of the Division and the Survey as institutions with something valuable to offer the public and the scientific community have been dealt a severe blow.

A surviving senior geologist, deploring the RIF procedure in a recent alumni newsletter of his university, spoke for most Survey scientists: "The USGS as an organization of colleagues bound together by mutual trust is gone forever."

Whether the above quote describes the future USGS is a matter of choice. The RIF and reorganization will affect the USGS, the scientific community, and the public for many years to come, long after present management has departed. The decisions therefore demand a careful reconsideration, with broad input from the earth-science and earth-science-user communities. Steps to help recapture the spirit of the Geologic Division and make it more effective could include: (1) assemble panels of distinguished scientists from inside and outside the organization to review the Division's organizational plans, and its missions and goals, especially with regard to the appropriate balance between applied science and basic research; (2) reinstate employees affected by the RIF who are still willing to return; (3) establish and use a credible, rigorous and objective system to evaluate employee (including managers) performance and value as an avenue for honing the organization and for any needed downsizing; (4) strive to restore a workplace where people are valued and their opinions important; and (5) allow free and open discussion of all issues, especially the difficult ones. A careful and deliberate reshaping of the Geologic Division could begin to reconstruct its damaged reputation and once again encourage its staff to give their best, and thus preserve the Geological Survey's value as a source of unbiased, authoritative science information.

Mary Dryovage
Law Offices of Mary Dryovage
San Francisco, California

Jeff Rush
General Counsel, Public Employees for Environmental Responsibility
Washington, D.C.

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Robert L. Fuchs

Brud Leighton Joins Board of Trustees

Morris W. "Brud" Leighton

Morris W. "Brud" Leighton was appointed to the Foundation's Board of Trustees, filling the vacancy resulting from the resignation of Fred Donath. At the conclusion of this partial term in October 1998, Leighton will be eligible to serve a new five-year term on the board. New trustees are selected and appointed by the board from a list of candidates approved by the GSA Council. Trustee terms of office are five years, and individuals can serve a maximum of two consecutive five-year terms, not including completion of the unexpired part of a predecessor trustee's term.

Brud Leighton is from the heartland of the United States. He began his career in geology with degrees from the University of Illinois (B.S., 1947) and the University of Chicago (M.S., 1948; Ph.D., 1951). He ended his formal working career as chief of the Illinois State Geological Survey, retiring in 1994. In the 32 years between graduation and appointment as chief of the Illinois Survey in 1983, Leighton enjoyed a geographically broad affiliation with Exxon Corporation and its predecessors in geology, research, and exploration management. Exxon highlights included research on reef-bearing strata, development of a carbonate rock classification, worldwide basin studies, management of exploration in Australia and the Bass Straits, and management positions in the Houston research laboratory, as chief geologist of Exxon's regional affiliate for Latin America.

When Brud Leighton became survey chief, he assumed a very visible public role, attested to by the many societies, committees, task forces, commissions, and boards on which he has served during the past 12 years. He has been particularly active in the Association of American State

Leighton *continued on p. 43*

Metsger and Nadeau Running Northeastern Section Campaign

Robert W. Metsger of Sparta, New Jersey, has replaced Jack Oliver as Second Century Fund chair for the Northeastern Section. A Senior Fellow of the Society, Metsger joined GSA in 1955. He has been active in the Northeastern Section, serving as chair in 1981, and also served three years on the Committee on Geology and Public Policy. As a student aid from Columbia, Metsger attended GSA's 50th annual meeting in New York in 1938; he was also at the Centennial meeting in Denver in 1988.

Bob Metsger has a degree in geology from Columbia (A.B., 1948), his years at that university lengthened due to World War II. As a naval communications officer, he served first on a destroyer and then took part in the invasions at Casablanca, Salerno, southern France, and Iwo Jima. After graduation, Metsger joined the New Jersey Zinc Co. at the Ogdensburg mine in northern New Jersey. He worked for NJZ until retirement in 1988, in mining geology and exploration in the northeast and at company properties elsewhere in the United States. Metsger maintained his ties to Columbia and Lamont-Doherty, collaborating with Jack Oliver and Maurice Ewing on an early geophysical observatory at Ogdensburg. In addition to consulting work for NJZ, he heads the retired commissioned officers association of northern New Jersey and is an Episcopal church senior warden.

Assisting Metsger as Vice Chair of the Northeastern Section campaign is Joseph E. Nadeau of Rider University in Lawrenceville, New Jersey. He is associate dean of science, having joined the Rider faculty in 1971. Nadeau received degrees from the University of Illinois (B.S., 1965), University of Tennessee (M.S., 1967), and Washington State University (Ph.D., 1971). His scientific specialization has been sedimentary and water mass chemistry, with field studies focused on Bermuda and the Caribbean. He is vice chair of the board of the New Jersey Marine Science Consortium.

Joe Nadeau brings considerable fund-raising experience to the Northeastern Section's campaign. He has served on Rider's Science Advisory Board, which entailed close interaction with the school's development function. Nadeau was on the board of trustees and an active money raiser for the Peddie School, a private prep school. He is a member of the council of the Yellowstone Bighorn Association and on the selection board of the Barry Goldwater National Science Scholarship program.

Both Metsger and Nadeau, in agreeing to work for the Second Century Fund, were quick to point out the need for volunteers in the Northeastern Section to join the team. The heart of the membership campaign is the personal contact and follow-up among members. If you have some time (not much is needed) to assist in this work, which will benefit the section's endowment as well as other GSA programs, please call Bob Metsger at (201) 729-7824 or Joe Nadeau at (609)896-5314. If you are a member of one of the other five GSA Sections, call or E-mail the Foundation office or send in the accompanying coupon. ■

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$225,000	$165,000	$210,000

Leighton *continued from p. 42*

Geologists—president in 1992–1993 and now an honorary member. Leighton made a distinguished lecture tour under American Association of Petroleum Geologists sponsorship in 1990. He has spent untold hours on matters and issues of both public and scientific importance, such as clean coal research, water resources, oil and gas recovery research, earthquake preparedness, geologic mapping, geographic information systems, and fund-raising for the geology department at the University of Illinois.

Leighton's family is a geology family. His father, Morris M. Leighton, was also chief of the Illinois Survey. His brother, Beach Leighton, is the retired founder and chairman of Leighton Associates, a leading geotechnical firm in the Los Angeles basin. Beach Leighton was also a GSA Foundation trustee, from 1987 to 1992, and he served as chair of the board in 1990. The Foundation's current Chair, Charles Mankin, said, "We were very sorry to lose Fred Donath, who gave countless hours to IEE and the Foundation for seven years. His departure created a serious vacancy, but I feel much better now that Brud Leighton has joined the board. During our acquaintance over many years, particularly in the AASG, I have found that Brud is efficient, effective, and extraordinarily dedicated to the job at hand. He has a strong commitment to public service and is one of our most knowledgeable geologists when it comes to understanding the ins and outs of government. These qualifications are a real asset to the Foundation and to GSA." Welcome, Brud. ■

IDEA:
A Tax-efficient Way to Support Elderly Relatives

Are you providing some financial support for your parents, an aged aunt, great uncle Al? Would you like to do this in a more tax-efficient way? Have you been thinking about a contribution to the GSA Foundation? A charitable remainder trust could be the answer. The creation of such a trust that pays income to a relative gives the donor a tax deduction, the amount based on the beneficiary's age and the trust payout. Call the Foundation to get more details about a better way to do something you may already be doing. ■

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Committees *continued on p. 45*

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1996

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Marriott City Center

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Colorado School of Mines, Dept. of Geology & Geological Engineering, Golden, CO 80401, (303) 273-3819, fax 303-273-3859
E-mail: jhumphre@mines.edu

Field Trip Chairs:
Charles L. Pillmore, *(303) 236-1240 and*
Ren A. Thompson, *(303) 236-0929*
U.S. Geological Survey, MS 913, P.O. Box 25046, Denver Federal Center, Denver, CO 80225

Call for Papers and First Announcement appears on p. 17 of this issue of *GSA Today.*

1997

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fax 208-236-4414
E-mail: linkpaul@isu.edu

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Department of Geology
Brigham Young University
Provo, UT 84602-4646
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GSA SECTION MEETINGS — 1996

ROCKY MOUNTAIN SECTION, ***April 18–19, 1996.*** Rapid City Civic Center, Rapid City, South Dakota. Information: Colin Paterson, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 East St. Joseph St., Rapid City, SD 57701-3995, (605) 394-5414, E-mail: paterson@silver.sdsmt.edu.

CORDILLERAN SECTION, ***April 22–24, 1996.*** Red Lion Hotel at Lloyd Center, Portland, Oregon. Information: Michael Cummings, Department of Geology, Portland State University, P.O. Box 751, Portland, OR 97207-0751, (503) 725-3022. E-mail: michael@ch1.pdx.edu.

NORTH-CENTRAL SECTION, ***May 2–3, 1996.*** Iowa State University, Ames, Iowa. Submit completed abstracts to: Kenneth E. Windom, Department of Geological and Atmospheric Sciences, Iowa State University, 253 Science I Building, Ames, IA 50011-3210, (515) 294-2430, E-mail: kewindom@iastate.edu.

Student Travel Grants

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North-Central*	George R. Hallberg, (319) 335-4500
South-Central	Rena M. Bonem, (817) 755-2361
Northeastern	Kenneth N. Weaver, (410) 554-5532
Southeastern	Harold H. Stowell, (205) 348-5098, http://www.geo.ua.edu/segsa/segsa.html

**Do not offer funds for travel to the Annual Meeting.*

Committees *continued from p. 44*

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

GSA Member of the AGI Government Affairs Program Advisory Committee
E-an Zen, 1995–1997; Dan Sarewitz, 1996–1997 (alternate)

GSA Representatives to the American Association for the Advancement of Science (AAAS)
Section E—Geology and Geography: J. Thomas Dutro, Jr., June 1, 1985–February 23, 1997; *Section W*—Atmospheric and Hydrospheric Sciences: John G. Weihaupt, July 1, 1988–February 23, 1997

GSA Representatives to the AAAS Consortium of Affiliates for International Programs (CAIP)
James W. Skehan, S.J.—President, GSA International Division; Donald M. Davidson, Jr.—GSA Staff Liaison

GSA Representatives to the North American Commission on Stratigraphic Nomenclature (NACSN)
Lee C. Gerhard, 1993–1996; James O. Jones, 1994–1997; W. Burleigh Harris, 1995–1998; Representative-elect: Ernest A. Mancini, 1996–1999 (term begins during the NACSN 1996 fall meeting in Denver)

GSA Representative to the *Treatise* Editorial Advisory and Technical Advisory Boards of the Paleontological Institute
Richard Arnold Davis—Chair, *Treatise on Invertebrate Paleontology* Advisory Committee

GSA Representatives to the Joint ASCE-GSA-AEG Committee on Engineering Geology (American Society of Civil Engineers, Association of Engineering Geologists)
John D. Rockaway, July 1, 1990–June 30, 1996; (vacant position; appointment to be determined)

GSA Representative to the U.S. National Committee on Tunneling Technology
(to be determined)

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

GSA and AASG Selection Committee for the John C. Frye Memorial Award in Environmental Geology (Association of American State Geologists)
Frank E. Kottlowski—Chair, AASG representative; John P. Kempton, GSA representative, 1995–1997; James Robertson, AASG representative ■

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Positions Open

GEOLOGICAL ENGINEERING
MONTANA TECH

The Department of Geological Engineering at Montana Tech invites applications for a tenure-track faculty position in hydrogeology/geochemistry. The appointment will be at the rank of Assistant Professor starting August 1996. A Ph.D. is required at the time of appointment. Registration as a Professional Geologist or Engineer is not required at the time of appointment, but is a prerequisite for tenure and promotion to the rank of professor. The candidate must possess the demonstrable ability to blend aqueous or/and isotope geochemistry and hydrogeology. The successful candidate will be expected to teach a rigorous introductory course in groundwater hydrogeology and other core courses in the undergraduate program, as well as courses in their areas of specialization. He or she should have a strong commitment to teaching, as well as to research and publication. Montana Tech is a unit of the University of Montana with an enrollment of approximately 2,000 students. The college has a strong tradition of undergraduate and graduate engineering instruction and research related to the mining and energy industries, with more recent emphasis on hydrogeological and environmental engineering. Montana Tech also offers degrees in chemistry and geochemistry, mathematics, computer science, occupational safety and health, business, and in the liberal arts. Montana Tech is located at Butte, in beautiful and geologically interesting southwestern Montana. There are abundant opportunities for outdoor recreation in the immediate area. Application deadline is April 15, 1996. Filling this position is contingent upon funding. Applicants should forward a resume; a description of their teaching and research interests; and the names, addresses, and telephone numbers of three references to: Chair, Search Committee, Department of Geological Engineering, Montana Tech, 1300 West Park St., Butte, MT 59701-8997. Montana Tech is an affirmative-action/equal-opportunity employer.

DIRECTOR
Ralph Roberts Center for Research in Economic Geology
Mackay School of Mines, University of Nevada, Reno

The Department of Geological Sciences, Mackay School of Mines, University of Nevada, Reno, invites applications and nominations for the position of Director of the newly formed Ralph Roberts Center for Research in Economic Geology (CREG), which is presently pending approval by the Board of Regents. CREG is a joint research unit involving geologists of the minerals industry of the State of Nevada, faculty of the Department of Geological Sciences and scientists of the U.S. Geological Survey. The Center will initially focus on developing a better understanding of the characteristics, occurrence, geological controls and conditions of formation of Carlin-type disseminated precious-metal deposits, which are important to the State of Nevada. A multidisciplinary approach involving deposit-to regional-scale stratigraphic, structural, geochemical, mineralogical, petrological, etc. studies will be emphasized.

The Director will be responsible for coordination and communication between the various individual and groups involved, facilitating project activities and reporting results to a Steering Committee composed of senior-level geologists from the minerals industry. Along with other faculty, the Director will be involved in the initiation, implementation and supervision of various graduate student research projects. Time will be available for personal research, with the expectation of significant contributions.

The successful applicant should have a Ph.D. degree (or equivalent) in the geological sciences and experience in mineral exploration and/or production. Research and publication in scientific journals, knowledge of sedimentary rock-hosted gold deposits and a record of productive scientific and professional involvement with individuals in industry, government and academia are highly desirable. The applicant must possess proven interpersonal skills and be able to deliver research products in a timely and cost-effective manner. The position is industry-supported, nontenure track, funded for a minimum of two (2) years, with possibility of future tenure-track appointment, contingent upon funding, with a twelve-month salary and benefits based on experience and qualifications.

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The Department of Geosciences at Penn State seeks up to four exceptional individuals in the broad area of surficial processes and hydrosciences, at the junior or senior level. Rank, salary, and tenure status will be commensurate with prior experience and qualifications.

We seek outstanding scientists and educators pursuing research in any of the following or related fields: physical hydrogeology, chemical hydrogeology, environmental geochemistry, soil geochemistry or mineralogy, geomorphology, and water-rock interaction. We are particularly interested in individuals whose research spans one or more of these fields and includes application to modern and/or paleo-environmental problems.

At the senior level we seek leadership and initiative to bring together departmental and campus-wide faculty for collaborative research and teaching in the hydrosciences. The successful candidates will join a large, dynamic and well-equipped department dedicated to innovative teaching and research, which seeks a national and international leadership role in these fields. Appointments are also available, as appropriate, as associates of the Earth System Science Center, an interdisciplinary research center in the College of Earth and Mineral Sciences.

Applicants should demonstrate a history of, or potential for, funded research and high-quality teaching. A Ph.D. is required at the time of appointment. Applications should include a complete resume, examples of published work, a statement outlining teaching and research interests and the names and addresses of at least four (4) individuals who could provide references. Send application materials to: HEAD, DEPARTMENT OF GEOSCIENCES, 503 DEIKE BUILDING, DEPT. GSA, THE PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PA 16802.

The search process begins immediately and will continue until suitable candidates are identified.

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Women and Minorities Encouraged to Apply.

Applications, complete with letter of interest, summary of relevant experience, and the names of three or more referees, should be submitted to the Chairman, CREG Search Committee, Department of Geological Sciences, MS 172, University of Nevada, Reno, Reno, NV 89557. Additional information can be obtained from Dr. Richard Schweickert at 702-784-6901 (E-mail richschw@ equinox.unr.edu; fax 702-784-1833) or D. C. Noble (tel & fax 702-784-6928). Application review will begin June 1. The University of Nevada is an affirmative action, equal opportunity employer.

GEOLOGY FACULTY

The Department of Geological Sciences at Salem State College invites applications for a full-time Fall Semester (September 1996 – January 1997) sabbatical replacement faculty position at the rank of Assistant Professor, A Ph.D. or completion of all requirements by time of appointment is preferred but ABDs will also be considered. We seek candidates from the field of geomorphology with a strong quantitative background and demonstrated computer skills. A commitment to undergraduate education and quality teaching is essential. Major teaching responsibilities include introductory Geology and an upper level course in Geomorphology. Salary is competitive and commensurate with education and experience.

Application review will begin immediately and continue until an adequate pool is achieved.

To apply, send letter of application, resume and three letters of reference to: Office of Equal Opportunity and Human Rights, Salem State College, 352 Lafayette St., Salem, MA 01970.

Salem State College is an equal opportunity/affirmative action employer. Persons of color, women, and persons with disabilities are strongly urged to apply.

APPOINTMENT IN EARTH SCIENCE
HARVARD UNIVERSITY

The Department of Earth and Planetary Sciences, Harvard University plans to make two appointments in areas dealing broadly with paleoclimate and surficial or near-surface processes.

The appointments will ordinarily be made at the junior level, although in exceptional circumstances a senior appointment may be considered.

In addition to carrying out an active research program, the successful candidate will be expected to teach at both the undergraduate and graduate levels. The appointments are expected to start in the spring or fall of 1997.

Applicants should send curriculum vitae, descriptions of research and teaching interests, and names of three references to Geology Search Committee, Department of Earth and Planetary Sciences, Harvard University, 20 Oxford Street, Cambridge, MA 02138. Applications are due by 1 May 1996.

Harvard Univerisity is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

THE UNIVERSITY OF TEXAS AT EL PASO
ASSISTANT/ASSOCIATE PROFESSOR
SEDIMENTARY GEOLOGIST
DEPARTMENT OF GEOLOGICAL SCIENCES

UTEP's Dept. of Geological Sciences is seeking a sedimentary geologist with primary interests in clastic sedimentary processes & depositional environments. We are seeking a person with active research interests in the origin, characteristics, transport, & deposition of clastic sediments. Reservoir or aquifer characterization & modeling are also appropriate fields of research interest. UTEP graduates enter both the resource & environmental fields; the person in this position should be able to teach courses in sedimentology, sedimentary petrology, & physical stratigraphy/depositional systems appropriate to these career paths. Research excellence & ability to obtain funding for research will be of fundamental importance. In addition, a commitment to excellence in both undergraduate & graduate instruction is essential. Position is tenure-track, & qualified persons will be considered forAssistant, Associate, or Full Professor appointment. Position is available 09-01-96. Ph.D. required at time of appointment.

UTEP offers Bachelors, Masters, & Ph.D. degrees in geological sciences. The dept. & many of its faculty participate in the new multi-disciplinary Environmental Science & Engineering Ph.D. Program. The Dept. of Geological Sciences offers many modern laboratory & classroom facilities located in one of the most diverse & striking geological terrains in the world.

Submit letter of interest describing research & teaching interests to pursue at UTEP, resume, & listing of three references (names, addresses, phone & fax numbers) to Dr. Charles G. Groat, Chair Search Committee, UTEP, Department of Geological Sciences, El Paso, TX 79968-0555. The University does not discriminate on the basis of race, color, national origin, sex, religion, age, or disability in employment or the provision of services.

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

The Department of Geology seeks to fill a position of Visiting Assistant Professor or Visiting Lecturer. The successful candidate is expected to teach courses in sedimentology and basin analysis, introductory courses in history of life and perhaps introductory oceanography. Experience in these or closely related branches of geology is highly desirable. Candidates with Ph.D. or equivalent in geosience are preferred, but applications from candidates who have not yet finished the dissertation will be considered. Applicants should be able to demonstrate promise of being excellent instructors with superior interpersonal skills.

The term of the appointment will be for one year with the possibility of renewal for additional years. This is a non-tenure track position. The starting date of the appointment will be August 21, 1996.

Applicants should send a curriculum vita, list of publications, statement of research interests, and the names of three references to: Professor R. James Kirkpatrick, Department of Geology, University of Illinois, 1301 W. Green Street, Urbana, IL 61801; (217) 333-1018; fax 217-244-4996. Preference will be given to applications received before April 21, 1996.

The University of Illinois is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

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Opportunities for Students

Postdoctoral Fellowships in Earth Sciences, Univeristy of Wisconsin - Madison. The Department of Geology and Geophysics announces two postdoctoral fellowships, funded by the Albert and Alice Weeks bequest to the department. Each fellowship is for one year, with the possibility of renewal for an additional year. Salary will be in the range of $29,000 to $34,000 per year, depending upon qualifications. We anticipate that the positions will begin in August or September 1996. A Ph.D. is required at the time the position is started.

Applications from all areas of earth science are encouraged. Applicants must contact one or more UW-Madison faculty to develop a collaborative research plan for inclusion in the application. Further information about the Department may be obtained on its World Wide Web page at http://geology.wisc.edu or by writing to the Department Chair: Professor Philip Brown, Chair, Department of Geology and Geophysics, 1215 West Dayton Street, University of Wisconsin, Madison, WI 53706. Applications should be mailed to the Department Chair. Screening of applications will begin Friday, April 19, 1996; applicants should ensure that three letters of recommendation reach the department by that date. The University of Wisconsin is an Affirmative Action/Equal Opportunity Employer.

Geology, Meteorology M.S. Teaching Assistantships in Earth System Science. South Dakota School of Mines and Technology offers two Teaching Assistantships for Master of Science candidates in Geology, Geological Engineering, or Meteorology. Appointments are for two years beginning Fall 1996. The students will assist in developing and teaching courses in 1) Earth System Science, and 2) Modeling and Monitoring Earth Systems. Applicants must have a strong interest in teaching and in conducting graduate research in some field of earth system science, such as global change or remote sensing studies. Familiarity with Internet communication and hypertext editors is desirable.

Deadline for graduate applications is June 15. For information contact: Dr. Edward F. Duke, Department of Geol. & Geol. Eng., SDSM&T, Rapid City, SD 57701-3995; (605) 394-2388, eduke@siler.sdsmt.edu.

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Teaching and Research Assistantships. The Department of Geology expects to be able to offer teaching and research assistantships to qualified masters-level students for teh 1996-97 academic year and beyond. The department offers coursework leading to the M.S. in Geology with thesis research in the general areas of hydrology and environmental geology, sedimentary geology, low-temperature geochemistry, and geophysics. Application deadline: May 1, 1996. For information and applications, please contact: Dr. Robert Horton, Graduate Coordinator, Department of Geology, California State University, 9001 Stockdale Hwy, Bakersfield, CA 93311-1099.

California Institute of Technology. Postdoctoral Fellowships in Molecular Geobiology. The Divisions of Biology and Geological and Planetary Sciences at Caltech announce two joint postdoctoral fellowships available in molecular geobiology. Researchers with backgrounds in the geological and biological sciences (or both) relevant to studies, at the molecular level, of the coupled evolution of the earth and the life that it supports are encouraged to apply. These fellowships have been established to support the research of scientists typically within two years after receipt of the Ph.D. The intent of the program is to identify and support innovative and creative work in geobiology, with particular emphasis on interdisciplinary studies at the interface between biology and geology.

The duration of the appointment will normally be for 2 years, contingent upon good progress in the first year. The annual stipend will be $30,000 or higher in the first year depending on qualifications, plus the cost of one-way travel to Pasadena. Scholars are eligible to participate in Caltech's health and dental programs.

A curriculum vitae including a list of publications, the names of three references and a one page statement of proposed research activities should be e-mailed by April 15, 1996 to: gabalegs.gps.caltech.edu. Alternatively, applications may be sent to Professor Geoff Blake, Chair, Committee on Geobiology, Mail Code 170-25, California Institute of Technology, Pasadena, CA 91125.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

Research Fellowships. Ralph Roberts Center for Research in Economic Geology, Department of Geological Sciences, Mackay School of Mines, University of Nevada, Reno. The Department of Geological Sciences, Mackay School of Mines, University of Nevada, Reno seeks to fill several one-half time graduate research fellowships for studies on Carlin-type gold deposits in Nevada and related topics. The successful applicants will have strong backgrounds in one or more of the following areas: metallogeny, stratigraphy, structure, geochemistry, tectonics, petrology, and an interest in studying Carlin-type precious metal mineralization. A Bachelor of Science degree is a minimum requirement and a Master of Science degree is desirable. Candidates with a background in economic geology and experience in the minerals industry will be given preference.

The successful applicants will work on research projects under the direction of faculty, U.S. Geological Survey scientists, and industry geologists, with coordination and integration of their research into the goals of the Center by the Director of the Ralph Roberts Center for Research in Economic Geology. Most of the projects will have a major field component.

The fellowships will be funded competitively, and funds will be provided for research expenses. Additional specific projects funded by industry may also be available. Interested geoscientists should contact the Department of Geological Sciences, MS-172, Mackay School of Mines, University of Nevada, Reno, 89557 for applications. The University requires that the Graduate Record Examination be taken and a satisfactory score achieved prior to consideration for admission. The completed application should be accompanied by a letter of interest citing a Carlin Research Fellowship and a statement of qualifications, along with the names and addresses of at least three references. The completed application package should be sent to the Chairman, Department of Geological Sciences at the above address. Application deadline for the 1996-97 academic year is June 01, 1996. The University of Nevada is an affirmative action equal opportunity employer.

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ANNUAL MEETING AND EXPOSITION

DENVER, COLORADO • OCTOBER 28–31, 1996

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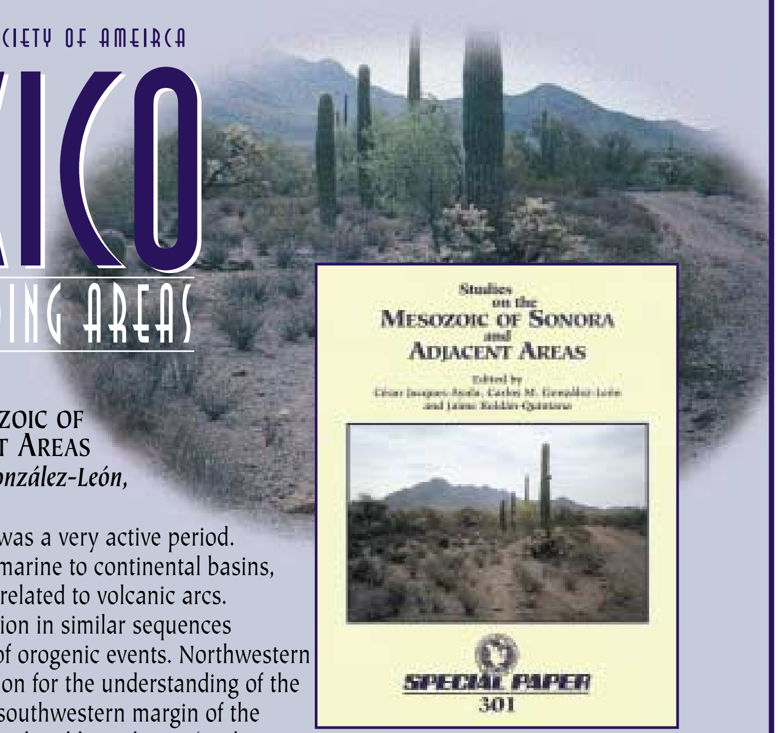

STUDIES ON THE MESOZOIC OF SONORA AND ADJACENT AREAS

C. Jacques-Ayala, C. M. González-León, J. Roldán-Quintana, 1996

Tectonically, the Mesozoic was a very active period. Sedimentation occurred in marine to continental basins, probably all of which were related to volcanic arcs. Different styles of deformation in similar sequences obscure the interpretation of orogenic events. Northwestern Mexico is an important region for the understanding of the geological evolution of the southwestern margin of the North American craton. Postulated hypotheses (such as accreted terrains, continuity of the Ouachita and Cordilleran realms, regional strike-slip faults, and orogenies) are still in need of geological studies to support or disprove them. This volume deals directly or indirectly with some of these hypotheses. One of the purposes of this work was to gather evidence for and/or against the Mojave/Sonora megashear; however, as the reader will notice, the controversy will continue.

SPE301, 284 p., paperback, indexed, ISBN 0–8137–2301–9, $75.00

All volumes are 8-1/2" x 11". Prices include shipping & handling.

OTHER TITLES OF REGIONAL INTEREST

Studies of Sonoran Geology
edited by E. Perez-Sequra and C. Jacques-Ayala, 1990
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The Gulf of Mexico Basin
edited by A, Salvador, 1992
GNA-J, 578 p., hardbound, 6 plates in slipcase, indexed, ISBN 0-8137-5216-7; $77.50

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Tectonostratigraphic Terranes and Tectonic Evolution of Mexico
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