Vol. 6, No. 2 February 1996

GSA TODAY

A Publication of the Geological Society of America

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Alternate Origins of the Coast Range Ophiolite (California): Introduction and Implications

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ABSTRACT

Correctly interpreting the tectonic evolution of the California continental margin requires understanding the origin of the Jurassic Coast Range Ophiolite, which represents a fragment of mafic-to-ultramafic crust of oceanic character lying depositionally beneath the western flank of the Great Valley forearc basin in fault contact with the Franciscan subduction complex of the California Coast Ranges. Three contrasting hypotheses for genesis of the ophiolite as seafloor are each based on internally consistent logic within the framework of plate tectonics, but are mutually exclusive and lead to strikingly different interpretations of regional tectonic relations, even though each assumes that the Sierra Nevada batholith to the east represents the eroded roots of a magmatic arc linked to subduction along the Mesozoic continental margin. To encourage the further work or analysis needed to develop a definitive interpretation, summary arguments for each hypothesis of Coast Range Ophiolite genesis in mid- to late Jurassic time are presented in parallel: (1) backarc spreading behind an east-facing intra-oceanic island arc that then collided and amalgamated with the Sierran continental-margin arc; (2) paleoequatorial mid-ocean spreading to form oceanic lithosphere that was then drawn northward toward a subduction zone in front of the Sierran continental-margin arc; and (3) forearc spreading within the forearc region of the Sierran continental-margin arc in response to transtensional deformation during slab rollback.

Multiple basaltic sills of the sheeted dike and sill complex, Point Sal remnant of the Middle Jurassic Coast Range ophiolite. The ridge in background exposes sheeted sills and (to left of tree on the skyline) base of the overlying pillow lavas.

INTRODUCTION

Widely distributed exposures of the Jurassic Coast Range Ophiolite in the California Coast Ranges represent deformed and structurally dismembered segments of oceanic crust and uppermost mantle now incorporated within the continental block (Bailey et al., 1970). The overall span of Middle to Late Jurassic radiometric ages for igneous components of ophiolite and postophiolite hypabyssal intrusions is ~170 to 155-150 Ma (Hopson et al., 1981, 1991; Saleeby et al., 1984; Mattinson and Hopson, 1992). Understanding correctly the origin and emplacement of the Coast Range Ophiolite is essential for understanding the Mesozoic evolution of the Cordilleran continental margin (Saleeby, 1992). The time is long past when geoscientists could assume that all ophiolites formed in the same way or have the same tectonic significance.

With the help of co-authors, we outline here three divergent views on the origin of the Coast Range Ophiolite. We emphasize that our areas of agreement are larger than our area of disagreement. We each interpret the Coast Range Ophiolite layered assemblage as a profile of mafic crust and lithosphere of oceanic character, and we infer that this profile was formed through magmatism induced by mantle upwelling linked to lithospheric extension or "spreading." We each also argue for emplacement of the ophiolite within the conceptual framework of plate tectonics, taking the Sierra Nevada composite batholith to the east to be the deeply eroded roots of Jurassic-Cretaceous magmatic arc belts, and regarding Franciscan rocks of the California Coast Ranges farther west as part of the subduction complex accreted near the trench that was paired with the Sierran-Klamath arc assemblage

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GSA TODAY

Vol. 6, No. 2 *February 1996*

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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(Fig. 1). We concur that the east flank of the Franciscan subduction complex was thrust beneath and otherwise faulted against the Coast Range Ophiolite , which formed the westernmost segment of the floor of the Great Valley forearc basin lying between Sierran arc and Franciscan trench.

We nevertheless ascribe generation of the Coast Range Ophiolite to three different tectonic settings: (1) Dickinson infers "backarc" seafloor spreading behind a migratory east-facing intraoceanic island arc, which collided with the west-facing Sierran arc along the continental margin (as intervening oceanic lithosphere was consumed), to lodge the migratory arc and its backarc seafloor against the continental margin; (2) Hopson infers "midocean" seafloor spreading along an intraoceanic ridge crest, followed by tectonic transport of the resulting seafloor to the continental margin (as Sierran subduction drew it ever closer), until the ophiolite docked against the continental margin prior to the onset of Franciscan accretion; (3) Saleeby infers "forearc" seafloor spreading induced by transtensional deformation within the west-facing Sierran-Klamath arc system (in response to rollback of the subducted slab during highly oblique convergence).

The three concepts have quite different implications for details of tectonic history. For example, models 1 and 3 both involve varieties of so-called supra–subduction-zone ophiolite forming the floors of interarc basins, whereas model 2 envisions only "normal" seafloor spreading in an open ocean basin; models 2 and 3 involve only a single west-facing Sierran magmatic arc, whereas model 1 includes a separate east-facing arc that was accreted tectonically to the Cordilleran continental margin; models 1 and 2 both require tectonic transport of the ophiolite to the continental margin, whereas model 3 envisions genesis of the ophiolite in place within an arc-trench system lying along the continental margin.

We thank conveners R. G. Anderson, D. M. Miller, and R. M. Tosdal for arranging the 1993 Penrose Conference on Jurassic Cordilleran magmatism at which our opposing thoughts were pointedly juxtaposed, and we dedicate the following discussions to the memory of E. H. Bailey (who started it all).

1. COAST RANGE OPHIOLITE AS BACK-ARC–INTER-ARC BASIN LITHOSPHERE

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The concept that the Coast Range Ophiolite was formed by backarc-interarc spreading behind an east-facing intraoceanic island arc that was accreted to the continent in Jurassic time by arc collision along a suture within the Sierra Nevada foothills has persisted for 25 years (Moores, 1970; Schweickert and Cowan, 1975; Moores and Day, 1984; Ingersoll and Schweickert, 1986). Remnants of the intraoceanic arc complex are identified as thick submarine successions of deformed and disrupted Jurassic lavas and pyroclastics, as much as 5000 m thick (Bogen, 1985), resting locally on shreds of ophiolitic basement along the Sierran foothills belt. Eruptive activity in the foothills arc was coeval with Jurassic phases of magmatism in the west-facing Sierran continental-margin arc, whose axis lay farther east along and beyond the Sierran crest from mid-Triassic to mid-Jurassic time (Schweickert, 1976; Busby-Spera, 1988; Dilles and Wright, 1988). A strong case can be made that the Jurassic intraoceanic and continental-margin arcs of the

Ophiolite *continued on p. 3*

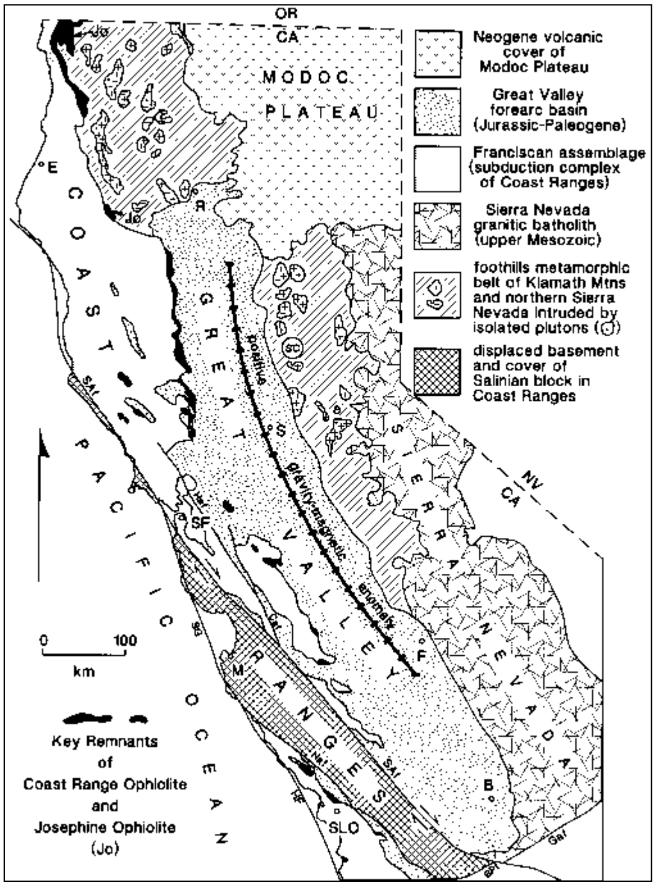

Figure 1. Geologic sketch map of part of California showing the regional relation of the Coast Range Ophiolite to key lithotectonic belts; SC—location of Smartville ophiolitic complex within foothills metamorphic belt; trend of Great Valley gravity-magnetic anomaly (high) after Cady (1975).

Ophiolite *continued from p. 2*

Sierra Nevada are genetically unrelated (Dilek et al., 1990).

Deformed and variably metamorphosed Paleozoic-Mesozoic marine strata (mainly chert-argillite sequences and turbidites), exposed between and thrust beneath the two arc assemblages, are interpreted as a suture belt of compound subduction complexes cut by multiple fault zones and melange belts emplaced during arc-arc collision (Schweickert and Cowan, 1975). A modern example of a remnant ocean basin closing by face-to-face arc-arc collision is afforded by the Molucca Sea (Ricci et al., 1985). In the Sierran foothills belt, metamorphosed Upper Jurassic turbidites of the partly volcaniclastic Mariposa Formation are inferred to be an overlap assemblage deposited in part in a remnant ocean basin but also onlapping the accreted intraoceanic arc complex (Ingersoll and Schweickert, 1986). Once the foothills arc-arc suture belt had fully closed, subduction stepped outboard to the California Coast Ranges, trapping backarc-interarc Jurassic oceanic crust as the Coast Range Ophiolite at the leading edge of the overriding plate. With the onset of Franciscan subduction in the California Coast Ranges, Sierran arc magmatism also stepped westward to overprint both the foothills suture belt and the accreted intraoceanic arc.

The arc assemblage of the Sierran foothills metamorphic belt (Fig. 1) may represent a complex of related but disrupted arc segments and remnant arcs juxtaposed across fault contacts (Paterson et al., 1987; Edelman and Sharp, 1989). Volcanogenic successions locally overlie ophiolitic sequences of both earliest Jurassic (~210–200 Ma) and intra-Jurassic (~165–160 Ma) age (Saleeby, 1982; Saleeby et al., 1989; Dilek, 1989b; Edelman et al., 1989). The best preserved remnant of mafic crust occurs in the northwestern foothills within the Smartville ophiolitic complex (Fig. 1) formed by intra-arc rifting and associated magmatism during Middle to Late Jurassic time (Menzies et al., 1980; Beard and Day, 1987); combined radiometric and fossil ages bracket the main interval of its formation as 165–155 Ma (Day et al., 1985; Edelman and Sharp, 1989). Widespread overlap of foothills volcanic units by the Mariposa Formation near the Oxfordian-Kimmeridgian boundary implies that the arc complex had lodged along the foothills belt by ~155 Ma in Late Jurassic time (Schweickert et al., 1984). Crosscutting plutons of the evolving Sierran arc were emplaced into foothills volcanogenic assemblages and melanges by latest Jurassic or earliest Cretaceous time (~150–140 Ma) (Saleeby et al., 1989).

Recent interpretations that the foothills arc complex was accreted to the continental margin prior to formation of the Smartville complex, which is then interpreted as the product of spreading in place within the west-facing Sierran forearc (Dilek, 1989a; Edelman et al., 1989), rely upon the presence in the northern foothills belt of Middle Jurassic (~165 Ma) granitoid plutons that cut thrusts placing Lower Jurassic elements of the foothills arc assemblage above metasedimentary melange. The resulting conclusion that accretion of the foothills arc complex was complete by Middle Jurassic time is not robust, however, because the intruded melange unit is not tied firmly to the continent and underthrusting of the eastern flank of an east-facing intraoceanic arc by melange would be expected prior to final suturing to the continent. Arc plutons unrelated to the Sierran continental arc could thus cut arc-melange thrusts in the late phases of intraoceanic arc evolution prior to accretion along the compound subduction complex of the foothills belt. Widespread Middle Jurassic deformation within the Sierran continental arc has been attributed in part to terrane accretion (Edelman and Sharp, 1989; Edelman et al., 1989), but could as well reflect intra-arc contraction.

Several workers (Shervais and Kimbrough, 1985; Shervais, 1990; Stern and Bloomer, 1992) have concluded that the Coast Range Ophiolite has geochemical affinities with supra–subduction-zone (SSZ) ophiolites (Pearce et al., 1984), implying the influence of a subducted slab on its generation. These workers and others (Evarts, 1977; Lagabrielle et al., 1986; Robertson, 1989) have variously inferred backarc, forearc, or intra-arc settings of either east-facing or west-facing arcs for its origin. Ophiolitic breccias locally overlying the Coast Range Ophiolite and resting concordantly beneath the Great Valley Group reflect local but widespread extensional deformation at the sites of their formation (Robertson, 1990). Following initiation of Franciscan subduction to the west, Great Valley forearc sedimentation was underway near the Kimmeridgian-Tithonian boundary (155–150 Ma).

Stern and Bloomer (1992) argued the case for forearc spreading to produce the Coast Range Ophiolite by drawing an analogy between the Jurassic Sierran arc and early stages in the evolution of the modern Izu-Bonin-Mariana arc of the western Pacific. As they note, however, the analogy is not exact because the concepts of "subduction-zone infancy" and "infant-arc crust," unquestionably applicable to the Eocene Izu-Bonin-Mariana arc, cannot apply to the Sierran arc, for which abundant radiometric ages for plutons indicate arc activity throughout the interval 215–80 Ma (Stern et al., 1981; Chen and Moore, 1982). Moreover, the Izu-

Ophiolite *continued on p. 4*

Ophiolite *continued from p. 3*

Bonin-Mariana arc is indisputably an intraoceanic arc, and geochemical analogies between the Coast Range Ophiolite and igneous rocks of the Izu-Bonin-Mariana system can be interpreted as strong evidence for origin of the former in close relation to an intraoceanic arc, rather than to the Sierran arc along the continental margin. Recent work near intraoceanic island arcs in the southwest Pacific has shown the difficulty of distinguishing geochemically among arc-related magmas erupted in backarc, intra-arc, and forearc settings (Hawkins, 1994).

Accordingly, origin of the Coast Range Ophiolite by backarc spreading behind an intraoceanic island arc that lodged in the Sierran foothills late in Jurassic time remains a viable hypothesis. Scraps of remnant arc structures within the ophiolite are to be expected in this case, along with overall SSZ geochemistry. If forearc rifting of the Sierran arc (model 3) were the correct interpretation, one would expect to find rifted fragments of prerift Sierran foothills melange units within the Coast Ranges, but such has never been reported. Moreover, the Coast Range Ophiolite is capped locally, as at Llanada, by ~1500 m of intermediate volcaniclastic rocks (Robertson, 1989; Hull et al., 1993), which could readily be derived from a rifting intraoceanic arc but are unlike chert-rich quartzolithic Upper Jurassic to Lower Cretaceous sandstones derived from a Sierran provenance and deposited in both the Mariposa Formation of the foothills belt and at lower horizons of the Great Valley forearc basin (Ingersoll, 1983; Short and Ingersoll, 1990). Upward transitions from distal to proximal volcaniclastic strata above the Coast Range Ophiolite are interpreted here as the result of progradation from arc sources, rather than the record of tectonic transport toward the arc (as in model 2).

If the Coast Range Ophiolite, as argued here, is an accreted fragment of backarc-interarc crust, then its formation at essentially the same time as the intra-arc Smartville complex of the Sierran foothills reflects the same general interval of extensional tectonism within an intraoceanic arc-trench system. The rather mafic crustal profile of the intervening Great Valley (Cady, 1975; Holbrook and Mooney, 1987) can be understood as representing similar ophiolitic materials, perhaps telescoped by deformation during accretion and certainly overprinted by subsequent Sierran plutonism. Recent interpretations of paleomagnetic data for several remnants of the Coast Range Ophiolite suggest paleolatitudinal concordance with North America (Butler et al., 1991; Mankinen et al., 1991; Hagstrum and Murchey, 1993), requiring no major north-south transport (model 2) but not precluding east-west transport behind an arriving island arc.

Pillow basalt with interpillow pelagic limestone. Volcanic member of the Middle Jurassic Coast Range ophiolite, Llanada remnant, southern Diablo Range, California.

Two residual questions remain. The first pertains to relations between the Sierran foothills belt and the Klamath Mountains, where the Josephine Ophiolite is inferred to have formed by interarc spreading along the continental margin within the interval 165–155 Ma (Saleeby et al., 1982; Harper and Wright, 1984; Wyld and Wright, 1988). This interval overlaps the time span inferred above for arc rifting within an offshore intraoceanic arc complex to form the Smartville complex and Coast Range Ophiolite. In the Klamaths, however, the Rogue Volcanics form a frontal arc coeval with the interarc basement of the Josephine Ophiolite, whereas no analogous assemblage has been discovered within the Coast Ranges. Spreading to form the Josephine Ophiolite may have been a response to arc-arc collision in the Sierran region farther south (Ingersoll and Schweickert, 1986).

The second issue pertains to the time of initiation of Franciscan subduction west of the Coast Range Ophiolite. Ages (K-Ar, U-Pb, Ar-Ar) of high-grade blueschist blocks within the Franciscan assemblage range from 140–145 to ~160 Ma (Wakabayashi, 1992). The oldest ages appear to overlap with the final phases of formation of the Smartville complex and Coast Range Ophiolite, whereas the tectonic model favored here holds that Franciscan subduction should postdate accretion of those intra-arc and backarc features by arc-arc collision in the Sierran foothills. Perhaps resolution of this paradox lies in a better understanding of the mechanisms by which subduction was arrested in the Sierran foothills and initiated in the Coast Ranges to the west. Some overlap in the timing of those two events is not difficult to envision as an intraoceanic arc system gradually lodged firmly against the continental margin.

2. COAST RANGE OPHIOLITE AS PALEOEQUATORIAL MID-OCEAN LITHOSPHERE

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The igneous pseudostratigraphy, structure, seismic velocity profile, petrology, and geochemistry of the mid-Jurassic (~170–165 Ma) Coast Range Ophiolite seem consistent with tectonically thinned, multiply altered oceanic crust, but provide no clear-cut guide to original tectonic setting. Lacking decisive evidence from the igneous rocks, we turn to the associated Jurassic sedimentary rocks. The succession of sediments entrapped within and accumulating on top of the igneous crust of a mobile oceanic plate make up its *plate stratigraphy* (Berger and Winterer, 1974), which is applicable to ophiolites and can provide a travel history for an ancient oceanic plate. For example, the plate stratigraphy of ophiolites formed at a divergent plate margin (mid-ocean ridge) will reflect transport *toward* a convergent margin, marked by progressive increase in the sedimentary products of arc

Ophiolite *continued on p. 5*

Ophiolite *continued from p. 4*

volcanism. Arc-related ophiolites, born behind convergent plate margins (i.e., above subduction zones), lie adjacent to arc volcanism from birth. Their travel histories might keep them close to the active arc (e.g., arc-parallel strike-slip transport) or take them farther away in the case of prolonged back-arc spreading, but will not carry them toward the arc from a distant birthplace.

Jurassic plate stratigraphy at the Point Sal, Stanley Mountain, Cuesta Ridge, and Llanada Coast Range Ophiolite remnants (Fig. 1) shows that the igneous oceanic crustal rocks originated beyond reach of terrigenous or volcanic arc sedimentation and were then carried progressively closer to the coeval Jurassic arc that fringed western North America. The lithostratigraphic succession begins with the sedimentary rocks entrapped as small scraps within the ophiolite volcanic member. These are mainly basaltic rubble, red jasper (silicified ferruginous hydrothermal sediment), and pelagic limestone. Limestone is the only externally derived sedimentary rock, indicating an open-ocean setting. Claims of arc-derived volcaniclastic strata interbedded with Coast Range Ophiolite lavas are incorrect; those strata belong to the unconformably overlying Late Jurassic (volcanopelagic) (VP) succession (see below), locally isolated between subvolcanic *intrusive* sheets (postophiolite sills, mistaken for ophiolite lava flows) that commonly concentrate along and just above the Coast Range Ophiolite–VP contact in some Coast Range Ophiolite remnants.

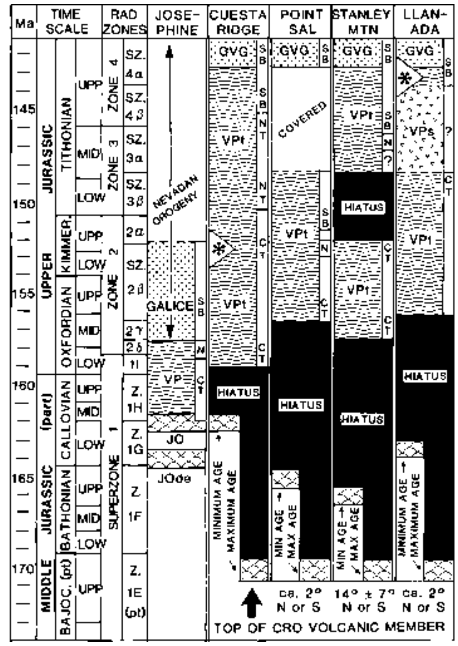

Figure 2. Tectonostratigraphic diagram comparing Coast Range Ophiolite (CRO) –VP– basal Great Valley Group (GVG) succession at Cuesta Ridge, Point Sal, Stanley Mountain, and Llanada with the Josephine Ophiolite (JO)–Galice succession. Time scale from Gradstein et al. (1994); top of the Jurassic from Bralower et al. (1990); radiolarian zonation from Pessagno et al. (1993). Minimum and estimated maximum possible ages of Coast Range Ophiolite remnants (only tops shown) are based on U/Pb and Pb/Pb isotopic ages, respectively (Mattinson and Hopson, 1992). The Josephine Ophiolite age is from Harper et al. (1994); Devils Elbow outlier (JODE) age from Wyld and Wright (1988). Black intervals span the depositional hiatus between Coast Range Ophiolite remnants and the overlying VP succession; also a hiatus within VP. VP spans time of volcanopelagic sedimentation including distal tuffaceous (VPt) and proximal sandy-fragmental (VPs) facies, respectively. Terrigenous sedimentation on Coast Range Ophiolite–VP began with basal strata of the Great Valley Group in the latest Jurassic. The GALICE interval spans the terrigenous graywacke-mudstone sequence above Josephine Ophiolite and thin VP strata. Nevadan orogeny (Klamath phase) from Harper et al. (1994). CT interval spans sedimentation in Central Tethyan Province, NT in Northern Tethyan Province, and SB in Southern Boreal Province; question-mark intervals lack diagnostic radiolarians. Asterisk wedges mark Late Jurassic magmatic (intrusive) and hydrothermal events.

Resting depositionally on the ophiolite lava is an Upper Jurassic (Oxfordian-Tithonian) *VP succession* (Hull et al., 1993) composed mainly of two original components: radiolarian ooze and rhyolitic to andesitic volcaniclastic marine sediment. Most VP remnants consist of a thin (50–130 m) *tuff-radiolarite facies* of tuffaceous radiolarian mudstone and chert, and altered tuffs representing submarine deposits of pyroclastic fallout (airborne tephra) mixed in varying proportions with radiolarian ooze. A thick upper *sandy-fragmental facies* composed of up to 300 m of bedded pumiceous and lithic lapilli tuff, volcaniclastic sandstone (including turbidites) and conglomerate, with interbeds of radiolarian tuffaceous mudstone, overlies the *tuff-radiolarite facies* at some central Coast Range localities (Llanada–Del Puerto–Hospital Creek), and locally (Llanada) grades up into an additional 500 m of cobbly to bouldery andesitic submarine debris-flow deposits capped by tuffaceous radiolarian chert. The tuff-radiolarite facies represents the submarine *distal tephra fringe* of an active, emergent volcanic arc; the upper sandy-fragmental facies is the corresponding coarser *proximal submarine apron.* This succession reflects transport of the oceanic plate (Coast Range Ophiolite) through the distal tephra fringe (VP tuff-radiolarite facies) downwind of an active Jurassic arc, then partly into the proximal volcaniclastic submarine apron (VP sandy-fragmental facies).

The Coast Range Ophiolite–VP contact is *unconformable*: pillow lavas below this contact carry interpillow limestone, whereas VP strata immediately above are mixtures of radiolarian ooze and volcanic ash. The unconformity marks a depositional hiatus (Fig. 2) that began when spreading carried Coast Range Ophiolite oceanic crust below the calcite compensation depth (CCD), ending carbonate deposition, and lasted until its entry into the tephra fringe of an arc. The Upper Jurassic and Cretaceous *Great Valley Group* of terrigenous clastic marine strata overlies the VP succession conformably. The uppermost Jurassic lower portion of the Great Valley Group, composed of mudstone with interbeds of turbiditic siltstone and sandstone, plus local lenticular (channel-fill) pebble conglomerate well above the base of the succession (Bailey et al., 1964; Page, 1972; Suchecki, 1984), correspond to submarine slope deposits prograding over basin-plain deposits (Suchecki, 1984). These basal Great Valley Group strata, derived from Klamath-Sierran tectonic highlands at the North American accretionary margin (Dickinson and Rich, 1972; Ingersoll, 1983), represent a terrigenous clastic apron that prograded over the deep ocean floor (Coast Range Ophiolite–VP succession) following onset of the Nevadan orogeny (Pessagno et al., 1996).

Interpillow pelagic (coccolithic) limestone near the top of the upper lava, Point Sal remnant of the Coast Range ophiolite, Santa Barbara County, California.

Ophiolite *continued on p. 6*

Ophiolite *continued from p. 5*

We accordingly infer that the Coast Range Ophiolite formed at a spreading center in an open-ocean region of pelagic carbonate sedimentation. Seafloor spreading carried Coast Range Ophiolite crust to sub-CCD abyssal depths, ending pelagic carbonate deposition for up to ~12 m.y. (Fig. 2), then into a realm of oceanic upwelling where radiolaria flourished and radiolarian ooze deposition began. This coincided approximately with entry into the distal tephra fringe of an active volcanic arc, where airborne ash mixed with radiolarian remains in the water column. Most parts of the mobile Coast Range Ophiolite plate moved through only the tephra fringe of the arc, accumulating radiolarian ooze and mainly fine ash (Fig. 2, VP tuff-radiolarite facies). But part of the Coast Range Ophiolite plate approached the volcanic arc more closely, passing first through its deep-sea tephra fringe and then into its proximal apron of volcaniclastic turbidites and debris flows (Fig. 2; Llanada remnant). Following VP arc sedimentation, which ended in the late Tithonian, latest Jurassic terrigenous turbidites and muds from Klamath-Sierran accreted terranes advanced out over the deep ocean floor. This Jurassic Coast Range Ophiolite–VP–basal Great Valley Group oceanic succession, uplifted when Franciscan subduction began farther outboard, then floored the new Cretaceous forearc basin.

A mobile interpretation of Coast Range Ophiolite–VP oceanic crust also stems from paleomagnetic and faunal evidence of large-scale Jurassic paleolatitudinal displacement indicated by (1) paleomagnetic measurements on pillow lavas at three Coast Range Ophiolite remnants, and (2) provinciality of radiolarian and molluscan faunas in VP–Great Valley Group strata that correlate roughly with paleolatitude. Paleoinclinations of remanent magnetism in Coast Range Ophiolite pillow lavas at Stanley Mountain (McWilliams and Howell, 1982), Point Sal, and Llanada (Beebe, 1986; Pessagno et al., 1996) were acquired in the Jurassic paleoequatorial region. Lower VP strata that rest on the Coast Range Ophiolite remnants consistently have *Central Tethyan* radiolarian assemblages, whereas progressively higher VP strata have Northern Tethyan and then *Southern Boreal* radiolarian assemblages, respectively (Fig. 2; Pessagno et al., 1996). Molluscans (Buchias) and radiolarians of the overlying Great Valley Group strata are Southern Boreal. Boundaries between Central Tethyan, Northern Tethyan, and Southern Boreal provinces are placed at approximately lat 22°N and 30°N, respectively, on the basis of global distributions of molluscan, radiolarian, and calpionelid faunas (e.g., Pessagno et al., 1987). These data show that the mid-Jurassic Coast Range Ophiolite oceanic crust formed near the paleoequator and was transported northward, passing progressively through Central Tethyan, Northern Tethyan, and Southern Boreal provinces during VP sedimentation in the Late Jurassic (Fig. 2).

Coast Range Ophiolite–VP remnants at Cuesta Ridge and Llanada (also Del Puerto) host swarms of Upper Jurassic basaltic-diabasic, keratophyric-microdioritic and quartz keratophyric–granophyric sills and dikes, and are overprinted by hydrothermal metamorphism. The widespread assumption that ophiolite genesis (mid-Jurassic) and pyroclastic arc volcanism were contemporaneous and closely adjacent, and consequently that the ophiolite formed near or within an active arc (Evarts, 1977; Evarts and Schiffman, 1982; Robertson, 1989), comes from the occurrence of sills (mistaken for ophiolite lava flows), dikes, and hydrothermal alteration within the VP succession. This interpretation is now rendered untenable by (1) recognition of the Coast Range Ophiolite–VP unconformity with a long depositional hiatus, (2) identification of supposed "ophiolite lava flows interbedded with arc volcaniclastics" as sills invading Upper Jurassic strata and yielding Late Jurassic radiometric ages, and (3) evidence that the Late Jurassic "sill event" took place at more northerly paleolatitudes than creation of Coast Range Ophiolite oceanic crust (Fig. 2).

The lithostratigraphic columns of Figure 2 can be used as map tracklines for individual segments of moving Coast Range Ophiolite oceanic lithosphere. The assemblage of tracklines, positioned geographically according to constraints imposed by the lithofacies succession, paleolatitude–faunal province, and age of each member, show the trajectories of individual segments of an oceanic plate moving from their origin through a succession of sedimentary environments toward the consuming plate margin (Fig. 3). We conclude that (1) the Coast Range Ophiolite is exotic to the Jurassic North American continental-margin arc; (2) the trackline assemblage cannot be fitted into a backarc, forearc, or infant-arc association; (3) the Coast Range Ophiolite–VP tracklines (plate motion) must be oriented approximately north-northeast–south-southwest to fit the age–paleolatitude–faunal province constraints; (4) the tracklines indicate dextral oblique subduction of oceanic lithosphere beneath the northwest-trending Jurassic arc system, (5) the subduction zone lay between the arc and VP tephra fringe, the trench forming a barrier to all but *airborne* volcaniclastic materials until the trench filled and was overlapped in late Tithonian time (Fig. 2; Llanada remnant) following the main pulse of the Nevadan orogeny; (6) the Late Jurassic subduction zone lies buried beneath California's Great Valley and thrust sheets of the Klamath Mountains; (7) the 162–164 Ma Josephine ophiolite (Figs. 1 and 2), formed in the backarc region behind the Middle to Late Jurassic Rogue-Chetco arc of the Klamath region (Harper, 1984; Harper et al., 1994), and is not related to the Coast Range Ophiolite; and (8) the diachronous Late Jurassic subvolcanic igneous and hydrothermal events took place beneath deep sea floor during VP sedimentation, and may represent rift-tip propagation of a new, Late Jurassic oceanic rift system through the older (mid-Jurassic) Coast Range Ophiolite plate (Hopson et al., 1991).

3. COAST RANGE OPHIOLITE AS PARAUTOCHTHONOUS FORE-ARC LITHOSPHERE

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The forearc generation model for the Coast Range Ophiolite is based on petrochemical and stratigraphic features of the ophiolite, relations of coeval ophiolitic and arc rocks of the western Klamath Mountains and Sierra Nevada, and consideration of relations in west Pacific fringing arc systems. A corollary of the forearc generation model is that at relatively short time scales (~5 m.y.) juvenile forearc crust may find itself residing either within an interarc basin or within the locus of arc construction. Such changes in tectonic setting may arise from evolving loci of arc construction working in series with the production of juvenile ophiolitic crust, and in the case of oblique subduction the tangential migration of active and inactive arc segments and basinal tracts into (and out of) ephemeral juxtapositions. This corollary and its possible application to the Coast Range Ophiolite is demonstrated by the nearby Josephine Ophiolite of the western Klamaths (Fig. 1). The Josephine Ophiolite may be broadly correlative with the northern Coast Range Ophiolite (Saleeby, 1981, 1992), but the former is easier to interpret because it is preserved in its emplacement configuration with little modification. In contrast, the Coast Range Ophiolite has been severely modified by Franciscan underthrusting and extensional attenuation (Jayko et al., 1987).

The Josephine Ophiolite formed in a transtensional basin that initially opened along the forearc edge of the Sierran-Klamath Middle Jurassic arc (Saleeby, 1982; Harper and Wright, 1984; Wyld and Wright, 1988; Saleeby and Harper, 1993). This arc was constructed in large part over a polygenetic basement of older ensimatic assemblages that were previously accreted

Ophiolite *continued on p. 7*

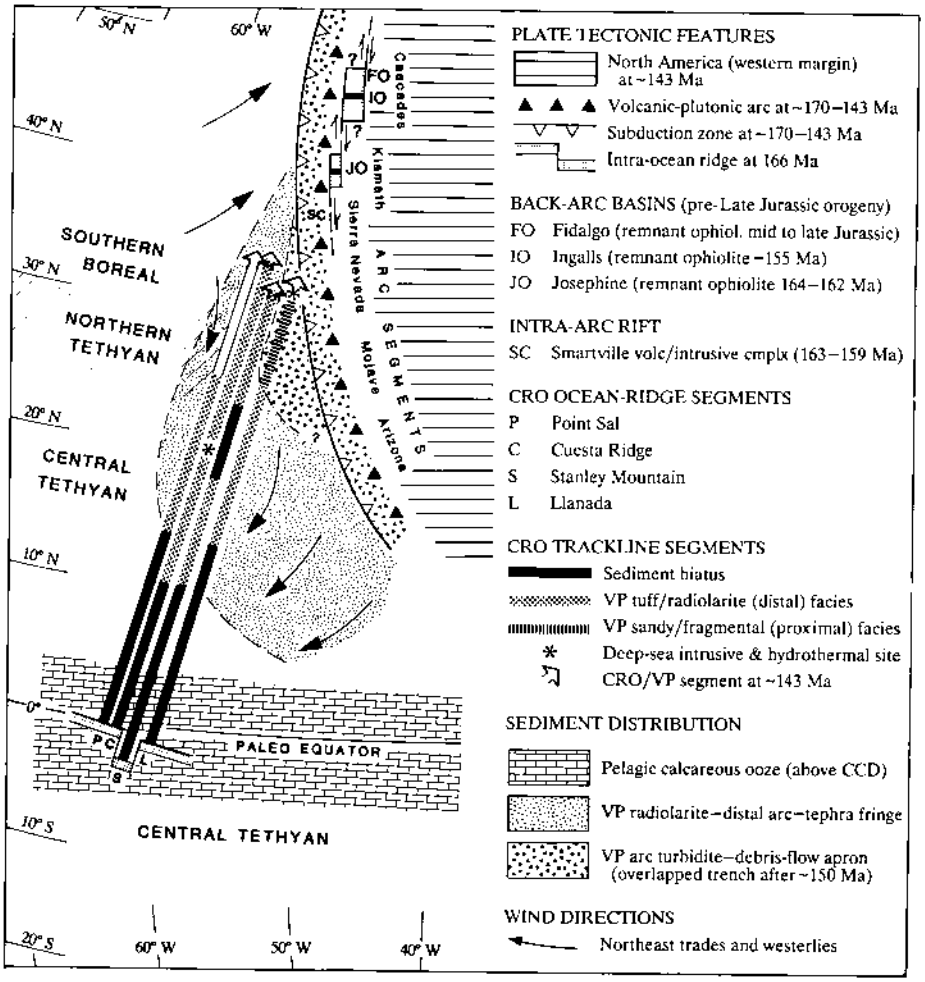

Figure 3. Eastern Pacific–western North America region showing key tectonic elements for part of Middle to latest Jurassic time (~166–143 Ma). Tracklines of Point Sal (P), Cuesta Ridge (C), Stanley Mountain (S), and Llanada (L) Coast Range Ophiolite segments trace their progression by sea-floor spreading from a 166 Ma paleoequatorial midocean ridge spreading center through deep-sea regions of (1) sub-CCD calcareous ooze starvation, (2) volcanopelagic sedimentation, to (3) their 143 Ma positions (arrowheads) just prior to burial beneath terrigenous clastic sediments (basal Great Valley Group) from the adjacent Nevadan orogen. Trackline positions and direction are constrained by data combined in Figure 2: the lithostratigraphy, biostratigraphy, Coast Range Ophiolite radiometric ages and paleomagnetic latitudes, and VP faunal provinces. Location of western North America at 143 Ma from Scotese and Denham (1988), modified to paleolatitudes of May et al. (1989). Triangles mark trend of Upper Jurassic arc volcanics and plutons. Jurassic subduction zone in front of the arc placed at the California Great Valley magnetic-gravity high (Fig. 1), where mafic high-velocity crust dips eastward beneath the Sierra Nevada (Mooney and Weaver, 1989); projection northward and southward is schematic. VP distal tuffaceous facies (from airborne tephra and radiolarian ooze) accumulated outboard of the Jurassic trench. VP proximal sandy-fragmental facies (volcaniclastic turbidites and debris flows) accumulated inboard, bounded by the trench until it filled in latest Jurassic time (see text). JO, IO, and FO schematically depict Middle to Late Jurassic back-arc basins whose oceanic crust–mantle remnants are the Josephine, Ingalls, and Fidalgo ophiolites (Harper, 1984; Miller et al., 1993). SC marks the Smartville intra-arc igneous complex (Beard and Day, 1987).

Ophiolite *continued from p. 6*

to the Cordilleran plate edge; to the southeast the arc tracks onto North American continental lithosphere, which prior to active-margin tectonism had been thinned by passive-margin formation. As Josephine Ophiolite forearc spreading progressed, arc magmatism to the east waned. By the cessation of spreading, arc magmatism relocated along the outer edge of the Josephine Ophiolite basin, capping both rifted screens of older Klamath (or Sierran) terranes and part of the Josephine Ophiolite basin floor. The entire system was then imbricated and crosscut by plutons during the Late Jurassic Nevadan orogeny. The forearc spreading generation, inter-arc basin residence, and thrust imbrication of the Josephine Ophiolite all occurred within ~10 m.y.

Geophysical and basement core data indicate that the Great Valley is underlain primarily by oceanic crust (Cady, 1975; Saleeby et al., 1986). These geophysical data as well as stratigraphic relations along the margins of the valley indicate that at least the western part of the valley is floored by the Coast Range Ophiolite, and that the eastern margin of the valley is floored by coeval mafic submarine arc strata of the western Sierra Nevada. These arc rocks and their polygenetic basement are cut by swarms of sheeted and individual dikes that are the same age as the Coast Range Ophiolite and Josephine Ophiolite, and which mark the waning of Middle Jurassic arc activity in this region (Saleeby, 1982, 1992; Saleeby et al., 1989). The forearc spreading model for the Coast Range Ophiolite considers these westernmost Sierran rocks to be the inner boundary of the Coast Range Ophiolite–Josephine Ophiolite basin system. As discussed below, the Josephine and Coast Range Ophiolites appear to have migrated northward shortly following spreading genesis, roughly placing the Josephine Ophiolite outboard of the western Sierra Nevada and the Coast Range Ophiolite farther south during basin formation. Unlike the Josephine Ophiolite segment of the basin system, the Coast Range Ophiolite–Great Valley segment survived the Nevadan orogeny. This difference may reflect ~100 km of eastward underthrusting of Josephine Ophiolite–related rocks beneath the central Klamaths following and partly in conjunction with northward translation (Saleeby and Harper, 1993); analogous underthrusting is not directly observed, nor imaged geophysically, for the Coast Range Ophiolite–Great Valley segment. The forearc spreading model thus considers the modern morphologic Great Valley as a partial remnant of the original basin.

The forearc spreading model implies that the Coast Range Ophiolite formed in a supra–subduction-zone (SSZ) setting, as suggested by abundant geochemical data (Shervais and Kimbrough, 1985; Shervais, 1990). An SSZ setting is further suggested by the presence of arc-derived pyroclastic, volcaniclastic, and hypabyssal material expressed mainly in the later phases of the Coast Range Ophiolite igneous and sedimentary succession (referenced in model 2). These later arc components are analogous to the constructional arc products that migrated westward to the outer fringes of the Josephine Ophiolite basin. The absence of rifted screens of older basement in the Coast Range Ophiolite (as noted in model 1) may stem from the limited outcrop area of the Coast Range Ophiolite relative to the probable original basin size.

The difficulties with model 1, which also envisions SSZ affinity, are outlined as follows (after Saleeby and Busby-Spera et al., 1992): (1) The implied Late Jurassic (Nevadan) collisional suture within the western Sierras and Klamaths cannot be

Ophiolite *continued on p. 8*

Tuffaceous radiolarian chert within the *tuff/radiolarite facies* of the Upper Jurassic volcanopelagic succession, lying unconformably on pillow lava (not shown) of the Middle Jurassic Coast Range ophiolite. Point Sal Coast Range Ophiolite–VP remnant, Santa Barbara, California.

Ophiolite *continued from p. 7*

delineated with confidence; the most likely structures are pre-Callovian (>169 Ma) in age, as indicated not only by local crosscutting relations of plutons but also by the occurrence of a regional belt of Middle Jurassic dioritic to peridotitic arc plutons that cut across the depositional basement of both hypothetical east- and west-facing arcs. (2) The entire subduction complex and forearc region of the postulated east-facing arc is missing; Tethyan limestone-bearing melange units purported to represent a sandwiched subduction complex reside as depositional basement for Jurassic arc rocks and thus represent an earlier phase of tectonic accretion. (3) Likewise, the Middle Jurassic forearc and subduction complex for the implied west-facing system are missing; the best candidates for such rocks are cut by copious Middle Jurassic arc plutons and, in the northern Sierra, are part of the depositional basement of Lower and Middle Jurassic arc strata. (4) Rock assemblages along the Sierran crest and farther east, considered to be the axial Jurassic arc, are dominated by silicic ignimbrites and by plutonic suites with scattered backarc geochemical affinities; the axis of the arc more likely lay farther west, represented in part by the regional belt of dioritic to peridotitic plutons, and in part by the western Sierran mafic arc strata. (5) The polarity of migration for constructional arc components is opposite to that expected for an east-facing arc–backarc basin–remnant arc system; migration was westward across the Coast Range Ophiolite basin following spreading and Sierran arc waning, analogous to the western Klamath pattern.

An in-situ forearc spreading model based on the early stages of the Eocene Izu-Bonin-Mariana system was also offered for the Coast Range Ophiolite by Stern and Bloomer (1992). They postulated that rapid slab rollback pulled forearc extension, and that this resulted from the subduction of an older cooler transform wall that was adjacent to the oceanic fracture zone along which subduction nucleated. The details of this mechanism encounter difficulty for the Coast Range Ophiolite, as discussed in model 2. An alternative, yet fundamentally similar slab rollback mechanism for the Coast Range Ophiolite is the subduction of old, cold Panthalassan lithosphere inherited from the Pangea regime (Saleeby and Busby-Spera et al., 1992). Upper-plate extension along the southwest Cordilleran plate edge may be recorded as far back as Early Jurassic time by earlier phases of forearc magmatism (Saleeby, 1992) as well as a tendency for much of the arc magmatism to have expressed itself by silicic ignimbrite ponding within a largely submarine graben depression system (Busby-Spera, 1988). The single largest pulse of ignimbrite ponding along the eastern Sierra Nevada corresponds precisely in time with the formation of the Coast Range and Josephine Ophiolites as well as the western Sierra dike swarms. We thus suggest that the broadly extensional arc-forearc region intensified in its extensional deformation toward the end of the Middle Jurassic, resulting in the production of ophiolitic forearc crust in the wake of the foundering slab. This analysis considers the dynamics of the subducting plate to be the prime factor in promoting forearc spreading.

As mentioned above, the Josephine Ophiolite and particularly the southern Coast Range Ophiolite, like many outer Cordilleran terranes, appear to record resolvable northward transport in Middle Jurassic time (model 2 discussion and reviewed in Saleeby and Busby-Spera, et al., 1992). We interpret these displacements to reflect the tangential sense and approximate magnitude of the oblique subduction of Panthalassan lithosphere during Middle Jurassic time. Northward transport of the Coast Range and Josephine Ophiolites is postulated to have occurred above the Cordilleran subduction zone within an oblique spreading basin system analogous to the active Andaman Sea (Curray et al., 1979). Taking into account superposed Late Cretaceous to Holocene disruptions, the Coast Range Ophiolite–Josephine Ophiolite basin system may have represented ~2000 km of the forearc (and ephemeral inter- to intra-arc) region along the Cordilleran plate edge. Available constraints on spreading kinematics recorded within the Josephine Ophiolite, and locally within the Coast Range Ophiolite, are permissive of a strong spreading component subparallel to the plate edge, suggesting that tangential transport was dynamically linked to spreading (Harper et al., 1985; Saleeby, 1992). Furthermore, regional linear gravity-magnetic anomalies oriented along the axis of the Great Valley (Fig. 1) may be modeled as a fossil transform system within the basin floor. Such longitudinal transform(s) could have served as zones of terrane removal as well as ophiolite accretion and translation (Saleeby and Busby-Spera, et al., 1992). Stratigraphic differences between Josephine Ophiolite and Coast Range Ophiolite can be reconciled with the northward transport model. Overlapping volcanic-poor turbidites are of Oxfordian-Kimmeridgian age above the Josephine Ophiolite and its fringing arc, and similar strata of the lowermost Great Valley Group young southward from late Kimmeridgian to Tithonian age above the Coast Range Ophiolite and its overlapping arc strata. In the western Sierra Nevada, similar strata locally range back to Callovian in age. These units are interpreted as different parts of a regional progradational submarine fan system derived from northerly Middle and Late Jurassic highlands and spread southward, first across the western Sierran belt and then sequentially across the Josephine Ophiolite and Coast Range Ophiolite as the various segments of the basin system migrated into their resting sites (Saleeby and Busby-Spera, et al., 1992).

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Manuscript received July 1, 1995; revision received September 19, 1995; accepted September 20, 1995. ■

WASHINGTON REPORT

Bruce F. Molnia

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

Farewell, U.S. Bureau of Mines

"The U.S. Department of Interior will recognize the accomplishments and honor the contributions of the U.S. Bureau of Mines in a commemorative ceremony Wednesday, December 13, 1995. The ceremony will focus on the research and achievements made by the 85 year old agency, slated for closure January 8, 1996, as a result of GOP budget cuts."

—Department of Interior Media Advisory, December 11, 1995

"When I accepted the responsibilities and challenges of being the 19th Director of the U.S. Bureau of Mines, I did so as a scientist who believes that scientists should invest in scientific leadership. It is critical that the focus of our research investments be on solving problems, rather than lost in conflict and chaos. I have observed threats to that focus for our nation that are truly staggering. We are a nation who relies on science and technology, yet we run away from science and technology leadership. First, the Office of Technology Assessment; second, the U.S. Bureau of Mines; third, who knows? Given the impasse in budget resolution over the past two and a half months, we should ask, 'How are we going to refocus our science and technology spending so that the national interest is the common ground?'"

—Bureau of Mines Director Rhea L. Graham, December 13, 1995

On December 13, 1995, the last workday before the start of the prolonged shutdown of the Federal Government, the Department of the Interior (DOI) paid tribute to the employees of the U.S. Bureau of Mines (USBM) for 85 years of outstanding public service and dedication to improving technology and protecting human resources.

In October 1995, as part of the budget appropriations process, the Congress voted to terminate all of the USBM programs in 90 days. It also directed that the USBM's health and safety research program activities be transferred to the Department of Energy, that some of its information analysis activities be transferred to the U.S. Geological Survey, and that the Mineral Land Assessment in Alaska be transferred to the U.S. Bureau of Land Management. USBM's helium program will be administered by the Secretary of the Interior until its proposed privatization is completed by 1997. Almost $100 million of USBM 1995 programs and activities were eliminated and 1200 employees separated. Discontinued programs include pollution prevention and control, environmental waste remediation, minerals land assessment, and minerals availability.

Facilities and offices that were closed are located at Spokane, Washington; Reno, Nevada; Salt Lake City, Utah; Denver, Colorado; Tuscaloosa, Alabama; Rolla, Missouri; Minneapolis, Minnesota; and Washington, D.C. The 90-day time line expired on January 8, 1996. At the commemoration, Secretary of the Interior Bruce Babbitt stated, "The Bureau of Mines has pioneered award-winning research and developed technologies to improve the life for the country in many areas. Their research and development helped to detect and prevent fires, reduce silica and coal dust exposure, prevent mine cave-ins, and reengineer dangerous practices and equipment to create a safer environment. The Bureau has played key roles in improving and protecting the health and safety of mine operators." Secretary Babbitt also stated, "As concerns for a cleaner

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environment grew, USBM applied its expertise to develop ways to improve mine reclamation, found ways to mitigate acid mine drainage, and remove selenium, arsenic, and lead from polluted waters. The USBM met the challenge and overcame many obstacles with professional results."

Statements by USBM Director Rhea L. Graham took a more assertive tone, questioning the decision that eliminated the USBM. "We in the USBM have always fought an uphill battle of understanding. The role that mining and minerals play in our society has frequently been framed in extremes: extraction versus preservation. Yet, the common ground is, everyday we all live off mining and minerals. Therefore, it was imperative that USBM staff render unbiased and professional research and analysis for use by our nation's leaders...." Graham continued "Always keeping one's eyes on the national interests is every public servant's responsibility and challenge. We in the USBM have a proud history of responding to a need, producing a product, and then moving forward to the next challenge. Ironically, our successes in completing what we started have brought us the fate we face today. Responding to change should not make an agency irrelevant. My fellow colleagues, you have used your skills well, and have served this nation faithfully. I would have preferred that the process of fiscal reduction in government services would have accorded all of the USBM functions continuing opportunities in public service. I would have enjoyed seeing your ingenuity applied to solving national problems into the next millennium."

The USBM was established in the DOI on July 1, 1910, founded by the Organic Act of May 16, 1910. The Organic Act was supplemented over the years to make USBM the world's premier minerals and fact-finding agency. USBM's establishment followed a series of mining disasters that claimed the lives of thousands of mine workers. In recent years, the bureau operated as a scientific research and information agency designed to solve health and safety problems that threatened the lives of miners and communities near mining operations. Beginning before World War II and throughout the cold war, USBM was a major contributor to decisions regarding the nation's defense and military readiness.

As it approached its ultimate fate, the USBM was praised for its recent accomplishments in protecting workers by preventing fires and explosions, developing emergency breathing devices, and preventing "black lung"; restoring the land by taking lead out of the environment and constructing wetlands; conserving resources by making recycling easier; preventing pollution through control technology; garnering research awards; monitoring minerals by maintaining the official U.S. statistics; providing analyses of legislation on mineral issues to federal policy makers; providing government scientific expertise where needed; and for its financial stewardship.

Secretary Babbitt concluded, "Science and technology programs are under attack by congressional Republicans. The employees of the Bureau of Mines have every reason to be very proud of their 85 years of service to the Department of the Interior and America. On behalf of the Administration, I want to express our appreciation for the Bureau's distinguished service and many outstanding accomplishments. Thank you for accepting the challenge; your contributions are investments that will continue to pay dividends for years to come." ■

PUBLICATIONS NEWS FROM GSA

BOOK NOOK

WATCH THIS COLUMN FOR NEWS ABOUT GSA PUBLICATIONS

JURASSIC MAGMATISM AND TECTONICS OF THE NORTH AMERICAN CORDILLERA

edited by D. M. Miller and C. Busby, 1995

The 19 papers in this book discuss diverse approaches to characterize the Jurassic tectono-magmatic event, identify variations in its timing and other characteristics from region to region, and consider its ultimate origin in terms of lithospheric processes. Crucial aspects of the Jurassic tectonic events from the Yukon to the southernmost U.S. are described. This is an important look into now-eroded initial subduction-driven orogeny of the Cordillera, the precursor to later events that so strongly shaped present geology. Most papers are data-intensive first-order studies, although some fresh synthesis studies are also present.

SPE299, 432 p., paperback, indexed, ISBN 0-8137-2299-3, $95.00

TERRESTRIAL AND SHALLOW MARINE GEOLOGY OF THE BAHAMAS AND BERMUDA

edited by H. A. Curran and B. White, 1995

The authors review the current knowledge of the Quaternary geologic history of the Bahama Archipelago and Bermuda, an area with unique terranes for the study of carbonate rocks, sediments, and environments. The exposed stratigraphic sequences of the islands reveal much about the history of global sea-level changes during Quaternary time. The focus is an interpretation of the characteristics of Bahamian and Bermudan rock units, their fossil faunas and floras, and the karst surface features of the islands. Information from studies of the modern shallow marine environments are used to help understand the rock record. Up-to-date summaries of the geologic history are presented along with models of stratigraphic development. Other articles cover a broad spectrum of subdisciplines, from paleontology to carbonate systems geochemistry. Chapters are case-book examples of the investigation of important aspects of carbonate island geology.

SPE300, 428 p., indexed, ISBN 0-8137-2300-0, $93.00

HISTORICAL PERSPECTIVE OF EARLY TWENTIETH CENTURY CARBONIFEROUS PALEOBOTANY IN NORTH AMERICA

Edited by P. C. Lyons, E. D. Morey, and R. H. Wagner, 1995

Contains a wealth of information on early 20th century Carboniferous paleobotany in North America. The 28 chapters focus on the interactions of European and American paleobotanists and the birth of discoveries in Carboniferous paleobotany. Central to these interactions and some of the discoveries is the research of W. C. Darrah, which is highlighted. Twenty-one chapters are portraits of: European paleobotanists W. J. Jongmans, W. Gothan, P. Bertrand, C. R. Florin, and M. Stopes; American paleobotanists D. White, R. Thiessen, E. H. Sellards, M. K. Elias, A. C. Noé, W. A. Bell, W. C. Darrah, F. D. Reed, J. M. Schopf, C. A. Arnold, C. B. Read, L. R. Wilson, and H. N. Andrews, Jr.; and amateur paleobotanists F. O. Thompson, G. Landford, Sr., and J. E. Jones. Other chapters deal with floral-zonation schemes, museum collections, coal-ball studies, and roof-shale floras. The book is rich in previously unpublished photographs and correspondence of W. C. Darrah, including humorous and controversial material of broad interest.

MWR185, 424 p., indexed, ISBN 0-8137-1185-1, $105.00

STRATIGRAPHY AND PALEOENVIRONMENTS OF LATE QUATERNARY VALLEY FILLS ON THE SOUTHERN HIGH PLAINS

V. T. Holliday, 1995

Reports on a five-year study of the late-Quaternary history of ten dry valleys or "draws" on the Southern High Plains of Texas and New Mexico. This record is a key to understanding the paleoenvironmental evolution of the region, important because of the long history of human occupation and because the High Plains is known to suffer from climatic extremes, historically. Sections are included on geomorphic characteristics and evolution, stratigraphy of the valley fill (the focus of the volume), and paleontology, paleobotany, and stable isotopes. The stratigraphy along and between draws is broadly synchronous and remarkably similar in lithologic and pedologic characteristics, suggesting that each draw underwent a similar, sequential evolution of the dominant depositional environments. The changing depositional environments suggest shifts in regional vegetation and climate, but there also were distinct local variations in environmental evolution.

MWR186, 142 p., indexed, ISBN 0-8137-1186-X, $54.00

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GSAF UPDATE

Robert L. Fuchs

Second Century Fund Passes Milestone

The Second Century Fund for Earth • Education • Environment passed an important milestone on the road to its goal of $10 million. During December 1995 total contributions and pledges topped the $4 million mark.

Growth of the fund has been achieved through contributions from a number of sources. The membership campaign, which began in August, is generating gifts from members in all of GSA's six sections. The goal of this campaign, which is being managed by the sections, is $1.5 million. There is a direct benefit to the sections and their student programs, because 20% of all unrestricted gifts will be added to section endowments at the Foundation. Members are being asked to consider a five-year pledge to the Second Century Fund, in the amount of $50 per year.

The Industry Support Program for Earth Science is another integral part of the Second Century Fund, with a goal set at $2.5 million. Nearly 30% of that goal has been reached through gifts from more than 20 companies. Industry has long been a strong supporter of geology and GSA's programs. In the early 1980s, the Foundation's Decade of North American Geology campaign was successful in raising $3.4 million from fewer than 30 resource companies, largely oil and gas, which provided the financial base for the publication of the DNAG volumes. The business world is tougher today, resource companies have merged, economic pressures are extreme, restructurings are rampant. On the other side of the coin, GSA now reaches a much broader universe of companies, including environmental, engineering, ground-water, publishing, forest products, and even manufacturing (a recent gift was received from Corning).

Another major component of the Second Century Fund is foundations, also with a goal of $2.5 million. Support has been strong from these organizations, including the National Science Foundation, with the result that more than 40% of this goal has been reached. Foundations generally provide financing for specific programs, such as research grants, and we can expect the continued growth of GSA's SAGE (Scientific Awareness Through Geoscience Education) and IEE (Institute for Environmental Education) programs to be accompanied by an expansion of foundation support.

The backbone of the Second Century Fund has been the major donors, GSA members who have pledged over $2 million in support of the Society and its work. These gifts have taken a variety of forms—cash, securities, artwork, trusts, insurance, and Pooled Income Fund participation. Most donations are directed toward the GSA or Foundation endowments, and a number of individuals have underwritten some of the costs of the Boulder headquarters addition. These major individual donors are continuing the history of personal financial commitment to the Society that began with R. A. F. Penrose, Jr., in 1931. His outstanding bequest exists today as the core of an endowment that has grown both internally and, in recent years, by significant accretion.

A milestone is by no means the end of the road, and there is still a distance to be traveled. The more support there is from members, the sooner the trip will be over. Information on the membership campaign and pledge cards have been sent to all members. Send in your card today with your five-year pledge, or call the Foundation if your card was lost along the way.

S E C O N D C E N T U R Y F U N D

E A R T H ◆ E D U C A T I O N ◆ E N V I R O N M E N T

MEMBERSHIP GOAL

$1.5 MILLION

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Ciriacks Heads Rocky Mountain Section Drive

Kenneth W. Ciriacks of Santa Fe, New Mexico, is the chair of the Rocky Mountain Section's Second Century Fund membership campaign; he replaces W. K. Hamblin, Provo, Utah, who resigned. Ken Ciriacks retired from Amoco in 1994 after a 31-year career in exploration and research. He worked both in the United States and internationally, his last position with the company being that of vice president of technology in Amoco's Chicago headquarters. Ciriacks graduated from the University of Wisconsin with a B.S. in geology, in 1958; he earned his Ph.D. from Columbia University in 1962. He majored in paleontology and stratigraphy and held a National Science Foundation postdoctoral fellowship prior to beginning a career in oil and gas exploration.

In undertaking the Rocky Mountain Section campaign, Ken Ciriacks pointed out the changes that have been occurring in geoscience in recent years, changes that he has also recognized in academic, governmental, industrial, and consulting areas of endeavor. In particular, there has been a pronounced decline in professional continuity, such as in job security, job longevity, and single career pathways. These conditions have created both an opportunity and a need for GSA and similar organizations to play a greater role in the careers of geoscientists. This expanded role will make the attainment of Second Century Fund goals extremely important to GSA and its members.

HELP WANTED!

The membership campaign section chairs need people to help with fund raising during 1996. If you feel the need to communicate a bit more with your fellow GSA members and also have the desire to give GSA some personal time and assistance, please consider volunteering to be a campaign worker. The work is not overly time consuming: calling and writing to 10 or 15 GSA members about their contributions to the Second Century Fund. You may just expand your own personal network in the process. ■

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Penrose Conference Report

Fault-Related Folding

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The Penrose Conference on fault-related folding held in Banff, Alberta, Canada, August 22–27, 1995, was organized to examine the connections between processes of faulting and folding from an interdisciplinary perspective. Field geologists, geophysicists, experimentalists, and theoreticians were brought together to evaluate the geometry, kinematics, and dynamics of fault-related folding and to examine the match between model predictions and observations from the field and laboratory.

The 82 participants came from a wide range of backgrounds. Eight countries were represented, including large contingents from the United States (53) and Canada (17). Professional academicians (33) were dominant, and there were 28 representatives from industry and nine individuals employed by government surveys. Of the industrial representatives, most came from petroleum companies interested in hydrocarbons in folded orogens; however, a substantial number represented companies involved in earthquake hazard assessment. Twelve students provided new insights and an opportunity to have an impact on research of the next generation of geoscientists.

The conference began in Calgary with a lecture by Ray Price on the regional tectonic setting of the Canadian thrust belt, a lecture that also served as an introduction to the first field trip. Regional transpression along a restraining bend was invoked to explain synchronous dextral strike slip in the interior ranges, southward-increasing thrust shortening in the eastern ranges, and subsidence in the Alberta basin. The next day's field trip took the participants from Calgary to Banff via the Turner Valley oil field and the Kananaskis highway. Field trip leaders Deborah Spratt, Philip Simony, Ray Price, and Paul MacKay pointed out a startling diversity of fold-fault relations, from outcrops with small-scale disharmonic folds to seismic profiles of the Turner Valley structure, a newly reinterpreted fault-bend fold in the western limb of the Alberta syncline–triangle zone. The need for three-dimensional (3D) incremental restorations and accurate field characterizations was evident in the vigorous discussions prompted by the Mount Kidd and Misty Range structures.

The first day of talks and posters concentrated on the geometry and kinematics of fault-fold relations in thrust-dominated orogens, although extensional and strike-slip orogens were also discussed. Rick Groshong started the session by showing that simplifications such as rigid-block displacement, single deformation mechanisms (e.g., flexural slip or oblique simple shear), self-similar geometries (which grow in size without limb rotations), and constant two-dimensional area are convenient for modeling but do not replicate many natural structures. Contributions from subsequent speakers and poster sessions made it apparent that previous divisions in

Folding *continued on p. 15*

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The series:

Joint Oceanographic Institutions, Inc./U.S. Science Advisory Committee (JOI/USSAC) is pleased to announce the 1996-97 JOI/USSAC Distinguished Lecturer Series. JOI/USSAC, associated with the international Ocean Drilling Program (ODP), initiated the series as a means to bring the results of ODP research to students at both the undergraduate and graduate levels and to the earth science community in general. During the 1996-97 season JOI/USSAC will sponsor eighteen talks, three by each of the speakers listed below.

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Distinguished lecturers:

Henry Dick, Woods Hole Oceanographic Institution
The formation of magmas and evolution of the oceanic mantle

Andrew Fisher, University of California at Santa Cruz
Measurements, models, and mysteries: Fluid flow and permeability within the upper oceanic crust

Michael Howell, University of South Carolina, Columbia
Eastern Mediterranean sapropels: The interplay between productivity, basin hydrography, and climate

Michael Mottl, University of Hawaii at Manoa
Massive hydrothermal circulation of seawater through mid-ocean ridge flanks: Insights from ocean drilling

Suzanne O'Connell, Wesleyan University
North Atlantic thermohaline circulation and climate change: A deep sea perspective

Charles Paull, University of North Carolina, Chapel Hill
Natural gas hydrates and ODP Leg 164: Sampling an ephemeral phase

Folding *continued from p. 14*

fault-bend, fault-propagation, and detachment folds must be viewed as end-member geometries, not as isolated entities. Basement-involved structures show related yet different structures, the zone of basement faulting widening upward into folds in the sedimentary cover. Field and incremental strain studies showed clear evidence for progressive limb rotation during folding about fixed fold hinges. Several studies emphasized the importance of mechanical stratigraphy, which can cause decoupling of different stratigraphic levels. In many cases, geometries alone are not sufficient to determine the kinematic and dynamic framework, because the same geometry can be generated in several different ways. There was general agreement that more observations of microstructures coupled with consideration of deformation mechanisms are needed.

The second day of the conference was spent in the field, viewing the classic structures of the Bow Valley. The prevalence of footwall synclines, structures commonly omitted from simple fault-fold kinematic models, was particularly striking. On-the-outcrop discussions about terminology, especially the tripartite fault-bend fold, fault-propagation fold, and detachment fold classification, brought out a broad range of opinions. Some participants viewed these as descriptive terms based on purely geometric criteria, whereas others advocated their use as genetic terms indicating a specific geometry and kinematic sequence. A third group took the middle ground and argued for using the terms as kinematic concepts, encompassing multiple geometries and deformation mechanisms. The overwhelming majority of the participants saw no need to specify exact definitions but agreed that uncertainties in our current understanding of fold and fault mechanisms make careful usage of the terms important.

The second day of talks focused on new constraints on fold and fault mechanisms from growth strata. Examples from seismic reflection profiles and surface geology showed that synchronous folding and deposition can indicate rates of fold and fault processes as well as differentiate between different kinematic models. Seismic profiles through growth structures were used to argue for both fixed and migrating fold hinges. Participants from the petroleum industry repeatedly cautioned, however, against using nonmigrated seismic time sections to prove limb geometries, because planar reflectors commonly become curved during velocity migrations and may have been neither horizontal nor isochronous during deposition. Detailed field studies of growth strata from the Pyrenees and Sicily show complex, progressive forelimb rotation of syndeformational sediments on the flanks of anticlinal uplifts. Growth strata in thrust belts were also used to confirm both the foreland progression of deformation and the continued reactivation of hinterland structures as predicted by critical wedge theory. Contested examples from offshore California indicate that it is crucial to evaluate all sources of data. In addition, special care must be used in applying fold-fault models developed in thin-skinned thrust orogens to basement-involved strike-slip orogens. The danger of oversubscription to any specific model was made clear by environmental hazard consultants, who wondered if some studies were determining the seismic hazard of an area or the seismic hazard of a specific model.

On the final morning of the conference, devoted to mechanical and analog modeling of fault-related folding, Peter Hudleston introduced new advances in mechanical modeling using analytical and numerical methods. Several participants applied new finite-element and discrete-element programs from mechanical engineering to the modeling of fault-related folding. Simple fault-bend fold geometries can be replicated even though the internal deformation in the folds may not match the predictions of earlier kinematic models. Analog models shown by John Dixon give another view of these structures, providing a time machine that allows viewing at different stages of folding. These models show detachment folds evolving into fault-propagation folds, with ramp spacing controlled by initial buckling instabilities, which then get transported as fault-bend folds. This fold-then-fault sequence is consistent with many field and microstructural observations from thin-skinned thrust belts. Both mechanical and analog modeling still have difficulty, however, in replicating flexural-slip folding, resulting in models with local regions of unreasonably high penetrative strain.

This Penrose Conference allowed the examination of the revolution in quantitative modeling of fault-fold relations. Detailed field, subsurface, and mechanical-analog modeling studies showed that earlier approximations of fault-fold kinematics need revision to reflect the common occurrence of fixed fold hinges and rotating fold limbs. Participants generally concluded that the detachment fold, fault-propagation fold, and fault-bend classification can be viewed both as a continuum and as a time sequence in many thin-skinned thrust belts. In some cases, however, such as the use of fault-bend folding in regional cross sections, the choice of the kinematic model is less important than the fact that the application of any area-balanced model will allow regional restorations and extrapolations.

Future observations of 3D fault-fold geometries, deformation mechanisms, incremental strain histories, growth strata, and seismically active structures coupled with more rigorous numerical and analog modeling will add to our understanding of fault-related folding. The constraints on 3D fault-fold relations are still being defined, partly because the computer technology needed for 3D balancing is currently unavailable to most structural geologists. In his concluding remarks, Ken McClay looked forward to the meshing of kinematic, mechanical, analog, and field-based models, an infolding of data and models. The participants of this Penrose Conference on fault-related folding anticipate a lot of work—and fun—as they expand their models to fit the diversity of natural structures. ■

Penrose Conference Participants

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Normand Begin
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Benjamin A. Brooks
Rob Butler
J. K. Campbell
Judith S. Chester
Michelle Cooke
Mark Cooper
Russ Cunningham
Joachim Deramond
John M. Dixon
James Dobson
Harald Drewes
Bill Dunne
John F. Dunn
Geri Eisbacher
Eric Erslev
David Ferrill
Sandy Figuers
Donald M. Fisher
Mary Beth Grey
Richard Groshong, Jr.
Stuart Hardy
Chris Hedlund
Peter Hennings
Robert Hickman
James E. Holl
Peter J. Hudleston
Gary J. Huftile
William Jamison
Marc J. Kamerling
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Charles F. Kluth
Thomas Kubli
D. Frizon de Lamotte
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Willem Langenberg
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David McConnell
Mark McNaught
Donald Medwedeff
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Andrew Nicol
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John Suppe
Aviva Sussman
Bruce Trudgill
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The Argentine Precordillera: A Laurentian Terrane?

Conveners

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The Precordillera of northwest Argentina is composed mainly of lower Paleozoic sedimentary strata. The range has been well known for over 25 years as the "San Juan" or "Mendoza" faunal province (e.g., Borrello, 1971), location of the only "Pacific" fauna with olenellid trilobites known outside of Laurentia, the ancestral North American craton that also included the northwestern British Isles with its olenellid fauna (Peach et al., 1907). At first considered only in paleobiologic terms, the olenellid fauna in the Argentine Precordillera was originally explained by larval transfer. Comparison of the Cambrian and Lower Ordovician stratigraphy of the Precordillera with that of the northern Appalachians, however, showed many similarities and led to the hypothesis by Ramos et al. (1986) and his colleagues that it constitutes a "far-traveled" exotic terrane.

Approaching the problem from a different perspective—namely, that Laurentia could have been located between East and West Gondwana in Neoproterozoic time (Moores, 1991; Dalziel, 1991; Hoffman, 1991) and tracked around the proto-Andean margin of the South American part of Gondwana during the Paleozoic Era (the so-called "end-run" hypothesis; Dalziel, 1991)—Dalla Salda et al. (1992a) proposed that the Precordillera was part of a larger terrane they named Occidentalia, which was transferred from Laurentia as a result of continent-continent collision during the Ordovician Period. They went on to propose, together with Dalziel, that the Taconic and Ocloyic orogenic belts of North and South America, respectively, were originally continuous, and that the Argentine Precordillera terrane had been detached from the Ouachita embayment of North America where Thomas (1976) and Lowe (1985) had suggested the presence of a now-missing microcontinental block within the Ouachita embayment (Dalla Salda et al., 1992b). Ricardo Astini and his colleagues at the Universidad Nacional de Córdoba subsequently supported a Ouachita embayment origin for the Precordillera with detailed stratigraphic studies (Astini et al., 1995), but adopted the "far-traveled terrane" model of Ramos et al., as elaborated below.

The consequences of the collisional hypothesis for Paleozoic paleogeography are far reaching indeed. If there was a continent-continent collision, Laurentia was in a position relative to Gondwana during Ordovician time far different from its conventional one of being separated from northwest Africa by 4500 km of the Iapetus Ocean basin—the "alternative paleogeographic reconstruction" vs. the "archetypal" reconstruction of Torsvik et al. (1995). Paleomagnetically, either is acceptable, given the absence of paleolongitudinal control and the paleolatitudinal uncertainty inherent in even the highest quality paleomagnetic data. Do the Taconic and Ocloyic "piercing points" proposed by Dalla Salda et al. (1992b) provide the missing relative longitudinal control? Could the Precordillera of northwestern Argentina indeed be a "tectonic tracer" (Dalziel, 1993) that positions Laurentia relative to Gondwana in early Paleozoic time as northwestern Scotland with its olenellid fauna reflects the position of North America relative to Europe prior to the early Cenozoic opening of the North Atlantic Ocean basin? Is the Precordillera, therefore, a critical clue that Laurentia was not always a northern continent, that it might have been between East and West Gondwanaland in Neoproterozoic time, and that it might have traveled around the South American margin during the Paleozoic Era as amplified by Dalziel et al. (1994)?

The conveners decided that the best way to approach these questions was to reexamine the fundamental issue of the origin of the rocks that compose the Precordillera. The best place to do that was clearly on the spot, in Argentina. By combining experts on the Laurentian craton in the Precordillera with their South American colleagues, it should be possible not only to decisively resolve the question of whether or not the Precordillera came from Laurentia, but also to at least address the potential follow-up question: which part of Laurentia? It was therefore with the help of colleagues in the Universidad Nacional de San Juan that the Penrose Conference took place October 15–20, 1995, in the city of San Juan on the eastern flank of the Precordillera. The 65 participants assembled from Argentina (25), the United States (23), Canada (6), Germany (6), France (2), Australia (1), Britain (1), and Chile (1). This cosmopolitan group represented many disciplines as well as many countries: paleontology, biostratigraphy, lithostratigraphy, sedimentology and sedimentary petrology, geophysics, igneous petrology and geochemistry, paleomagnetism, and structural geology and tectonics. The program consisted of one day of introductory talks, two days of field trips to examine the basic stratigraphy and structure of the Precordillera at key localities along the San Juan and Jáchal rivers, and two days during which the participants used their individual expertise to address major questions concerning the Precordillera. The field trips were expertly and enthusiastically led by geologists from the local Universidad Nacional de San Juan and the Universidad Nacional de Córdoba, with contributions from German and U.S. workers; it was a difficult task, given the size of the group, the limited time, and Andean logistics. Guidebooks were prepared by Silvio Peralta, Osvaldo Bordonaro, and Matilde Beresi (San Juan), and by Ricardo Astini, Emilio Vaccari, Fernando Cañas, Luis Benedetto, Edsel Brussa, and Marcelo Carrera (Córdoba).

There is exceptional unanimity among paleontologists of varied expertise that diverse shallow-water faunas provide an excellent biogeographic signal, whereas marginal faunas provide evidence of open ocean circulation but are not so diagnostic biogeographically. The shallow-water biofacies Cambrian trilobite fauna of the Argentine Precordillera, studied in detail by Luis Benedetto, Emilio Vaccari, and their colleagues at the Universidad Nacional de Córdoba, and Osvaldo Bordonaro of the Universidad Nacional de San Juan, has Laurentian affinities (Palmer, 1972), in many cases even to the species level. This continues through the La Silla Formation (Tremadocian) and into at least the lower part of the San Juan Formation (Arenigian). On the contrary, there is clear evidence from the presence of cool-water Hirnantian faunas that by Late Ordovician time (Ashgillian) the terrane was associated with the partly glaciated Gondwanaland supercontinent, the Laurentian faunal affinities having disappeared.

Thus, the general conclusion of the conference participants is that the Precordillera is an exotic terrane with respect to South America, that it came from tropical latitudes in Laurentia, and that it was amalgamated with Gondwana-

land during Ordovician (Arenigian-Ashgillian) times.

The transition from faunas of wholly Laurentian to wholly Gondwana character occurs in this Arenigian-Ashgillian time interval of 20 to 30 m.y., which also marks the appearance and disappearance of certain endemic faunas unique to the Argentine Precordillera terrane. The timing of the faunal "switch over" depends on the exact fauna being considered, being different for brachiopods, conodonts, and sponges, for example. Open-ocean agnostoid trilobites and slope facies appeared in the western Precordillera by Middle Cambrian time. There is no evidence on the Laurentian craton of shallow-water faunal exchange with Gondwana, a critical point against the hypothesis of mid-Ordovician craton-to-craton collision. The distinction of warm-water "Pacific" realm graptolite forms in the Precordillera and cool-water "Atlantic" realm forms on the Gondwana craton, however, persisted through the Llanvirnian.

The time of detachment of the Argentine Precordillera from Laurentia is not revealed by the faunas alone. As pointed out by Richard Fortey (Natural History Museum, London), the terrane would presumably have been able to "recruit" species directly from the Laurentian craton as long as it remained within the paleoequatorial belt—indeed, the first Gondwana recruits were tropical. Clearly, the presence of the slope facies and open-ocean trilobite forms in Middle and Upper Cambrian strata suggests a wide enough southward-opening rift to the western side of the Precordillera platform (present coordinates) to permit open-ocean conditions by latest Middle Cambrian time. As was recognized by all the participants, however, and emphasized by Ian Dalziel on the basis of his experience participating in drilling on the Falkland-Malvinas Plateau, "open-ocean conditions" need not mean oceanic lithosphere.

The time of "docking" of the Argentine Precordillera terrane with Gondwana appears to be constrained by the Middle to Late Ordovician age of deformation and metamorphism within the Famatinian belt on the eastern side of the Precordillera and by development of a foreland basin. This is compatible with the faunal evidence that can be used to argue, on the basis of knowledge of larval dispersal among recent shallow marine arthropods and brachiopods (up to 1000 km), for the Precordillera being separated from its parent Laurentian craton by up to 2000–2500 km of ocean water by the time it acquired its Gondwana fauna, a cratonic separation near the limit indicated by paleomagnetic data if proto-Appalachian Laurentia and proto-Andean South America were at the same longitude. As pointed out by Werner Von Gosen (University of Erlangen, Germany), however, evidence of extension within the Argentine Precordillera from mid-Ordovician through Silurian time must be reconciled with this picture.

On the follow-up question of the original location of the Argentine Precordillera, there was nearly unanimous agreement with the hypotheses of Dalla Salda et al. (1992b) and Astini et al. (1995) that it originated in the Ouachita embayment. Critical support for this solution was recognized by all the participants in the detailed stratigraphic comparison of the Precordillera and southern Appalachians published after the scheduling of the meeting and just before it took place (Astini et al., 1995). The results were outlined for conference participants by Ricardo Astini. Together with Martin Keller (University of Erlangen, Germany), who has worked in the Precordillera and across the "southern cone" of the Laurentian craton from Texas and Oklahoma to the Great Basin, geologists familiar with western North America ruled out the Cordillera there as a point of origin on stratigraphic grounds. Although Henry Williams (Memorial University of Newfoundland) and others pointed to stratigraphic similarities between the northern Appalachians and the Precordillera, there is no evidence north of the Ouachita embayment of a missing block the size of the Precordillera. Also, there was strong support for the views of Cees van Staal (Geological Survey of Canada) and Pierre Cousineau (Université du Quebec à Chicoutimi) that it would have been difficult for the Precordillera terrane to have bypassed the system of Taconic arcs in Late Cambrian and Early Ordovician time from the craton margin of the northern Appalachians. The arcs were close to Laurentia on faunal and paleomagnetic grounds. The participants turned repeatedly to the fact that, as pointed out by Eldridge Moores (University of California, Davis), early Paleozoic Iapetus became a closing Pacific-type ocean basin with heavy "traffic" of arcs and other terranes in both directions.

Thus, backed with the elegant independent structural and stratigraphic analysis by Bill Thomas (University of Kentucky), who for several years has recognized that a continental fragment was extracted from the Ouachita

Precordillera *continued on p. 18*

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Heinrich Bahlburg
Christopher M. Bailey
Bruno A. Baldis
Christopher R. Barnes
Juan L. Benedetto
Stig Bergstrom
Osvaldo Bordonaro
Edsel Brussa
Werner Buggisch
Fernando Cañas
Marcelo Carrera
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Tim Coughlin
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J. C. Vicente
George W. Viele
Juan Fransisco Vilas
Werner Von Gosen
Graciela Vujovich
S. Henry Williams
Patricia Wood Dickerson

The conference was also attended by science journalist Tim Appenzeller, who is writing an article on the topic for *Discover* magazine.

Precordillera *continued from p. 17*

embayment (Thomas, 1976, 1991), that embayment became what might be referred to as a unique candidate for the original position of the Argentine Precordillera terrane. Strong evidence in support of this hypothesis is provided by the geochemical evidence from metamorphic xenoliths in Miocene plutons that intrude the terrane, evidence outlined by Suzanne Kay (Cornell University). The xenoliths contain 1100 Ma zircons with a common lead signature characteristic of juvenile Grenville rocks from eastern and southern North America, notably the Adirondack Mountains of New York State and the Llano uplift of Texas. Although not totally diagnostic or unique, these data are exactly what is expected for a basement block derived from the Ouachita embayment. This hypothetical block was dubbed "Bill Thomas Land," or "Guillermo Thomasia," at the meeting!

Everyone then agreed that the next critical question to be addressed is the age of the first true oceanic lithosphere that developed between Laurentia and the Argentine Precordillera platform. If true ocean floor developed in Cambrian time, the Ouachita ocean of Thomas, then the Precordillera terrane must have traveled across Iapetus as an independent microcontinent, as implied by Ramos et al. (1986) and illustrated by Astini et al. (1995). Most of the participants, given the faunal evidence outlined above, were inclined to this view. John Cooper (California State University, Fullerton) referred to this as the "funeral ship" model. Under these circumstances, the Precordillera offers only indirect control over the relative positions of Laurentia and Gondwana early in the Paleozoic Era.

The only evidence of ocean floor adjacent to the Precordillera is the presence of pillow basalts with E-MORB chemistry analyzed by Sue Kay (in Ramos et al., 1986), stratigraphically interlayered with shale containing Llandeilian-Caradocian graptolites in the Calingasta Valley on the western margin of the Precordillera. An important, but undated ophiolite complex is also exposed between the Precordillera and the Cordillera Frontal to the west—the as yet poorly understood Chilenia terrane of Victor Ramos and Constantino Mpodozis of Chile. The ophiolite is currently under study by Steve Davis, Eldridge Moores, and Sarah Roeske (University of California, Davis). A Llanvirnian or older date would be strong evidence that the Precordillera terrane separated from Laurentia before it docked with Gondwana—the funeral ship; but a younger age would leave open the possibility that the Precordillera terrane was attached to Laurentia by stretched continental crust until separation in Caradocian time—in some modified form, the tectonic tracer model of Dalla Salda et al. (1992b).

This Penrose Conference was an unqualified success in that it resolved the main question regarding a possible Laurentian origin for the Argentine Precordillera terrane and went on to provide a likely answer to the subsequent question regarding from which part of Laurentia the terrane could have been derived. The far-reaching, yet tractable, nature of the problem, together with its interdisciplinary nature and intercontinental scope, lent itself ideally to the Penrose format. As anticipated by the conveners and the Penrose Conference Committee, the discussions also opened up many avenues for future research, notably the age of separation of the Precordillera from Laurentia, the mechanisms of transfer of different faunal groups, the source and correlation of volcanically derived K bentonites, the location of an Ordovician suture on the "inboard" side of the Precordillera, and the relation of the Precordillera to the early Paleozoic Pampean magmatic arc to the east.

A symposium "The Origin and Evolution of the Ouachita Embayment" is being convened as part of the South-Central Section Meeting of the Geological Society of America in Austin, Texas, March 11–12, 1996. With support from the Geology Foundation of the Department of Geological Sciences and the Institute for Geophysics of the University of Texas at Austin, several Penrose Conference participants from Argentina, Germany, and various regions of the United States will present talks and take part in discussion designed to inform others of up-to-the-minute ideas concerning the Argentine-Texas ("ARTEX") connection.

The conveners hope that, as originally intended, it will be possible to organize a meeting in North America with a field trip, which clearly should now be around the Ouachita embayment. This is tentatively planned for the Northern Hemisphere autumn of 1997. It will be followed by a symposium at the Geological Society of America Annual Meeting in Salt Lake City, Utah. This symposium will be sponsored by the International Division of the Geological Society of America, and may have cosponsors from one or more disciplinary divisions of the Society.

The meeting in San Juan clearly demonstrated that not even ancient inner biofacies of large cratons can be considered in isolation. As GSA President-Elect (now President) Eldridge Moores commented as the meeting broke up, "What we have just witnessed constitutes a strong case for a Geological Society of the Americas."

ACKNOWLEDGMENTS

Support for participation in the conference was provided by the Tectonics Program of the National Science Foundation, by CONICET of Argentina, and by IGCP 376, a project embracing the full scope of possible Laurentia-Gondwana interactions before the amalgamation of Pangea. Funds for logistics and communications were provided by the Institute for Geophysics of the University of Texas at Austin, and by the Centro de Investigaciones Geológicas of the Universidad Nacional de La Plata. The conveners and participants thank Bruno Baldis and his colleagues at the Universidad Nacional de San Juan for their warm welcome in the face of this invasion of geological gringos.

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FIELD TRIPS WITH A DIFFERENCE …

1996 GEOVENTURES

GEOHOSTELS

Mount St. Helens and Mount Rainier

June 22–27, Packwood and Kelso, Washington

LEADERS

Richard B. Waitt, *U.S. Geological Survey, Vancouver*
Donald Swanson, *U.S. Geological Survey, Seattle*
Patrick Pringle, *Washington Dept. of Natural Resources*

Member Fee: $650
Nonmember Fee: $700

Geology of the Glacier Park Region

July 20–25,
The Big I SOLD OUT **Vhitefish, Montana**

LEADERS

Robert Thomas *and* ***Sheila Roberts,*** *Western Montana College*

Member Fee: $670
Nonmember Fee: $720

For full information see January *GSA Today,* or see GSA's World Wide Web site *(details at the bottom of this page).*

Space will go quickly, so get in touch with us if you are interested. Detailed information on itineraries, registration fees, and travel arrangements will be sent on request. No obligation. Questions welcomed.

1-800-472-1988, ext. 134 or 303-447-2020
E-mail: ecollis@geosociety.org
Fax 303-447-0648

The Geology of the Wine Country in Western Oregon

August 17–22,
Portland State University, Portland, Oregon

LEADER

Scott Burns, *Portland State University*

Member Fee: $580
Nonmember Fee: $630

CALL FOR NOMINATIONS REMINDERS

Materials and supporting information for any of the following nominations may be sent to GSA Executive Director, Geological Society of America, P.O. Box 9140, Boulder, CO 80301. For more detailed information about the nomination procedures, refer to the October 1995 issue of *GSA Today,* or call headquarters at (303) 447-2020, extension 136.

DISTINGUISHED SERVICE AWARD

The GSA Distinguished Service Award was established by Council in 1988 to recognize individuals for their exceptional service to the Society. GSA Members, Fellows, Associates, or, in exceptional circumstances, GSA employees may be nominated for consideration. Any GSA member or employee may make a nomination for the award. Awardees will be selected by the Executive Committee, and all selections must be ratified by the Council. Awards may be made annually, or less frequently, at the discretion of Council. This award will be presented during the annual meeting of the Society. Deadline for nominations for 1996 is **MARCH 1, 1996.**

JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys. The award is a $1000 cash prize from the endowment income of the GSA Foundation's John C. Frye Memorial Fund. The 1996 award will be presented at the autumn AASG meeting to be held during the GSA Annual Meeting in Denver.

Nominations can be made by anyone, based on the following criteria: (1) paper must be selected from GSA or state geological survey publications, (2) paper must be selected from those published during the preceding three full calendar years, (3) nomination must include a paragraph stating the pertinence of the paper.

Nominated papers must establish an environmental problem or need, provide substantive information on the basic geology or geologic process pertinent to the problem, relate the geology to the problem or need, suggest solutions or provide appropriate land use recommendations based on the geology, present the information in a manner that is understandable and directly usable by geologists, and address the environmental need or resolve the problem. It is preferred that the paper be directly applicable by informed laypersons (e.g., planners, engineers). Deadline for nominations for 1996 is **APRIL 1, 1996.**

NATIONAL AWARDS

The deadline is **April 30, 1996,** for submitting nominations for these four awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, Alan T. Waterman Award.

GSA ON THE WEB

What's new on the GSA home page on the World Wide Web? If you haven't yet connected to the Web, the Uniform Resource Locator (URL) is **http://www.geosociety.org.**

If you want to know more about the GSA Employment Service or about becoming a GSA Campus Representative, check the **Membership** section, which also has information on nominating a member to fellowship and on obtaining forms for applying to become a **GSA Member** or **Student Associate**.

See the **Geoscience Calendar** section for a listing of meetings of general geological interest.

The **Publications** section has a monthly table of contents and abstracts of articles for the *GSA Bulletin* and *Geology*. Also in this section is a guide for authors preparing manuscripts for submission to GSA publications. *GSA Today* issues are posted here for downloading and viewing.

For Congressional Contact Information, see the **Administration** section. ■

Multimedia and Geoscience Education

Alan Morris, Stuart Birnbaum, Leslie Kanat, *Cambrian Systems, Incorporated*

IMAGINE

Seven-fifteen a.m. at Jaffee Middle School, in rural New York State, and Leticia, leader of Blue Team, is already logged onto the computer. Michael, Valerie, and Miguel, the rest of the team, won't get there for another fifteen minutes and Leticia wants to download some images before they arrive. Blue Team is responsible for monitoring southern Mexico, and Popocatepetl has become seismically active. By the time the science teacher arrives, Blue Team has explored the eruptive history of Popocatepetl, downloaded seismic data from southern Mexico, studied infrared images of the region, and formulated several questions for the class discussion.

Move now to Florida, where a group of seventh graders are plotting hurricane tracks on their computers while accessing the current data from the Internet. They have developed a model of storm behavior and have the statistical records of previous hurricanes in the mid-Atlantic region. They are enthusiastic about testing their hypotheses regarding landfall.

Is this happening in your local schools? Do you recognize this as the way the geosciences are learned where you live? To borrow from a popular advertisement, "you will."

THE FUTURE IS UPON US

The Geological Society of America (GSA), in conjunction with Cambrian Systems, Inc. (CSI), is developing the ***Geoscience Education Through Intelligent Tutors*** (GETIT™) Project, which is supported by a National Science Foundation (NSF)–Instructional Materials Development grant. The purpose of GETIT™ is to make the above classroom situations a reality.

THE GETIT™ PROJECT

In too many classrooms, students are given a book and a box of rocks and fossils, and are required to memorize names for which they have no context to create understanding. Teachers, faced with the task of managing their classrooms, often have difficulty maintaining a high level of proficiency in their content area. Few teachers are trained as scientists, and many find it challenging to convey some scientific concepts accurately.

What is required is content and context development for the teacher, and active involvement and excitement for the students. Students should be able to work with real data, develop their own hypotheses, make predictions, and test their hypotheses. In short, they should think and act like scientists. By becoming engaged in their own education, students develop an understanding of the methods of science and appreciate the purpose and results of their inquiries.

The GETIT™ Project will help teachers gain a better understanding of scientific concepts, classrooms will become more intellectually stimulating, and students will become more emotionally involved with the curriculum and the learning process. Our goal is to improve the quality of science education in middle schools (grades 5–8) by using geoscience as the link between the natural sciences. These results can be achieved by using modern technology to create a learning environment in which middle school students become actively engaged.

PHILOSOPHY BEHIND GETIT™

It is important to gain content knowledge through an understanding of the essential nature of science. Memorization of facts is an inadequate way to learn and foster appreciation of science. The ways in which we learn and teach should be consistent with the methods of science. Interactive tutoring systems use the power of the computer to its best advantage, permitting students to explore aspects of science that are otherwise unattainable, observe the effects of manipulating variables, and use visual imagery (photographs, video clips, and graphs), and sound. This, in turn, allows students to modify their ideas as they explore topics more fully.

Our experience is in accord with the findings of the National Research Council ([NRC] 1993): it is impractical and undesirable to overburden students with facts ("Imagination is more important than knowledge"—Einstein). GETIT™ allows students to assimilate information regarding natural processes using the methods of science and their senses to develop theories that explain their observations. Learning requires critical thinking using various modes of inquiry. The techniques and skills used in all scientific endeavors (observation, classification, measurement, interpretation, inference, communication, control of variables, development of models and theories, the creation of hypotheses, and prediction skills [Aldridge, 1992a]) are incorporated. GETIT™ is designed to be exploratory and self-paced and to allow for continuous performance assessment, thereby allowing the student to repeat parts of the lesson as often as desired.

Students who have developed an understanding of a concept by defining it from their own observations will understand it better and remember it longer than if they are simply told about it. GETIT™ stresses the importance of exploration, discovery, problem solving, and model building wherever possible. This is consistent with pedagogical perspectives espoused by the American Association for the Advancement of Science (Rutherford and Ahlgren, 1990), and the National Science Teachers Association (NSTA) (Aldridge, 1992b). GETIT™ incorporates databases that allow students to manipulate data and develop models as professional scientists do. The result is a unique body of work, principally a workbook, produced by the student.

GETIT™ treats students as adults by placing them in the role of a professional scientist. We attempt to cross boundaries between disciplines by integrating themes—for example, the ocean-atmosphere and the core-mantle systems are both manifestations of the same fundamental process: heat transfer. We allow the student to make observations and draw conclusions, rather than presenting science as a mere list of facts; this approach helps develop critical thinking and exposes the true nature of science (Tobias, 1993).

FEATURES OF GETIT™

GETIT™ employs the methods of science and is consistent with the pedagogical style proposed by NSTA (Aldridge, 1992b), which asks: "What do we mean? How do we know? Why do we believe?" Our pedagogical approach offers multiple entries into the lessons. We are designing a challenge-based scenario (a problem-solving game) in order to engage students who may otherwise be uninterested in learning science, a discovery-inquiry approach that relies upon the teacher for assignments, and a more structured entry that teaches and explains distinct and explicit areas before moving toward the abstract. For example, lesson sequences may be centered around solving a specific earth science problem. In this approach, students are provided with the necessary tools, data, and suggestions to analyze

Multimedia *continued on p. 21*

Multimedia *continued from p. 20*

and construct solutions. Students will use real databases representing natural phenomena. The results of student investigations will depend upon the data they select. Students may reach various conclusions, but they should be able to produce defensible arguments for their ideas, and they will be able to find patterns that have meaning in application to future inquiry. Exercises such as these encourage cooperative learning and engage students and teachers in a quest for understanding. GETIT™ applications are intellectually challenging, promote the use of advanced technology in the classroom, and have a comfortable and simple user interface.

Benefits to Students

- more freedom for students—self-paced
- students produce their own workbook
- students evaluate their own progress via performance assessments.

Benefits to Teachers

- an interactive, flexible learning tool
- customized teaching units—teachers can customize their own lessons
- resource guide for teachers
- student monitoring module built into GETIT™.

WHO'S WHO AND WHAT'S WHEN

GSA received the NSF grant in September 1995, and subcontracted with CSI to develop the GETIT™ Project. CSI is a small business, based in San Antonio, Texas, devoted to developing interactive educational software. It is managed by three geologists who are active in college-level teaching, scientific research, and K–12 teacher enhancement projects, and who publish in peer-reviewed journals. GETIT™ will be developed by CSI with the assistance of a design team of middle-school science and math teachers.

Middle-school teachers nationwide will be involved at numerous levels of project development serving as test teams. We will form a national pilot test team and a national field test team; these teams will help ensure that the user interface and content are appropriate for the cognitive level of middle-school students, the intended target audience. If you are a middle-school teacher, or know a middle-school teacher who would like to participate in the GETIT™ Project, please contact Ed Geary at GSA (E-mail: egeary@geosociety.org). The GETIT™ Project will be completed early in 1998.

THE FUTURE IS NOW

Astronauts have no prior experience with space flight; however, they are trained and prepared for missions by means of computer simulations that provide them with realistic problems to respond to. The purpose of GETIT™ is to provide students with real data and data analysis tools so they can teach themselves how to become scientists.

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ENVIRONMENT MATTERS

Geology as a Social Science

Daniel Sarewitz, Program Manager, Institute for Environmental Education

Progress is a difficult concept to measure, but if anthropological studies of stone-age cultures are to be trusted, modern society has only in the past century achieved average standards of living equivalent to those of our big-game–hunting forebears 20,000 years ago. In his book *Cannibals and Kings*, anthropologist Marvin Harris portrays Paleolithic hunting cultures as enjoying "relatively high standards of comfort and security … with rich furs for rugs and beds, as well as plenty of dried animal dung or fat-laden bones for the hearth, [providing] a quality of shelter superior in many respects to contemporary inner-city apartments…. Vast herds of mammoth, horses, deer, reindeer, and bison [were exploited for food] systematically and efficiently. Moreover, the skeletal remains of the hunters themselves bear witness to the fact that they were unusually well nourished." And comparison with hunter-collector cultures in Africa today suggests that the average stone-age workday may have lasted about three hours. Wages were minimal, but benefits were generous.

The final pulse of Pleistocene glaciation marked the end of this period of plenty. Since then, tension between human cultural aspirations and Earth's environment has been a perennial theme of societal evolution, as humanity has depended on continual technological innovation to leverage Earth's resources into the products necessary for the sustenance and comfort of an ever-growing population.

VOX POPULI

When I asked the members of the Geology and Environment Public Outreach Program (GEPOP)—IEE's volunteer outreach network—for their technical assessment of geoenvironmental priorities, I was not thinking in grandiose terms. I was simply interested in getting a sense of the range of environmental issues that were currently of interest and concern to the geoscience community. More than 225 "Issue Assessment Questionnaires" were mailed out, and I received about 75 responses. The questionnaire asked: "What are the one or two most important environmental problems and/or controversies facing people in your region today that would be more successfully resolved through greater involvement of geoscientists and increased use of existing geoscientific knowledge?" Views on national and global geoenvironmental concerns were also solicited.

At first glance, the range of responses was fairly predictable: supply and quality of water, both on and below the surface, was a dominant issue; clean-up and storage of various types of hazardous waste was also a prime concern. The threat of natural hazards was mentioned several times; energy resource problems, in contrast, appeared on only two questionnaires. More surprising, to me at least, was the frequency with which the term "land use," or "land-use planning" appeared in connection with other issues. Some respondents mentioned land use in the context of hazards, such as flooding, earthquakes, and coastal erosion; others discussed it in the context of water supply, of toxic waste clean-up in inner-city areas, and of waste-disposal siting. A few made the connection between land use and population growth—in the mega-cities of the developing world, and also in the American southwest, where urban expansion creates mounting pressure on water resources. On my third foray through the pile of questionnaires, technical distinctions between the various responses began to fade in significance, and "land-use" seemed to emerge on virtually every page. From complaints about the "NIMBY" mentality that can obstruct efforts to dispose of hazardous wastes or develop natural resources, to discussions of the damaging effects of engineered structures on fragile ecosystems, the unifying theme was that of a society confronted by increasingly difficult and controversial choices about conflicting land-use goals and philosophies.

GEOLOGY AND DEMOGRAPHY

In other words, the social value of geology increasingly derives from the environmental tensions created by the resource and land-use needs of an expanding population. Quality of life for the eight or ten billion people who will inhabit the planet by the end of the coming century will depend on how well these unavoidable tensions are managed. Thus, our scientific agenda is inextricably bound not just to geological phenomena, but also to the relation between those phenomena and the behavioral patterns of human beings. Geology is a social science.

The perspective of the geoscientist is informed by an appreciation of geologic time, an understanding of geologic rates of change—of the normality of change itself—but the audience for our work is thinking about tomorrow's paycheck, next month's vacation, next year's election. Reconciling these perspectives is difficult. Why don't people just LISTEN to us? Here is another theme of the questionnaires—an undercurrent of frustration about people's unwillingness to act on geologic information: "In the case of the barrier beach the problems and solutions have been known and documented for over 30 years.… Despite this all 'solutions' are political and do not solve the problem." In the case of mining, the "fear of environmental damage outweighs the facts, and mitigation through application of geologically sound principles is simply not given any weight." In the case of solid waste disposal, "oftentimes good geologic data is available, but the decision makers do not have the necessary background to understand the implications."

Scientific data may fail to dictate solutions that are compatible with the way that the human world operates, or to speak to very real political, economic, ethical, and esthetic dilemmas.

GEOLOGY AND DEMOCRACY

Of course, the reasons why society fails to act on scientific data may be diverse and complex. Scientific illiteracy and political expediency are commonly cited; on the other hand, scientific data may fail to dictate solutions that are compatible with the way that the human world operates, or to speak to very real political, economic, ethical, and esthetic dilemmas. Some Nevadans may legitimately feel that one nuclear facility in their state is enough, in which case no amount of data demonstrating the safety of the Yucca Mountain high-level nuclear-waste repository will convince them otherwise. Some Americans look at the Alaska National Wildlife Refuge and see a major oil reserve that offers economic and geopolitical benefits to the nation; others see a pristine wilderness whose intrinsic value outweighs that of any oil potential. Science cannot reconcile such differing perspectives; scientific "answers" to environmental problems will always be integrated into a cultural context.

Social Science *continued on p. 23*

Social Science *continued from p. 22*

If scientists seek to influence environmental decision making simply by supplying data and other information to policy makers and the public, they will probably wind up disappointed and disillusioned. On the other hand, by becoming involved in the decision-making process, by understanding the kinds of information that are both needed and usable in a real-world context, by engaging in dialogue—rather than monologue—with stakeholders in environmental issues, scientists may find that they can have a tangible impact on the design and implementation of practical solutions. This is where geoscientists can be particularly effective, because, unlike many other scientific disciplines, geological insight is predominantly synthetic and interpretational, rather than reductionist. That is, while most of the natural sciences use the laboratory to isolate particular phenomena from their broader natural context, geology seeks to understand the context itself. The intellectual tools and processes regularly used by geoscientists are thus ideally suited for understanding and confronting complex real-world problems. The question, then, is how to get involved.

PART OF THE SOLUTION

That's where IEE comes in. IEE's general mission is to increase the effective contributions of the geosciences to the resolution of environmental problems. Ongoing activities include: raising awareness within GSA of the potential role of geoscientists in environmental problem-solving, through forums, symposia, and theme sessions at GSA meetings; conducting media workshops that teach geoscientists to communicate more effectively with the public through the mass media; and identifying productive activities for GEPOP network volunteers in support of IEE's mission. A new program—The Roy Shlemon Mentors in Applied Geology—will sponsor workshops in applied environmental geoscience for senior undergraduate and graduate students, beginning at several of this spring's GSA section meetings. Future initiatives will focus on technical workshops, public roundtables and forums, and other mechanisms designed to foster productive dialogue among scientists and stakeholders in environmental issues.

The GEPOP network will be a principal technical resource for future IEE activities. For more information on GEPOP, or to become a member of the network, write to me at the Institute for Environmental Education, P.O. Box 9140, Boulder, CO, 80301, call (303) 447-2020, or E-mail iee@geosociety.org. ■

CALENDAR

Only new or changed information is being published in *GSA Today* . A complete listing can be found in the **Geoscience 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

April

April 15–18, **Applied Geoscience,** Warwick University. Coventry, UK. Information: Conference Office, Geological Society, Burlington House, Piccadilly, London W1V 0JU, UK, phone 44-171-434-9944, fax 44-171-439-8975.

April 28–May 1, **11th Himalaya-Karakoram-Tibet Workshop,** Flagstaff, Arizona. Information: Allison M. Macfarlane, Dept. of Geography & Earth Systems Science, George Mason University, Fairfax, VA 22030-4444, (703) 993-1207, fax 703-993-1216, E-mail: amacfarl@gmu.edu.

May

May 21–24, **Mineral Resources of the Commonwealth of Independent States,** St. Petersburg, Russia. Information: Organizing Committee, Mineral Resources Meeting, P.O. Box 215, 199004, St. Petersburg, Russia, phone 7-812-355-7952, 164-7711, fax 7-812-213-5926, 112-2348, E-mail: vsg@sovamsu.sovusa.com.

June

June 12–19, **Geological Institute of Romania 90th Anniversary Meeting,** Bucharest, Romania. Information: G. Udubasa, IGR—90th Anniversary, Str. Caresebes No. 1, RO-78344 Buchuresti 32, Romania, phone 40-1-665-6720, fax 40-1-312-8440, E-mail: udubasa@igr.ro.

September

September 3–7, **13th Annual International Pittsburgh Coal Conference,** Pittsburgh, Pennsylvania. Information: Adrian DiNardo, Pittsburgh Coal Conference Office, University of Pittsburgh, 1140 Benedum Hall, Pittsburgh, PA 15261, (412) 624-7440, fax 412-624-1480, E-mail: dinardo@engrng.civ.pitt.edu.

September 22–27, **Third USA/CIS Joint Conference on Environmental Hydrology and Hydrogeology,** Water: Sustaining a Critical Resource, Tashkent, Uzbekistan. Information: American Institute of Hydrology, 3416 University Ave. S.E., Minneapolis, MN 55414-328, (612) 378-0169, E-mail: AlHydro@aol.com.

November

November 9–10, **Aspects of Triassic-Jurassic Rift Basin Geoscience,** Dinosaur State Park, Rocky Hill, Connecticut. Information: Peter LeTourneau, Lamont-Doherty Earth Observatory, P.O. Box 1000, Palisades, NY 10964-8000, (914) 359-2900, fax 914-365-8154, E-mail: letour@ldeo.columbia.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.

SEG Offers Research Grants

The Society of Economic Geologists will offer six research grants for 1996.

Five $1000 grants from the McKinstry Fund are for field or laboratory studies by graduate students, faculty, or geologists on study leave from their employment. Projects must be beneficial to the science of economic geology and especially to work in field situations. The application deadline is *March 31, 1996.*

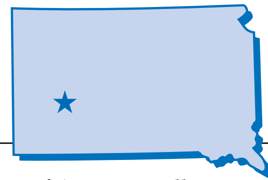
One $2000 grant from the Hickok-Radford Fund is intended to support research projects that emphasize geologic field studies related to minerals exploration. Projects in Alaska, British Columbia, or other regions north of latitude 60ºN are preferred, but projects in challenging terrain in other parts of the world will be considered. Applicants should be studying geology at the undergraduate or graduate level, or have completed a degree in geology or a related earth science within the past two years. The application deadlines is *February 28, 1996.*

Submit applications to Special Grants Committee, Society of Economic Geologists Foundation, 5803 South Rapp St., Littleton, CO 80120.

Final Announcement

ROCKY MOUNTAIN SECTION, GSA
48th Annual Meeting

Rapid City, South Dakota
April 18–19, 1996



The Rocky Mountain Section of the Geological Society of America will meet jointly with the Rocky Mountain Section of the Paleontological Society of America and the Southwest Section of the National Association of Geology Teachers at the Rapid City Civic Center. The host for the meeting is the Department of Geology and Geological Engineering, South Dakota School of Mines and Technology.

SETTING

Rapid City, population of 68,000 in and around the city, is the gateway to the Black Hills. The city is located on Mesozoic rocks that dip gently eastward off the Black Hills, a Laramide uplift. Excellent exposures of Mesozoic and Paleozoic rocks are within a few miles of Rapid City. Precambrian metamorphic and igneous rocks are exposed in the central Black Hills. These rocks contain world-famous pegmatites near Mount Rushmore. The northern Black Hills area contains numerous Tertiary igneous intrusive centers, including beautifully exposed examples of laccoliths. Four major gold mines, including the Homestake mine, are currently operating.

The climate during April is typically unpredictable, ranging from warm temperatures in the 60's to near freezing. Precipitation is normally as rain, although a snowstorm is likely sometime in April.

REGISTRATION

PREREGISTRATION DEADLINE: March 8, 1996 (no exceptions).

If you preregister, you will not have to wait in long registration lines to pick up badges in the registration area, because they will be *mailed* within two weeks prior to the meeting. Save yourself time and money—preregister today! There is savings in fees if you register before the preregistration deadline. Advance registration is suggested for many of the special activities because of participation limits. Use the preregistration form provided in this announcement.

Badges must be worn for access to ALL activities, 6 p.m. April 17 through 5 p.m. April 19.

Registration discounts are given to both GSA and Associated Societies members listed on the registration form. Please indicate your affiliation(s) to register using the member rates.

Full payment MUST acccompany registration. Unpaid purchase orders are NOT accepted as valid registration. Charge cards are accepted as indicated on the preregistration form. If using a charge card, please recheck the card number given. Errors will delay your registration. The confirmation card will be your receipt for all payments. No other receipt will be sent.

Register one professional or student per form. Copy the form for your records.

Guest registration is required for those attending guest activities, technical sessions, or the exhibit hall. Guest registrants MUST be accompanied by either a registered professional or student. A guest is defined as a nongeologist spouse or friend of a professional or student registrant.

Students and K–12 teachers must show a CURRENT ID in order to obtain these rates. Students or teachers not having a current ID when registering will be required to pay the professional fee.

Because the badges are mailed in advance, it is imperative that ALL preregistrations are RECEIVED by the preregistration deadline of March 8, 1996. All registrations received after this date will be held for on-site processing and charged the on-site rates.

CANCELLATIONS, CHANGES, AND REFUNDS

All requests for registration additions, changes, and cancellations must be made in writing and received by March 15, 1996. GSA will refund or credit preregistration fees for cancellations received in writing by March 15, 1996. NO REFUNDS OR CREDITS WILL BE MADE ON CANCELLATION NOTICES RECEIVED AFTER THIS DATE. Refunds will be mailed from GSA after the meeting. Fees paid by credit card will be credited according to the card number on the preregistration form. There will be NO refunds for on-site registration and ticket sales.

ON-SITE REGISTRATION SCHEDULE:

Wednesday, April 17
4:30 p.m. to 8:00 p.m.
Thursday, April 18
7:30 a.m. to 4:30 p.m.
Friday, April 19
7:30 a.m. to 11:30 a.m.

Preregistration by mail will be handled by the Geological Society of America Meetings Department, P.O. Box 9140, Boulder, CO 80301-9140. For lower registration fees and to assist the local committee in planning, please preregister. On-site registration will be held beginning at 4:30 p.m. on Wednesday, April 17, 1996, in the Upper East Concourse of the Rapid City Civic Center.

GSA is committed to making every event at the 1996 Rocky Mountain Section Meeting accessible to all people interested in attending. If you have special requirements, such as an interpreter or wheelchair accessibility, please indicate this on the registration form, or call Perry Rahn, (605) 394-2464. If possible please let us know by March 8, 1996.

TRAVEL

Air service to Rapid City Regional Airport is provided by United Express, Northwest, and Delta airlines. Car rental agencies operating at the airport are Avis, Budget, Hertz, National, Sears, and Thrifty. Off-airport car rentals include Alamo, Dollar, Economy, Enterprise, Rent-A-Wreck, and Practical. Rapid City Regional Airport is about 10 miles from Rapid City. Many hotels provide courtesy bus service from the airport to their hotel. Also, an inexpensive airport shuttle service to Rapid City is available for all flights; check at counter in the baggage claim area. Because there are numerous hotels within easy walking distance of the Civic

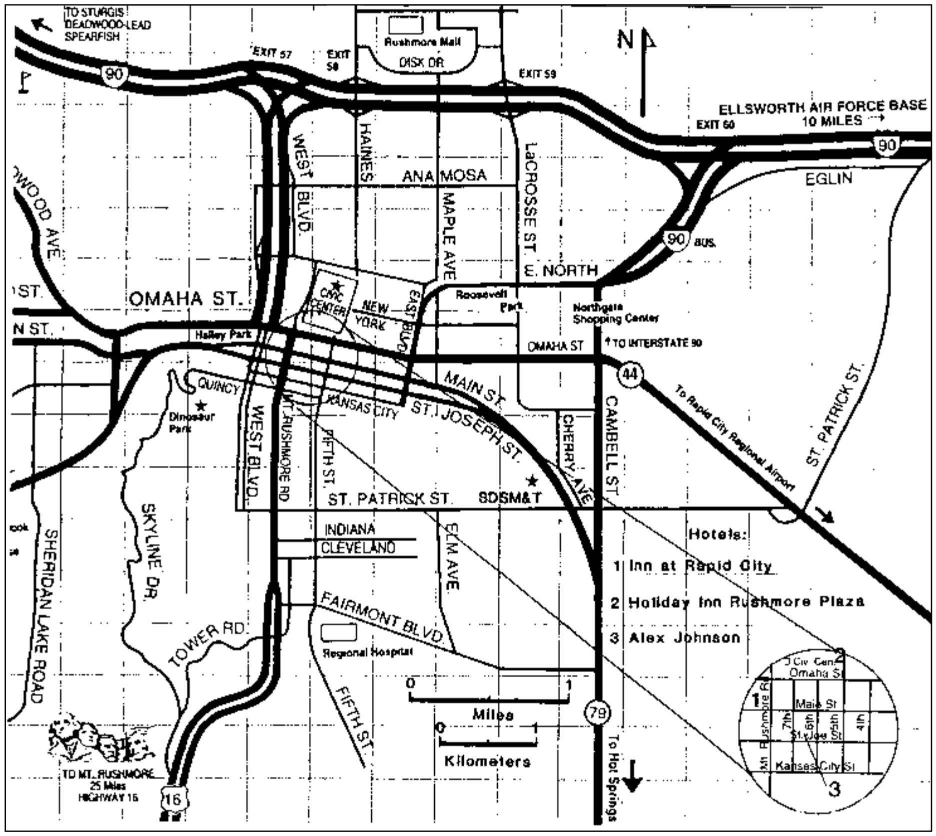
REGISTRATION FEES

	Advance (*by 3/8/96*)		On-site	
	Full Meeting	One Day	Full Meeting	One Day
Professional—Member	$55	$35	$70	$50
Professional—Nonmember	$70	$50	$85	$65
Student—Member	$15	$10	$20	$15
Student—Nonmember	$20	$15	$25	$20
K–12 Professional	$15	N/A	$20	N/A
Guest/Spouse	$10	N/A	$10	N/A
Field Trip Only	$15		$15	

Center, there is no shuttle bus service between hotels and the Civic Center. See the index map of central Rapid City.

ACCOMMODATIONS

Blocks of rooms have been reserved at special convention rates for GSA meeting attendees at three Rapid City hotels (all within easy walking distance from the convention center): **Hotel Alex Johnson** (4 blocks from Civic Center), 523 6th St., $39 single or double occupancy, 1-800-888-2539; **The Inn at Rapid City** (4 blocks from Civic Center), 445 Mt. Rushmore Rd., $55 single or double occupancy, 1-800-456-3750; and **Holiday Inn Rushmore Plaza** (adjacent to Civic Center), 505 North 5th St., $62, $72, $82 single occupancy or $70, $80, $90 double occupancy, 1-800-777-1023. A tax of 8% is added to all rates. To make reservations, telephone the hotel directly and indicate that you are attending the 1996 GSA meeting. Please make your reservations early, because the special rates are on a space-available basis only. After March 17, 1996, these rates may no longer be in effect. In addition to these hotels, there are about 60 motels, hotels, and bed and breakfast lodgings in the Rapid City area. To inquire about them or about other travel information, call the Rapid City Area Hospitality Association, 1-800-487-3223.



RAPID CITY AREA

FIELD TRIPS

Both premeeting and postmeeting field trips are planned. All field trips will begin in the parking lot (south side) by the main entrance to the Holiday Inn Rushmore Plaza (next to the Civic Center), 505 North 5th St. For details, contact the respective field trip leaders. General questions should be addressed to Jack Redden, Field Trip Coordinator, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703.

Preregistration for all trips is required. Participants will be accepted on a first-come, first-served basis through GSA headquarters. Complete the form provided with this announcement. Participants preregistering for a field trip *only* must pay a $15 nonregistrant fee in addition to the charge for the field trip. **Preregistration deadline is March 8, 1996**.

The cancellation deadline is March 15, 1996. All cancellations must be in writing; no refunds will be given for cancellation notice received after this date. If GSA must cancel a trip, that cancellation will be announced by March 22, 1996. Full refunds will be issued after the meeting.

Field trip guidebooks containing road logs for most of the field trips as well as technical papers on Black Hills geology will be provided with most of the field trips (see individual descriptions) and will also be available for sale at the meeting.

Premeeting

1. **Tertiary Tectonism in the Northern Great Plains.** 2–3 days, April 15–17, 1996. Shallow folds and faults in the Little Badlands, North Dakota, and the spectacular slump-type structures of the northern Slim Buttes (South Dakota), where the displaced White River Group is overlain angularly by the Arikaree. On the third day we would examine faults and clastic dikes in Badlands National Park. Allan Ashworth, Dept. of Geosciences, North Dakota State University, Fargo, ND 58105, (701) 231-7919, fax 701-231-7149; George Shurr, Dept. of Earth Sciences, St. Cloud State University, St. Cloud, MN 56301, (612) 255-2009, fax 612-255-4262; and Rachel C. Benton and Edward G. Murphy. Cost: $155 (includes 2 nights accommodation, 2 lunches, guidebook). Limit: 26.

2. **Paleogene Stratigraphy and Sedimentation.** Wednesday, April 17, 1996. Classic sections in Badlands National Park, with additional emphasis on structural features (this trip is the same as the third day of trip #1). Rachel Benton, Badlands National Park, P.O. Box 6, Interior, SD 57750, (605) 433-5361, fax 605-433-5404, Internet: rachel_benton@nps.gov; Dennis Terry and Kimberlee Stevens. Cost: $60 (includes transportation, lunch, guidebook). Limit: 26.

3. **Hydrogeology of the Central Black Hills.** Wednesday, April 17, 1996. General Black Hills geology, recharging streams, springs in Precambrian and Paleozoic rocks, and a brief look at hydrogeology of abandoned mines. Includes a two-hour hike along Boxelder Creek. Perry Rahn, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2464, fax 605-394-6703; Tim Hayes. Cost: $55 (includes transportation, coffee and doughnuts, guidebook). Limit: 24.

4. **Major Unconformities of the Black Hills.** Wednesday, April 17, 1996. Well-exposed Middle Proterozoic, Precambrian-Cambrian, Ordovician–Upper Devonian, Mississippian-Pennsylvanian, and Tertiary unconformities in the northern and east-central Black Hills. Jack Redden, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703; Mark Fahrenbach. Cost: $55 (includes transportation, lunch, guidebook). Limit: 26.

5. **Reclamation at Northern Black Hills Gold Mines.** Wednesday, April 17, 1996. Reclamation activities that include mitigation of acid-generating sulfide waste rock at LAC Mineral's Richmond Hill gold

Rocky Mountan *continued on p. 26*

Rocky Mountan *continued from p. 25*

mine. Also concurrent and final reclamation activities at the active Wharf Resources gold mine. Tom Durkin, Office of Minerals and Mining, S.D. Dept. of Environment and Natural Resources, Joe Foss Building, 523 E. Capitol Ave., Pierre, SD 57501-3181, (605) 773-4201. Cost: $52 (includes transportation, lunch, guidebook). Limit: 28.

Postmeeting

6. **Homestake Iron-Formation–Hosted Gold Deposit—Underground Tour.** Friday, April 19, 1996 (evening tour, departing Holiday Inn Rushmore Plaza at 2:45 p.m.). Underground tour of a gold mine that has operated since 1876, and which is developed to the 8000 foot level in an Early Proterozoic, structurally complex iron-formation host. Moderate physical condition required. Chief Mine Geologist, Homestake Mining Company, 630 E. Summit St., Lead, SD 57754-1700, (605) 584-4841. Cost: $42 (includes transportation and handouts). Limit: 15.

7. **Geologic Hazards of the Black Hills.** Saturday, April 20, 1996. Landslides, swelling soils, flood plains, and gypsum solution features in the areas of Rapid City, Lead, and Spearfish. Perry Rahn, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2464, fax 605-394-6703; Arden Davis. Cost: $60 (includes transportation, coffee and doughnuts, guidebook). Limit: 24.

8. **Late Cretaceous Marine Stratigraphy and Paleontology of the Southern Black Hills.** Saturday and Sunday, April 20 and 21, 1996. Key sections and fossil localities representing the entire sequence of Upper Cretaceous marine rocks. James Martin, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2427, fax 605-394-6703; Gorden Bell. Cost: $130 (includes transportation, 2 lunches, double-occupancy motel room for 1 night, guidebook; $150 for single occupancy accommodation). Limit: 26.

9. **Tectonic and Plutonic Development and Associated Metamorphism-Metasomatism in the Southern Black Hills.** Saturday and Sunday, April 20 and 21, 1996. Key structural, metamorphic, and igneous outcrops (including Mount Rushmore and the Etta pegmatite mine) illustrating the complex Proterozoic history and metamorphism and metasomatism associated with the 1.7 Ga S-type Harney Peak granite. Jack Redden, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703; Edward Duke. Cost: $95 (includes transportation, 2 lunches, 1 night double-occupancy motel room, guidebook; $115 for single-occupancy accommodation). Limit: 26.

10. **Lower Paleozoic Stratigraphy of the Black Hills.** Saturday, April 20, 1996. Outcrops of Cambrian through Permian rocks in the northern Black Hills (South Dakota and Wyoming), especially Cambrian and Devonian rocks of the Lead-Deadwood area, and Pennsylvanian rocks of the Sand Creek area (Wyoming). James Fox, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2468, fax 605-394-6703; Mark Fahrenbach and John Rezac. Cost: $55 (includes transportation, lunch, guidebook). Limit: 26.

11. **Tertiary Igneous Systems and Related Au-Ag Mineralization of the Northern Black Hills.** Saturday and Sunday, April 20 and 21, 1996. Petrologic, structural, and gold-ore relations, and the character of dikes, stocks, sills, and laccoliths, illustrated in natural and open-pit mine exposures of the Laramide igneous province. Mine visits include Gilt Edge gold mine, Homestake open cut, and Annie Creek–Foley Ridge gold mine. James Kirchner, Dept. of Geography-Geology, Campus Box 4400, Illinois State University, Normal, IL 61790, (309) 438-8922, fax 309-438-5310. Internet: jgkirch@ilstu.edu; Alvis Lisenbee and Colin Paterson. Cost: $135 (includes transportation, 2 lunches, 1 dinner, double-occupancy motel room for 1 night, guidebook; $155 for single-occupancy accommodation. Limit: 24.

TECHNICAL SESSIONS AND SYMPOSIA

General sessions will include structural geology and tectonics, economic geology, igneous and metamorphic petrology, stratigraphy and sedimentation, paleontology, hydrogeology, engineering geology, geomorphology, geophysics, and general geology. Technical sessions will allow 15 minutes for presentation and 5 minutes for questions and discussion. Session chairs and speakers are asked to adhere stringently to these time limits.

The following symposia will include both invited papers and selected volunteered papers. General questions should be addressed to Alvis Lisenbee, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605)394-2463, fax 605-394-6703. Abstracts limited to 250 words and submitted camera ready on official 1996 GSA abstract forms were required to be sent by Friday, January 5, 1996, to conveners of the symposia or to Alvis Lisenbee.

1. **Precambrian Geology of the North-Central United States.** Development of Proterozoic igneous and associated metamorphic events in the Black Hills and southern Trans-Hudson orogen. Jack Redden and Ed Duke, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5113, fax 605-394-6703.

2. **Applications of Geographic Information Systems and Computers in Geology.** Maribeth Price, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2492, fax 605-394-6703, Internet: price@gis.sdsmt.edu.

3. **Late Cretaceous Marine Paleontology and Biostratigraphy.** Interdisciplinary approaches to Late Cretaceous marine successions in the Rocky Mountain and Great Plains provinces, with emphasis on integration and correlation of various biostratigraphic scales with fossil vertebrate ranges. James Martin and Gorden L. Bell, Jr., Museum of Geology, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2427, fax 605-394-6703, Internet: jmartin@msmailgw.sdsmt.edu.

4. **Tertiary Alkalic Igneous Rocks of the Northern Rockies.** Silica-saturated and silica-deficient alkali-rich rocks, lamprophyres, and carbonatites. James Kirchner, Dept. of Geography-Geology, Campus Box 4400, Illinois State University, Normal, IL 61790, (309) 438-8922, fax 309-438-5310, Internet: jgkirch@ilstu.edu.

5. **Hydrology of Karst Aquifers.** Permeability and chemistry of karst aquifers, with special emphasis on the Madison Limestone of the Rocky Mountain region. Perry Rahn and Arden Davis, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2461, fax 605-394-6703.

6. **Contaminant Hydrogeology of the Northern Rocky Mountain Region.** Abandoned mines, defense base cleanups, leaking underground storage tanks, EPA Superfund sites, and related issues. Cathleen Webb, Dept. of Chemistry and Chemical Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-1239, fax 605-394-1232, Internet: cwebb@silver.sdsmt.edu; Tim Hayes, U.S. Geological Survey, 1608 Mountain View Rd., Rapid City, SD 57702, (605) 394-1780, ext. 215, fax 605-394-5373.

7. **Northern Great Plains and Rocky Mountain Cenozoic Depositional Systems, Stratigraphy, and Paleontology.** Recent developments in Great Plains and Rocky Mountain Cenozoic deposition, stratigraphy, and paleontology. Rachel Benton, Badlands National Park, P.O. Box 6, Interior, SD 57750, (605)

433-5361, fax 605-433-5404, Internet: rachel_benton@nps.gov.

8. **Metallogeny of Gold in the Northern Rockies.** Recent advances in understanding of gold metallogenesis, including greenstone–iron-formation–hosted deposits and alkalic igneous-associated deposits. Colin Paterson, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5114, fax 605-394-6703, Internet: paterson@silver.sdsmt.edu.

9. **Perspectives on the Western Interior Cretaceous Seaway.** The center of the seaway, where perspectives from both the eastern and western margins illustrate how interpretations of depositional environments and paleotectonics are influenced by the geographic location of the data sets. Richard Hammond, S.D. Geological Survey, University Science Center, Vermillion, SD 57069; Karen Porter, Montana Bureau of Mines, Montana College of Mineral Science and Technology, Butte, MT 59701. Abstracts to George Shurr, Dept. of Earth Sciences, St. Cloud State University, St. Cloud, MN 56301, (612) 255-2009, fax 612-255-4262.

10. **Geoscience Education in Native American Communities.** Discussions of the unique cultural interactions, pedagogical approaches, and practical experiences of those who teach earth sciences to predominantly Native American populations in K–12 schools, tribal colleges, affiliated universities, or collaborative outreach programs. Steven Semken, Navajo Drylands Environments Laboratory, Navajo Community College, P.O. Box 580, Shiprock, Navajo Nation, NM 87420-0580, (505) 368-5291, fax 505-368-4993.

PROJECTION EQUIPMENT

All slides must be 2″ × 2″ and fit standard 35 mm carousel trays. Two projectors and two screens will be available for oral sessions. Authors are strongly encouraged to bring their own preloaded carousels. The organizing committee will not be responsible if a carousel is unavailable for your talk. A limited number of carousels will be available in the speaker-ready room (Civic Center room 102).

POSTER SESSIONS

Poster sessions will be located adjacent to the exhibit and registration area. If you wish to present a poster, indicate your preference on your abstract form. Presenters will each be provided with two 8′ wide x 4′ high boards (white); posters are to be attached by thumbtacks. Presenters should provide their own supplies for pinning the posters.

There will be a special poster session on Geologic Maps of the Black Hills and South Dakota, displaying 7.5′ quadrangle maps of the northern Black Hills, a 1:100,000 scale map of the central Black Hills, a 1:250,000 scale 1° × 2° quadrangles of South Dakota, and the new 1:500,000 scale South Dakota State Geological Map. New AVIRIS remote-sensing data will also be displayed. Inquiries regarding posters should be directed to Lynn Hedges, S.D. Department of Environment and Natural Resources, 2050 W. Main St., Suite 1, Rapid City, SD 57702, (605) 394-2229.

FIELD TRIP–WORKSHOP FOR K–12 EARTH SCIENCE EDUCATORS

A one-day field trip–workshop will be offered, titled An Illustration of Basic Principles of Geology Using Outcrops in the Black Hills as a Natural Laboratory. Attendance will be limited to 40 persons, and is specifically intended for K–12 educators, and those involved in educational management and processes in earth science disciplines. The cost of meeting registration, bus travel (for the field trip), lunch, and course materials is $60. Departure will be at 8:00 a.m. Wednesday, April 17, 1996, from the parking lot by the main entrance of the Holiday Inn Rushmore Plaza on 5th Street. Travel will be by bus, returning to the departure point by 5:00 p.m. For more information or to sign up, contact Rick Baker (K–12 chair) at (605) 342-4105. The workshop sign-up deadline is March 8, 1996, and the course fee is due by April 5, 1996. Any notice of cancellation will be made by March 22, 1996.

If they request it, K–12 teachers may receive 1 credit of Geology 490, Special Topics in Geology, through the South Dakota School of Mines and Technology. Those wishing to receive course credit must register through the Registrar's Office at SDSM&T by April 5, 1996. Tuition and fees are approximately $86 for South Dakota residents and nonresidents. The Registrar's Office can be reached at (605) 394-2414; each person must make his or her own arrangements in this regard.

Attendees may apply for a block grant from the Geological Society of America to assist in expenses for attendance. The grant application should list your name, address, educational involvement and interest, and a detailed accounting of your expense request. Send applications to Rick Baker, c/o Dept. of Geology and Geological Engineering, SDSM&T, 501 E. St. Joseph St., Rapid City, SD 57701-3995. The grant request must be received by March 8, 1996, and notification of acceptance will be made by March 22, 1996.

EXHIBITS

Exhibits are planned for the registration–poster session area. The cost per booth is $50 per 12′ x 10′ space. Additional adjacent booths may be purchased for $50 each to expand display space. For further information and booth reservation, contact Lynn Hedges or Foster Sawyer, S.D. Department of Environment and Natural Resources, 2050 W. Main St., Suite 1, Rapid City, SD 57702, (605) 394-2229.

STUDENT PRESENTATIONS

The Museum of Geology at the South Dakota School of Mines and Technology will provide a $50 award for the best paper by an undergraduate, and $25 for the second best paper.

The Paleontological Society will sponsor an award for the best student paper in paleontology. A nonstudent can be coauthor, but the student must be both the presenter and senior (primary) author. To be eligible, the speaker must be currently enrolled in a graduate or undergraduate program or have completed such a program no more than one month prior to the meeting. The award will be a one-year subscription to *Paleobiology*.

STUDENT ACTIVITIES

A special activity for students, especially those interested in environmental and engineering geology, The Roy Shlemon Mentors in Applied Geology, will be sponsored by GSA's Institute for Environmental Education. Rick Baker, engineering geologist from FMG, Inc., will present a workshop on practical aspects of engineering geology, including management of geotechnical projects, communication, and ethics. This presentation will take place on Thursday, April 18, at the Civic Center. A complimentary luncheon is included as part of the workshop program. Following the lectures there will be an opportunity for one-on-one discussion with Rick Baker.

Undergraduate or graduate students who wish to attend this function should write a one-page letter by March 1, 1996, to Perry H. Rahn, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701. The letter should document why the student would benefit from this experience. Twenty applicants will be selected and notified by March 15, 1996.

STUDENT TRAVEL SUPPORT

The Rocky Mountain Section has funds available to support student associates of the Geological Society of America who plan to attend the meeting. Preference for support will be given to presenters of papers and posters and to group applications. Students are strongly encouraged to apply for these grants. Send a letter of application which identifies all student travelers in the group, GSA Student Associate member numbers, and a

Rocky Mountan *continued on p. 28*

Rocky Mountan *continued from p. 27*

summary of costs to Rocky Mountain Section Secretary Ken Kolm, Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, CO 80401, (303) 273-3932, fax 303-273-3858, Internet: kkolm@mines.colorado.edu. If you are presenting a paper or poster, please include a copy of your notification of acceptance. Applications must be received by Ken Kolm by Friday, March 15, 1996.

The Rocky Mountain Section, GSA, will award full or partial field-trip registration for two students on each field trip. To receive free registration, the students must write letters that describe why participation in the field trip will enhance their research or education. Letters may also address financial need and minority status. Letters must be sent to Perry Rahn, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-2464, fax 605-394-6703. *Letters must be received by March 15, 1996.*

SPECIAL EVENTS

A **welcoming reception** with cash bar and free hors d'oeuvres will be held at the Rapid City Civic Center (Rushmore H and adjacent Upper Concourse) on Wednesday, April 17, 1996, beginning at 6:30 p.m. One free drink ticket will be provided with the registration materials.

The annual business-luncheon meeting of the **Rocky Mountain Section of the Paleontological Society** will be held on Thursday, April 18, 1996, at 12 noon in Room 101 at the Civic Center.

The **National Association of Geoscience Teachers** will be holding a breakfast on Friday, April 19, 1996, from 7:00 a.m. to 830 a.m. Cost: $6.50. Information to be announced at a later date.

The **GSA Rocky Mountain Section Education Committee meeting** will be held on Thursday, April 18, 1996, from 5:00 p.m. to 6:00 p.m. in the Civic Center.

Larry Agenbroad has offered to guide registrants and registered guests on **a tour of the Mammoth Site in Hot Springs**, about 1 hour south of Rapid City. If enough people are interested, transportation may be arranged for a visit to the site on Thursday evening, April 18, leaving the Civic Center at 6:00 p.m. Cost: $10. Please indicate your interest on the registration form.

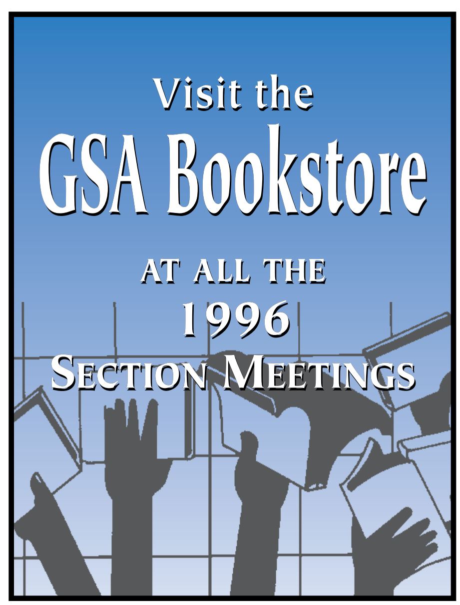
The annual business-luncheon meeting of the **GSA Rocky Mountain Section** will be held at 12 noon on Friday, April 19, 1996, in Room 101 at the Civic Center.

GUEST PROGRAM

Mount Rushmore and Custer State Park are well-known attractions in the Rapid City and Black Hills area, and there are many scenic drives in the Black Hills and Badlands. The Civic Center is conveniently located near the downtown area, which features galleries, shops, hotels, and other attractions. The depot for the Rapid Ride bus system is a two-minute walk from the Civic Center; routes include the Rushmore Mall and other parts of Rapid City. The Museum of Geology at the South Dakota School of Mines and Technology has outstanding exhibits and research collections and is a major tourist attraction. A guidebook for a walking tour of downtown Rapid City will be available for purchase. Organized activities will depend on the number of preregistered guests.

DETAILED INFORMATION

More detailed information will be provided in the Rocky Mountain Section *Abstracts with Programs.* To order *Abstracts with Programs,* fill out and mail in the form on p. 34. Address questions and suggestions to Colin Paterson, GSA Meeting Chair, Dept. of Geology and Geological Engineering, South Dakota School of Mines and Technology, 501 E. St. Joseph St., Rapid City, SD 57701, (605) 394-5114, fax 605-394-6703, Internet: paterson@silver.sdsmt.edu. ■



PREREGISTRATION FORM

GSA Rocky Mountain Section

Preregistration Deadline: March 8, 1996 **Rapid City, South Dakota • April 18–19, 1996**

Please print clearly • THIS AREA IS FOR YOUR BADGE

Name as it should appear on your badge (last name first)

Employer/University Affiliation

City State or Country

Mailing Address (use two lines if necessary)

City State

ZIP Code Country (if other than USA)

Circle member affiliation (to qualify for registration member discount): (A) GSA (B) PS (C) NAGT

GUEST INFORMATION • Please print clearly • This area is for badge

Name as it should appear on your guest's badge

City State or Country

Please indicate if you or your guest will need services to accommodate a disability: ☐ Yes

( ) - **Business Phone**

( ) - **fax**

( ) - Home Phone

Preregistration Deadline: March 8
Cancellation Deadline: March 15

MAIL TO:
GSA ROCKY MOUNTAIN SECTION MEETING,
P.O. BOX 9140, BOULDER, CO 80301

Remit in U.S. funds payable to:
1996 GSA Rocky Mountain Section Meeting
(All preregistrations must be prepaid.
Purchase Orders not accepted.)

Payment by (check one):
☐ Check ☐ American Express ☐ VISA ☐ MasterCard

Card Number

Signature Expires

FOR OFFICE USE

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REGISTRATION FEES

	Full Meeting	One Day	Amount
Professional Member*	(01) $55 ☐	(02) $35 ☐	$
Professional Nonmember	(03) $70 ☐	(04) $50 ☐	$
Student Member*	(05) $15 ☐	(06) $10 ☐	$
Student Nonmember	(07) $20 ☐	(08) $15 ☐	$
K–12 Professional	(42) $15 ☐		$
Guest or Spouse	(09) $10 ☐		$
Field Trip Only Fee	(98) $15 ☐		$

*Member fee applies to any current Professional OR Student Member of GSA or Associated Societies listed at left. Discount does not apply to guest registrants.

SPECIAL EVENTS

1. Paleontological Society Business Luncheon ....April 18 ....(61) $ 8 $ ______
2. Tour to Mammoth Site, Hot Springs ....April 18 ....(62) $ 10 $ ______
3. NAGT Breakfast ....April 19 ....(63) $6.50 $ ______
4. GSA Rocky Mountain Section Business Luncheon ....April 19 ....(64) $ 8 $ ______

WORKSHOP

Field Trip for K–12 Science Educators ....April 17 ....(50) $ 60 $ ______

FIELD TRIPS

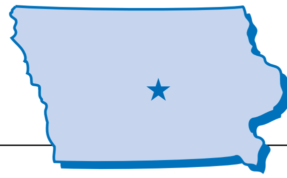
1. Tertiary Tectonism in Northern Great Plains ....April 15–17 ...(101) $155 $ ______
2. Paleogene Stratigraphy and Sedimentation ....April 17 ....(102) $ 60 $ ______
3. Hydrogeology of Central Black Hills ....April 17 ....(103) $ 55 $ ______
4. Major Unconformities of Black Hills ....April 17 ....(104) $ 55 $ ______
5. Reclamation at Northern Black Hills Gold Mines ....April 17 ....(105) $ 52 $ ______
6. Homestake Iron-Formation–Hosted Gold Deposit ....April 19 ....(106) $ 42 $ ______
7. Geologic Hazards of the Black Hills ....April 20 ....(107) $ 60 $ ______
8. Late Cretaceous Marine Stratigraphy and Paleontology of Southern Black Hills
   Double Occupancy ....April 20–21 ...(108) $130 $ ______
   Single Occupancy ....(109) $150 $ ______
9. Tectonic and Plutonic Development and Associated Metamorphism-Metasomatism in Southern Black Hills
   Double Occupancy ....April 20–21 ...(110) $ 95 $ ______
   Single Occupancy ....(111) $115 $ ______
10. Lower Paleozoic Stratigraphy of Black Hills ....April 20 ....(112) $ 55 $ ______
11. Tertiary Igneous Systems and Related Au-Ag Mineralization of Northern Black Hills
   Double Occupancy ....April 20–21 ...(113) $ 135 $ ______
   Single Occupancy ....(114) $ 155 $ ______

TOTAL FEES $ ______

Final Announcement

NORTH-CENTRAL SECTION, GSA
30th Annual Meeting

Ames, Iowa
May 2–3, 1996



The Department of Geological and Atmospheric Sciences at Iowa State University at Ames will host the 30th Annual Meeting of the North-Central Section of the Geological Society of America. The meeting will be held on campus in the Scheman Center for Continuing Education. Scientific sessions will begin at 8:00 a.m. on Thursday, May 2, and will end at 5:00 p.m. Friday, May 3. Societies that will meet in conjunction with the North-Central Section of GSA include the North-Central Section of the Paleontological Society, the Great Lakes Section of SEPM, and the Central Section of the National Association of Geoscience Teachers. Additional information can be found on the World Wide Web at URL http://www.public.iastate.edu/~geat/ncgsa/intro.html.

REGISTRATION

Preregistration Deadline: March 29, 1996

Preregistration by mail will be handled by the Geological Society of America Meetings Department, P.O. Box 9140, Boulder, CO 80301-9140. Full payment MUST accompany registration (purchase orders are NOT accepted). Charge cards are accepted as indicated on the preregistration form. Your confirmation letter from GSA will be your receipt; *no other receipt will be sent.* Register one professional or student per form. Copy the form for your records. Preregistration forms received after the March 29 deadline will be charged at the on-site rate.

Early registration is strongly recommended for all field trips and many of the special activities because of participant limits.

Badges must be worn for access to ALL activities. Guest registration is required to attend guest activities. To obtain the guest rate, all guests must be accompanied by a registered professional or a registered student. Current student ID is required to obtain student rates. Students not carrying a current student ID when they arrive to pick up registration materials will be required to pay the professional fee.

GSA is committed to making every event at the 1996 North-Central Section Meeting accessible to all people interested in attending. If you have special requirements, such as an interpreter or wheelchair accessibility, please indicate this on the registration form, or call Carl F. Vondra at (515) 294-4477. If possible, please let us know by March 29, 1996.

Cancellations, Changes, and Refunds. All requests for registration additions, changes, and cancellations must be made in writing and received by April 5, 1996. Faxes will be accepted. Advance registrations will be refunded for all such cancellations. NO REFUNDS WILL BE MADE ON CANCELLATION NOTICES RECEIVED AFTER APRIL 5, 1996. Refunds for fees paid by credit card will be credited according to the card number on the preregistration form. NO refunds will be given for on-site registration and ticket sales.

ON-SITE REGISTRATION SCHEDULE

Registration will be held on the second floor of the Scheman Continuing Education Building,
Wednesday, May 1, 4:30 p.m. to 8:00 p.m.
Thursday, May 2, 7:30 a.m. to 4:30 p.m.
Friday, May 3, 7:30 a.m. to 12:00 noon.

REGISTRATION FEES

	Advance *(by March 29)*		On-site	
	Full Meeting	One Day	Full Meeting	One Day
Professional—Member	$60	$35	$70	$40
Professional—Nonmember	$65	$40	$75	$45
Student—Member	$20	$15	$25	$20
Student—Nonmember	$25	$20	$30	$25
K–12 Professional	$15	N/A	$20	N/A
Guest/Spouse	$10	N/A	$15	N/A

STUDENT PAPERS AND TRAVEL ASSISTANCE

The North-Central Section of GSA will award $75 for each of the eight papers judged best whose principal author and presenter is a graduate or undergraduate student. Abstracts of papers submitted for consideration for these awards should be so indicated on the abstract form. In addition, awards for travel assistance of up to $200 may be made to student members and associates. The assistance will be offered on a first-come, first-served basis, with priority given to students presenting oral or poster papers, if funds are limiting. Students must be currently enrolled in an academic department and certify their student membership. Applications for travel assistance awards may be obtained by writing to the General Chair, Carl F. Vondra, Department of Geological & Atmospheric Sciences, 253 Science I, Iowa State University, Ames, IA 50011-3212 or by calling (515) 294-4477. Applications for travel assistance must be received no later than February 16, 1996.

SPECIAL EVENTS

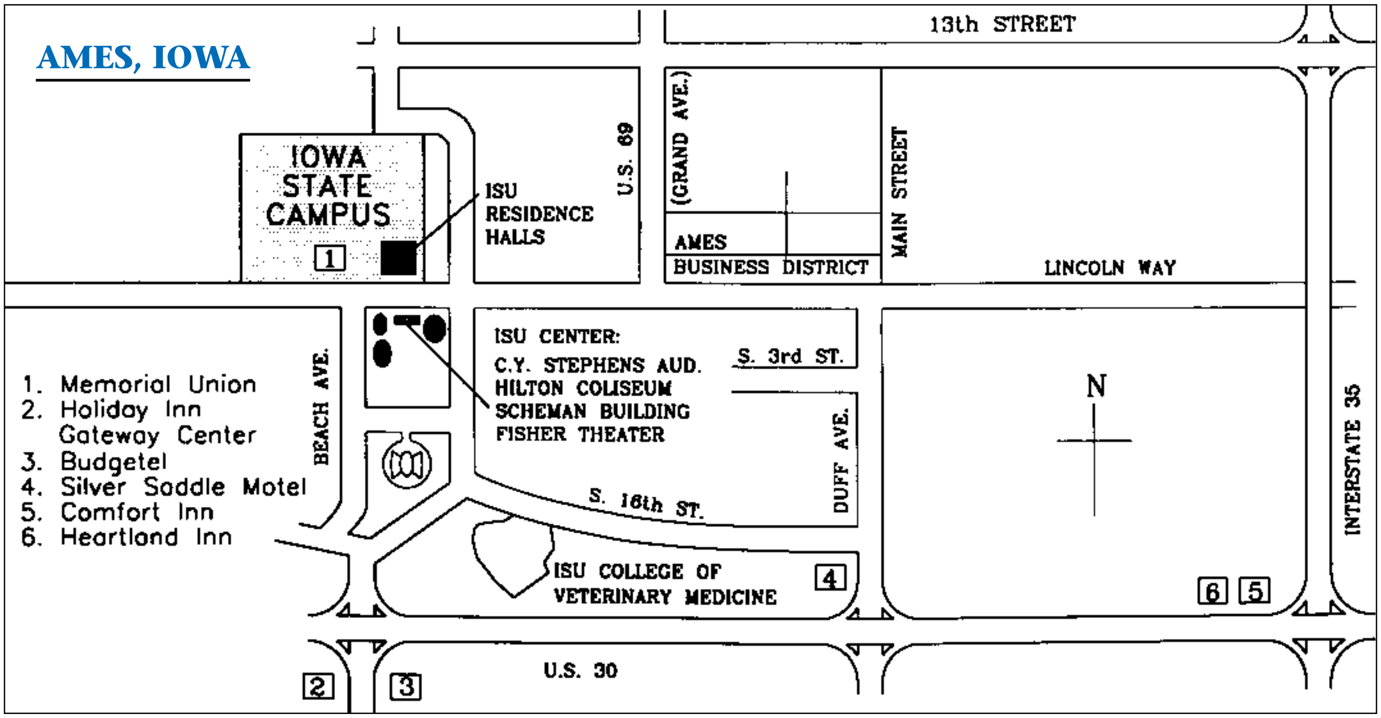
All special events will be held in the Scheman Building. A **welcoming reception** will be held on Wednesday, May 1, 1996. The **annual banquet** will be held Thursday, May 2, preceded by a social hour beginning at 6:00 p.m. and followed by a short business meeting. Cost for the banquet is $20. Please indicate which entree you prefer, on the preregistration form. A **special address** titled "Employment and Education in the Geosciences, 1996–2006" will be given by Gordon P. Eaton, Director of the U.S. Geological Survey, following the banquet in Benton Auditorium. The lecture will be open to all registrants.

The **GSA North-Central Section Management Board** will hold its business meeting with breakfast on May 2, 1996, at 7:00 a.m. A breakfast for the **North-Central GSA Campus Representatives** will be on Friday, May 3, at 7:00 a.m.

The **North-Central Section of the Paleontological Society** will hold a luncheon on Thursday, May 2, at 12:00 noon. The **National Association of Geology Teachers** will hold a luncheon on Friday, May 3, at 12:00 noon. Cost for each luncheon is $10. The **American Women in Geoscience** will hold a breakfast on Friday, May 3, at 7:00 a.m. Cost for this breakfast is $3.00.

SPOUSE AND GUEST ACTIVITIES

1. **Campus Walking Tour.** A free guided tour of the Iowa State Campus will be available. Because this is a walking tour and requires good weather, we will set time and date at the begin-



ning of the meeting. Please watch for announcements.

Iowa State University is situated on a beautiful 1770-acre campus. Founded in 1858, it has a mixture of modern and historical buildings, including the recently renovated Carrie Chapman Catt Hall. The 1 to 1-1/2 hour tour will end with a visit to the Iowa College Salon, a show of prize-winning artwork of students from Iowa colleges and universities, at the Brunnier Gallery.

2. **Pella.** The town of Pella is a little piece of Holland in the American midwest. The picturesque 150-year-old town is especially famous for its annual tulip festival, which celebrates its 60th year in 1996. Most of the several hundred thousand tulips should be in bloom during our visit. We will have a guided tour through the town, visit the historical village, and see the restored Scholte House, mansion of the town's founder, with its beautiful gardens.

This is an all-day tour, leaving Thursday, May 2, at 9:00 a.m., and returning around 4:45 p.m. Cost: $35 per person, including transportation (van), guide, and admissions. Lunch is not included; you will have time to sample one of the original Dutch eating establishments on your own. Minimum: 5 participants.

3. **Des Moines: Iowa State Historical Museum and Living History Farms.** This day trip to Des Moines will visit the Iowa State Historical Building and Living History Farms. The State Historical Building will be hosting the unique exhibit, Land of the Fragile Giants, an artistic interpretation of the extraordinary landscape of the Iowa Loess Hills through the eyes of 27 professional artists from the midwest.

Living History Farms is an outdoor museum that takes you through the history of farming in the Midwest from prehistoric, Native American times through the 21st century. Some easy walking will be required on this tour. In case of bad weather we will visit an indoor museum instead.

The tour will leave Ames on Friday, May 3, at 10:00 a.m., and return around 6:00 p.m. Cost: $25 per person, including transportation (van) and all admissions, excluding lunch. Minimum: 5 participants.

4. **Bridges of Madison County and John Wayne Birthplace.** Yes, there really is a Madison County, Iowa, with covered bridges, and the historic little town of Winterset. We will visit the town, the covered bridges from both the book and the movie version of *Bridges of Madison County*, and "Francesca's Home," now a museum. Winterset also happens to be the birthplace of John Wayne, whose house we will be visiting as well.

The tour is tentatively set for Friday, May 3, leaving Ames at 9:00 a.m., and returning around 4:00 p.m. Cost: $35 per person, including transportation and all admissions, excluding lunch. Minimum: 5 participants.

ACCOMMODATIONS

A total of more than 400 rooms has been reserved at several local motels for meeting participants. **Please note that participants are responsible for making their own lodging arrangements.** Reservations should be made **no later than April 1, 1996,** to guarantee the rates given. Be sure to indicate that you are participating in the North-Central Section of the Geological Society of America to receive the special meeting rate.

1. **Memorial Union**—ISU Campus at Lincolnway and Morrill Road, Ames, IA 50011, (515) 292-1111, $40–$50.
2. **Holiday Inn/Gateway Conference Center**—U.S. Highway 30 at Elwood Drive, Ames, IA 50010, (515) 292-8600, (800)-HOLIDAY, $64–$76.
3. **Budgetel Inn**—Hwy 30 and Elwood Drive, Ames, IA 50010, (515) 296-2500, $44.95–$50.95.
4. **Silver Saddle Motel**—U.S. Hwy 30 and South Duff Ave., Ames, IA 50010, (515) 232-8363, $45.
5. **Comfort Inn**—1605 S. Dayton, Ames, IA 50010, (515) 232-0689, $54.95.
6. **Heartland Inn**—Junction of I-35 and U.S. Hwy 30, Ames, IA 50010, (515) 233-6060, (800) 334-3277, $35.

MEALS

Lunch will be available in the Scheman Center on both Thursday and Friday for $7.00. Tickets must be purchased in advance to take advantage of this service (see registration form). A wide variety of restaurants in Ames, ranging from fast food to formal dining, also offer meal service. A list will be provided in the registration materials.

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TRANSPORTATION

Iowa State University is near I-35 and U.S. Hwy 30. Major commercial airlines serve Des Moines International Airport, located approximately 45 miles from campus. Ames Municipal Airport is an all-weather airport designed to accommodate general aviation, including small corporate jets. Bus service directly into Ames is provided by both Greyhound and Jefferson bus lines.

The Scheman Center for Continuing Education has 100 parking spaces immediately adjacent to the building. An additional 900 spaces are available in the surrounding Iowa State Center complex. There is no charge for parking in any of these locations.

Shuttle service from the hotels to the Scheman Center for Continuing Education begins at 6:45 a.m. and ends at 10 p.m. on May 2 and 5:30 p.m. on May 3. Schedule information will be posted in the hotels during the meeting.

TECHNICAL PROGRAM

Questions regarding the technical program should be addressed to Kenneth E. Windom, Dept. of Geological and Atmospheric Sciences, 253 Science I, Iowa State University, Ames, IA 50011-3212, phone (515) 294-2430, fax 515-294-6049, E-mail: kewindom@iastate.edu.

SYMPOSIA

The following symposia have been organized. Authors are encouraged to contact the individual symposium organizers for information.

1. **Applications of Hydrogeology in Agricultural Water Quality Studies.** Sponsored by the Institute for Environmental Education. William W. Simpkins, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011-3212, (515) 294-7814, fax 515-294-6049, E-mail: bsimp@iastate.edu; George R. Hallberg, University of Iowa Hygienic Laboratory, 102 Oakdale Campus, University of Iowa, Iowa City, IA 52242-5002, (319) 335-4500, fax 319-335-4600, E-mail: ghallber@uhl.uiowa.edu.
2. **Groundwater Consultants' Symposium: Role of Geology in the Characterization and Remediation of Contaminated Sites** (Joint with Great Lakes SEPM). Roger Bruner, Foth and Van Dyke Inc., 10340 Viking Drive, Suite 100, Eden Prairie, MN 55344, (612) 942-0396, fax 612-942-0865, E-mail: drbmn@aol.com; Doug Connell, Barr Engineering, Minneapolis, MN, E-mail: dconnell@barr.com.
3. **Robert V. Ruhe Symposium: Historical Perspectives of Research in Soil Science and Quaternary Geology.** Tom Fenton, Dept. of Agronomy, Iowa State University, Ames, IA 50011-1010, (515) 294-2414, fax 515-294-3517, E-mail: tefenton@iastate.edu; Gerry Miller, Dept. of Agronomy, Iowa State University, Ames, IA 50011-1010, (515) 294-1923, fax 515-294-3517, E-mail: soil@iastate.edu; Carolyn Olson, USDA, Lincoln, NE, 68508-3866, (402) 437-5423, fax 402-437-5336, E-mail: agro202@unlvm.unl.edu. (Invited papers only; contributed papers on this topic will be put together in a special poster session.)
4. **Subduction Zone Magmatism.** James Walker, Dept. of Geology, Northern Illinois University, Dekalb, IL 60115-1943, (815) 753-7936, fax 815-753-1945, E-mail: jim@geol.niu.edu; Shanaka L. de Silva, Dept. of Geography and Geology, Indiana State University, Terre Haute, IN 47809, (812) 237-2269, fax 812-237-8029, E-mail: GESILVA@scifac.indstate.edu.
5. **Mesozoic Paleoenvironments of North America** (Joint with Great Lakes SEPM). Greg Ludvigson, Geological Survey Bureau, Iowa DNR, Iowa City, IA 52242-1319, (319) 335-1761, fax 319-335-2754, E-mail: gregoryludvigson@uiowa.edu; Brian J. Witzke, Dept. of Geology, University of Iowa, Iowa City, IA 52242-1319, (319) 335-1761, fax 319-335-2754, E-mail: brian-witze@uiowa.edu; Carl F. Vondra, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011-3212, (515) 294-4477, fax 515-294-6049, E-mail: dfrisk@iastate.edu.
6. **Edge-wise Conglomerates** (Joint with Great Lakes SEPM). Roger Bain, Dept. of Geology, University of Akron, Akron, OH 44325-4101, (216) 972-7659, fax 216-972-6990, E-mail: rbain@uakron.edu.
7. **Earth Science Educators and National Standards.** Tim Cooney, Dept. of Earth Sciences, University of Northern Iowa, Cedar Falls, IA 50614, (319) 273-2918, fax 319-273-7124, E-mail: Timothy.Cooney@UNI.EDU; Frederick P. DeLuca, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50010-3212, (515) 294-7254, fax 515-294-6049, E-mail: fpdeluca@iastate.edu.
8. **Historical Perspectives on Mid-continent Geology** (Cosponsored by Central Section of NAGT). Wayne I. Anderson, Dept. of Earth Sciences, University of Northern Iowa, Cedar Falls, IA 50614, (319) 273-2759, fax 319-273-7124, E-mail: Wayne.Anderson@UNI.EDU. (Invited papers only; contributed papers on this topic will be put together in a special poster session.)
9. **Geology and General Education** (Cosponsored by NAGT). Robert Corbett, Dept. of Geography-Geology, Illinois State University, Normal, IL 61790-4400, (309) 438-7649, fax 309-438-5310, E-mail: rcorbett@rs6000.cmp.ilstu.edu.
10. **Undergraduate Research Results.** Robert W. Baker, Dept. of Plant and Earth Science, University of Wisconsin, River Falls, WI 54022, (715) 425-3345, fax 715-425-3785; Sam Huffman, Dept. of Plant and Earth Science, University of Wisconsin, River Falls, WI 54022, (715) 425-3345, fax 715-425-3785, E-mail: samuel.huffman@uwfr.edu; Robert D. Shuster, Dept. of Geography and Geology, 260 Durham Science Center, University of Nebraska—Omaha, Omaha, NE 68182-0199, (402) 554-2457, fax 402-554-3518, E-mail: bshuster@cwis.unomaha.edu.
11. **Geomicrobiology: From Basic Science to Implications for Bioremediation.** Blythe Hoyle, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011-3212, (515) 294-6583, fax 515-294-6049, E-mail: blhoyle@iastate.edu; Pedro Alvarez, Dept. of Civil and Environmental Engineering, University of Iowa, Iowa City, IA 52242, (319) 335-5065, E-mail: pedroalvarez@uiowa.edu.
12. **Recent Studies of Precambrian Geology in the Mid-continent.** Raymond R. Anderson, Geological Survey Bureau, Iowa DNR, Iowa City, IA 52242-1319, (319) 335-1575, fax 319-335-2754, E-mail: randerson@gsbthpo.igsb.uiowa.edu; Kenneth E. Windom, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011-3212, (515) 294-2430, fax 515-294-6049, E-mail: kewindom@iastate.edu.
13. **Long-term Effect of Mass Extinction.** Patricia E. Kelley, Dept. of Geology and Geological Engineering, University of North Dakota, Grand Forks, ND 58202, (701) 777-2380, fax 701-777-4449, E-mail: patriciakelley@mail.und.nodak.edu; Joanne Kluessendorf, Dept. of Geology, University of Illinois, Urbana, IL 61801, (217) 367-5916, fax 217-244-4996.
14. **The Geology of Early Hominids.** James L. Aronson, Dept. of Geological Sciences, Case Western Reserve University, 10900 Euclid Ave., A.W. Smith #112, Cleveland, OH 44106-7216; Carl F. Vondra, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011, (515) 294-4477, fax 515-294-6049, E-mail: dfrisk@iastate.edu.
15. **The Des Moines Lobe: Sediment, Landforms, and Modeling.** Carrie Patterson, Minnesota Geological Survey, (612) 627-4815, fax 612-627-4778, E-mail: patte018@maroon.tc.umn.edu; Mark Johnson, Gustavus Adolphus College, St. Peter, Minnesota, (507) 933-7442, fax 507-933-7042, E-mail: mdj@gac.edu.

WORKSHOPS

1. **AutoCAD for Geologists.** A two-day workshop to be held Saturday and Sunday following the meeting. This course will provide an introduction to AutoCAD, with emphasis on those features of most utility to geologists. It is expected that sufficient grounding can be provided so that participants can go on to master AutoCAD on

their own. The training sessions will include several geologically useful AutoCAD add-in programs, such as for performing contouring. Care will be taken to select only those programs that are freeware or modestly priced. Approval is being sought for participants to receive continuing education credit through the Continuing Education Program at Iowa State University. The course will be offered by Carl E. Jacobson, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011-3212, (515) 294-4480, fax 515-294-6049, E-mail: cejac@iastate.edu. Fee: $50 for professionals, $30 for students; includes two box lunches. Limit: 20.

2. **Roy Shleman Mentors in Applied Geology Program: Workshop for Students.** Sponsored by the GSA Institute for Environmental Education. Dean Lewis and other personnel from ATC Environmental, Inc. will present a workshop for upper-level undergraduate and graduate students covering processes involved in an environmental site assessment. Case studies will be used to illustrate environmental geological issues, with emphasis on investigations of underground storage tanks containing petroleum products. A demonstration of an environmental drilling and monitoring well installation is planned. There is no charge to students for this short course; however, space is limited to two students per participating college or university. (A waiting list will be maintained of other students interested, in case additional spaces are available.) Preregistration is required. For additional information, contact R. Dean Lewis, ATC Environmental, Inc., ISU Research Park, 2625 North Loop Dr., Ste. 2150, Ames, IA 50010, (515) 296-6850, fax 515-296-6851.

PROJECTION EQUIPMENT

Two standard 35 mm carousel projectors for 2" x 2" slides and one overhead projector for transparencies will be provided in each meeting room. Please bring your own loaded carousel tray(s) identified with speaker's name, session, and speaker number to your session room before the start of the session. A speaker-ready room equipped with projectors will be available for review and practice.

POSTER SESSIONS

Students and professionals are encouraged to take advantage of this effective means of presentation. Please indicate Poster Session on the GSA abstract form. Each poster booth will contain a 4′ high × 8′ wide board arranged at table height. Poster sessions will be located in the area near exhibits and will be available for viewing for one-half day.

Poster sessions will include all topics listed on the GSA abstract form. In addition, two thematic poster sessions will be held.

Poster Session 1: **Recent Research in Soil Science and Quaternary Geology in the Midcontinent.** This session will be for contributed presentations and is meant to complement the Ruhe Symposium (#3, above). Presenters interested in further information should contact one of the organizers of that symposium.

Poster Session 2: **Special Poster Session on Undergraduate Research.** The Council on Undergraduate Research and the NAGT will be sponsoring a special poster session highlighting undergraduate research. These papers are to be written and presented by undergraduate students on their research. Coauthored papers for which the student is senior author will also be considered. The session will form a separate poster session or be part of another poster session, depending on the response. Undergraduate students who have been involved in research are strongly urged to submit abstracts on their research projects, activities, techniques, and/or preliminary results for this session. Additional information can be obtained by contacting Samuel F. Huffman, Dept. of Plant & Earth Sciences, University of Wisconsin, River Falls, WI 54022, (715) 425-3345, fax 715-425-3785; E-mail: samuel.huffman@uwrf.edu; or Robert D. Shuster, Dept. of Geography & Geology, University of Nebraska—Omaha; Omaha, NE 68182, (402) 554-2457, fax 402-554-3518; E-mail: bshuster@cwis.unomaha.edu.

ABSTRACTS

Abstracts must be submitted camera-ready on official GSA abstract forms in accordance with instructions on the forms. Abstract forms are available from: Abstracts Coordinator, Geological Society of America, P.O. Box 9140, Boulder, CO 80301-9140; (303) 447-2020, E-mail: ncarlson@geosociety.org, or from Kenneth E. Windom, North-Central Program Coordinator, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011-3212, (515) 294-2430, E-mail: kewindom@iastate.edu. Forms are also available from GSA campus representatives at most colleges and universities and from symposium organizers.

FIELD TRIPS

Premeeting, during meeting, and postmeeting field trips are planned. Preregistration for field trips is recommended because participants will be accepted on a first-come, first-served basis. Field trip participants must also register for at least one day of the meeting. All trips are technical in nature and may be physically demanding for participants. Weather in early May is variable, so winter parkas, rain gear, and boots are all recommended. All field trips will begin and end at the north entrance to the Scheman Center for Continuing Education. Full refunds will be issued for trips canceled due to logistical reasons. Questions about the field trips may be addressed to Field Trip Coordinator William W. Simpkins, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011, (515) 294-7814, fax 515-294-6049, E-mail: bsimp@iastate. edu.

Premeeting

1. **Mid-Cretaceous Fluvial Deposits of the Eastern Margin, Western Interior Basin: Nishnabotna Member, Dakota Formation.** Brian J. Witzke and Greg A. Ludvigson, Iowa Department of Natural Resources–Geological Survey Bureau, Trowbridge Hall, University of Iowa, Iowa City, IA 52242, (319) 335-1575, fax 319-335-2754, E-mail: bwitzke@gsbth-po.igsb.uiowa.edu, or gludvigson@gsbth-po.igsb.uiowa.edu. This field trip will examine coarse-grained clastic units deposited by westward-flowing river systems that drained the cratonic margin of the Cretaceous Western Interior basin. Recent research suggests that the late Albian deposits intertongue westward with marginal marine facies of the Skull Creek–Kiowa marine cycle. One day, May 1. Lunch and snacks provided. Cost: $50. Limit: 30.

2. **Greenfield Quadrangle—Revisited.** Gerald A. Miller and Thomas E. Fenton, Dept. of Agronomy, Iowa State University, Ames, IA 50011, (515) 294-1923 (Miller), or (515) 294-2414 (Fenton), fax 515-294-3163, E-mail: soil@iastate.edu, or tefenton@iastate.edu. This field trip will travel to southern Iowa to review the soil geo-

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morphic relations investigated during the early 1950s by Robert V. Ruhe. Classic soil landscapes and soil profiles will be examined. One day, May 1. Lunch and snacks provided. Cost: $55. Limit: 90.

During Meeting

3. **Hydrogeology and Water Quality of the Walnut Creek Watershed.** Sponsored by the Institute for Environmental Education. William W. Simpkins, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011, (515) 294-7814, fax 515-294-6049, E-mail: bsimp@iastate.edu; Michael R. Burkart, USDA-ARS, National Soil Tilth Laboratory, Ames, IA 50011, (515) 294-5809, fax 515-294-8125, E-mail: mburkart@iastate.edu; James M. Eidem, Beth L. Johnson, Martin F. Helmke, Hyejeung H. Seo, Heyo Van Iten, Mikael S. Brown, and Sarah R. Vlachos, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011. Since 1990, research in the Walnut Creek watershed—one of three U.S. Department of Agriculture Management System Evaluation Areas (MSEA) in Iowa—has focused on the impact of current and future farming practices on ground- and surface-water quality. The field trip will examine the hydrogeological aspects of this study, including the glacial and alluvial stratigraphy, ground-water flow in till and alluvium, ground-water–surface-water interaction, and the fate and transport of agrichemicals in the watershed. One-half day, May 3, afternoon. Snack provided. Cost: $40. No limit.

Postmeeting

4. **Jurassic Gypsum Deposits near Fort Dodge, Iowa.** Robert D. Cody, Dept. of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011, (515) 294-1714, fax 515-294-6049, E-mail: gypsum@iastate.edu. This field trip will visit locales that illustrate the three major facies of the Jurassic-age Fort Dodge Formation: the underlying basal clastic unit, the laminated gypsum bed, and the overlying clastic units known informally as the Soldier Creek beds. We will discuss the origin of the gypsum and associated sediments. We will end the trip with a visit to the U.S. Gypsum wallboard (sheetrock) plant, where we will discuss the economic value of gypsum to the Fort Dodge area. One day, May 4. Lunch and snacks provided. Cost: $50. Limit: 25.

5. **Hogs, Bogs, and Logs: Quaternary Deposits and Environmental Geology of the Des Moines Lobe.** Sponsored by the Institute for Environmental Education. E. Art Bettis III, Debra J. Quade, Carol A. Thompson, Robert D. Libra, Iowa Department of Natural Resources–Geological Survey Bureau, Trowbridge Hall, University of Iowa, Iowa City, IA 52242, (319) 335-1575; fax 319-335-2754, E-mail: abettis@gsbth-po.igsb.uiowa.edu; Timothy J. Kemmis, Rust Environmental and Infrastructure, Sheboygan, Wisconsin, (414) 451-2657, fax 414-458-0550; Thomas E. Fenton, Dept. of Agronomy, Iowa State University, Ames, IA 50011, (515) 294-2414, fax 515-294-3163, E-mail: tefenton@iastate.edu; Angela Rieck-Hinz, Agricultural Extension Program, Iowa State University, Ames, IA 50011, (515) 294-0577, fax 515-294-9985, E-mail: amrieck@iastate.edu. This field trip will examine the Quaternary sedimentary and landform assemblages of the Des Moines lobe in north-central Iowa that were formed by an active surge advance and subsequent glacial stagnation. We will visit subglacial and supraglacial deposits in outcrop and will view landforms consisting of linked depressions, circular disintegration features (ice-walled lakes), proximal outwash terraces, and fens. We will discuss the development of large-scale hog confinement operations, the spreading of manure from these facilities near agricultural drainage wells, and the results of hydrogeological investigations at earthen manure storage facilities. Two days, May 4 and 5; 1 breakfast, 2 lunches, 4 snacks, 1 dinner at the Lakeside Laboratory; overnight lodging. Cost: $115. Limit: 40.

EXHIBITS

Exhibits of educational and commercial organizations will be on display in the Scheman Building in proximity to the symposia, technical, and poster sessions. Exhibit space must be reserved by February 23, 1996. For further information, contact Scott Thieben, Dept. of Geological and Atmospheric Sciences, 253 Science I, Iowa State University, Ames, IA 50011-3212, (515) 294-9686, fax 515-294-6049, E-mail: sthieben@iastate.edu. ■

Preregistration Form

GSA North-Central Section

Preregistration Deadline: March 29, 1996

Ames, Iowa • May 2–3, 1996

Please print clearly • THIS AREA IS FOR YOUR BADGE

Name as it should appear on your badge (last name first)

Employer/University Affiliation

City | State or Country

Mailing Address (use two lines if necessary)

City | State

ZIP Code | Country (if other than USA)

Circle member affiliation (to qualify for registration member discount): (A) GSA (B) PS (C) SEPM (D) NAGT

GUEST INFORMATION • Please print clearly • This area is for badge

Name as it should appear on your guest's badge

City | State or Country

Please indicate if you or your guest will need services to accommodate a disability: ☐ Yes

( ) - Business Phone

( ) - fax

( ) - Home Phone

Preregistration Deadline: March 29
Cancellation Deadline: April 5

MAIL TO:
GSA NORTH-CENTRAL SECTION MEETING, P.O. BOX 9140, BOULDER, CO 80301

Remit in U.S. funds payable to:
1996 GSA North-Central Section Meeting
(All preregistrations must be prepaid. Purchase Orders not accepted.)

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REGISTRATION FEES

	Full Meeting	One Day	Amount
Professional Member*	(01) $ 60 ☐	(02) $ 35 ☐	$ ____
Professional Nonmember	(03) $ 65 ☐	(04) $ 40 ☐	$ ____
Student Member*	(05) $ 20 ☐	(06) $ 15 ☐	$ ____
Student Nonmember	(07) $ 25 ☐	(08) $ 20 ☐	$ ____
K–12 Professional	(42) $ 15 ☐		$ ____
Guest or Spouse	(09) $ 10 ☐		$ ____

*Member fee applies to any current Professional OR Student Member of GSA or Associated Societies listed at left. Discount does not apply to guest registrants.

GUEST EVENTS

1. Campus Walking Tour	TBA	(20) FREE	$ ____
2. Pella	May 2	(21) $ 35	$ ____
3. Des Moines	May 3	(22) $ 25	$ ____
4. Madison County	May 3	(23) $ 35	$ ____

SPECIAL EVENTS

1. GSA N-C Section Management Board Breakfast	May 2	(60) FREE	$ ____
2. Paleontological Society Luncheon	May 2	(61) $ 10	$ ____
3. Lunch at Scheman	May 2	(62) $ 7	$ ____
4. Annual Banquet	May 2		
Stuffed Pork Loin		(63) $ 20	$ ____
Vegetarian Lasagna		(64) $ 20	$ ____
5. GSA Campus Representatives Breakfast	May 3	(65) FREE	$ ____
6. Assoc. for American Women Geoscientists Breakfast	May 3	(66) $ 3	$ ____
7. Central Section NAGT Luncheon	May 3	(67) $ 10	$ ____
8. Lunch at Scheman	May 3	(68) $ 7	$ ____

WORKSHOP

Roy Shlemon Mentors in Applied Geology Program	May 4	(50) FREE	$ ____

FIELD TRIPS

1. Mid-Cretaceous Fluvial Deposits	May 1	(101) $ 50	$ ____
2. Greenfield Quadrangle	May 1	(102) $ 55	$ ____
3. Hydrogeology and Water Quality—Walnut Creek	May 3	(103) $ 40	$ ____
4. Jurassic-age Gypsum Deposits	May 4	(104) $ 50	$ ____
5. Hogs, Bogs, and Logs	May 4–5	(105) $ 115	$ ____

CONTINUING EDUCATION COURSE

AutoCAD Workshop	May 4–5		
Professional		(150) $ 50	$ ____
Student		(151) $ 30	$ ____

TOTAL FEES $ ____

New Orleans — 1995 GSA ANNUAL MEETING

NEW ORLEANS

BRIDGING THE GULF

Statistics

TECHNICAL PROGRAM

Abstracts submitted	2360
Abstracts presented	2260
Abstracts rejected or withdrawn	100
Percentage of abstracts accepted	98%
Poster presentations (including theme posters)	524
Oral presentations	1736
Oral presentations, discipline sessions	915
Oral presentations, theme sessions	512
Oral presentations, symposia	309
Highest number of concurrent oral sessions	16

REGISTRATION

Professional	2863
Student	1420
Exhibitor	488
Guest	344
Total attendance	5115

SHORT COURSES

Number of GSA-sponsored courses	10
Participants	290

FIELD TRIPS

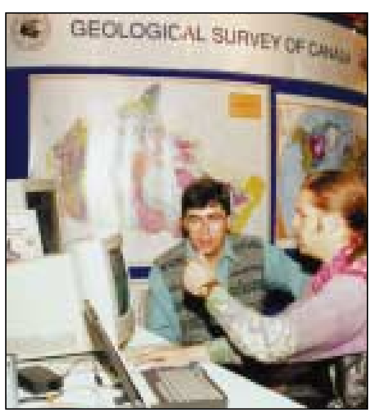
Number of trips	11
Participants	262

EXHIBITS

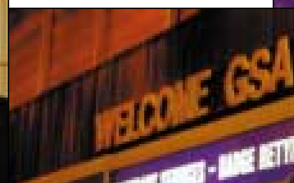
Number of booths	211
Number of exhibiting companies	152

EMPLOYMENT SERVICE

Applicants	336
Employers	26
Interviews	329
Positions available	49

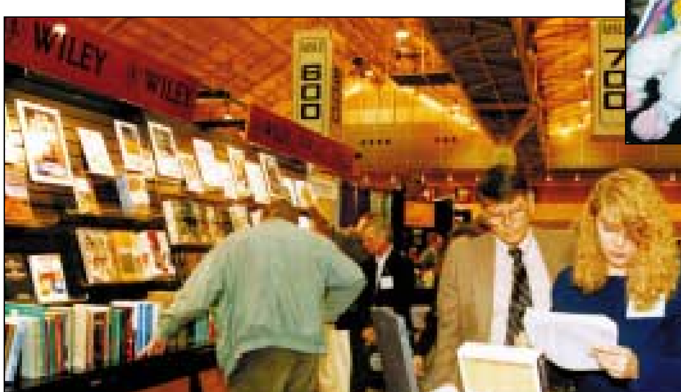



Software Fair


WELCOME GSA


Earth


UNIVERSITY OF MASSACHUSETTS
AMHERST
Department of Geoscience


WILEY
WILEY
600
700


1996 GSA Field
Cooking Contest

GSA ANNUAL MEETINGS

1996

Denver, Colorado • October 28–31
Colorado Convention Center, Marriott City Center

General Chairs: ***Gregory S. Holden*** *and* ***Kenneth E. Kolm,*** *Colorado School of Mines*

Technical Program Chairs: ***John D. Humphrey*** *and* ***John E. Warme,*** *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*

1997

Salt Lake City, Utah • October 20–23
Salt Palace Convention Center, Little America

General Chair: ***M. Lee Allison,*** *Utah Geological Survey*

Technical Program Chair: ***John Bartley,*** *University of Utah*

Call for Field Trip Proposals: We are interested in proposals for single-day and multi-day field trips beginning or ending in Salt Lake City, and dealing with all aspects of the geosciences. Please contact the field trip chairs listed below.

Paul Link
Department of Geology
Idaho State University
Pocatello, ID 83209-8072
(208) 236-3365
fax 208-236-4414
E-mail: linkpaul@isu.edu

Bart Kowallis
Department of Geology
Brigham Young University
Provo, UT 84602-4646
(801) 378-3918
fax 801-378-2265
E-mail: bjk@geology.byu.edu

Field trip guides will be published jointly by Brigham Young University Geology Studies and the Utah Geological Survey. Review drafts of field guides will be due March 15, 1997.

EARTH SYSTEM SUMMIT Denver

For general information on any meeting call the GSA Meetings Department
1-800-472-1988 or (303) 447-2020, ext. 133
E-mail: meetings@geosociety.org

GSA SECTION MEETINGS — 1996

SOUTH-CENTRAL SECTION, ***March 11–12, 1996.*** University of Texas, Austin, Texas. Information: Mark Cloos, Department of Geological Sciences, University of Texas, Austin, TX 78712, (512) 471-4170, fax 512-471-9425, E-mail: cloos@maestro.geo.utexas.edu.

SOUTHEASTERN SECTION, ***March 14–15, 1996.*** Ramada Plaza Hotel, Jackson, Mississippi. Information: Darrel Schmitz, Department of Geosciences, P.O. Box 5448, Mississippi State University, Mississippi State, MS 39762, (601) 325-2904; or Charles Swann, Mississippi Mineral Resources Institute, 220 Old Chemistry Bldg., University, MS 38677, (601) 232-7320, E-mail: cts@mmri.olemiss.edu.

NORTHEASTERN SECTION, ***March 21–23, 1996.*** Hyatt Regency, Buffalo, New York. Information: Parker E. Caulkin, Department of Geology, SUNY at Buffalo, 876 NSM, Buffalo, NY 14260, (716) 645-6800, ext. 3985, fax 716-645-3999, or preferably by E-mail: glgparkr@ubvms.cc.buffalo.edu. *Preregistration Deadline: February 26, 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. *Preregistration Deadline: March 8, 1996.*

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. *Preregistration deadline: March 15, 1996.*

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. *Preregistration Deadline: March 29, 1996.*

Student Travel Grants

The GSA Foundation will award matching grants up to a total of $3500 each to the six GSA Sections. The money, when combined with equal funds from the Sections, will be used to assist GSA Student Associates traveling to the 1996 GSA Annual Meeting in Denver in October and to the 1996 Section meetings. Contact your Section Secretary for application procedures.

Cordilleran .... Bruce A. Blackerby (209) 278-2955

Rocky Mountain ..... Kenneth E. Kolm (303) 273-3932

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

CLASSIFIED ADVERTISING

Published on the 1st of the month of issue. Ads (or cancellations) must reach the GSA Advertising office one month prior. Contact Advertising Department (303) 447-2020, 1-800-472-1988, fax 303-447-1133, or E-mail:acrawfor@geosociety.org. Please include complete address, phone number, and E-mail address with all correspondence.

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Positions Open

NEWTON HORACE WINCHELL SCHOOL OF EARTH SCIENCES
University of Minnesota, Minneapolis, MN 55455 USA

Applications are invited for a tenure-track assistant professor position in the Department of Geology and Geophysics from individuals with a demonstrated ability to apply chemical and physical principles to the integrated study of the solid Earth. Candidates must be capable of establishing a vigorous research program and exhibit a breadth in research interests that complements our strengths in Earth Structure and Tectonics, Geodynamics, Geofluids, Sedimentary Basin Analysis, Mineral/Rock Physics, Rock Magnetism, Aqueous and Isotope Geochemistry, Limnogeology, or Earth System studies. We emphasize opportunities for collaboration and interaction with ongoing research programs in the School of Earth Sciences and the availability of state-of-the-art instrumentation and computational facilities for geoscience research.

The succssful candidate will be expected to teach at all levels through advanced graduate classes, as well as participate in teaching Petrology in our innovative curriculum, and supervise graduate-student research. Applicants must have an earned doctorate degree and must demonstrate a clear promise of creative scientific achievement, leadership and teaching ability in the geosciences.

The Department of Geology and Geophysics comprises about 60 graduate students, 28 research associates and post-doctoral fellows, and 22 faculty with an exceptional record of funded research and interdisciplinary collaboration in both research and teaching. With this appointment, we seek to augment our current atmosphere of excitement in research and teaching that focuses on interactive Earth dynamics. Our Web site, http://www.geo.umn.edu, provides additional information about the School of Earth Sciences and the Department of Geology and Geophysics.

Applicants should submit a resume with a statement of research and teaching interests, official graduate transcripts, and arrange to have at least three letters of reference sent to: Professor V. Rama Murthy, Chair, Faculty Search Committee, Department of Geology and Geophysics, 310 Pillsbury Drive, S.E., University of Minnesota, Minneapolis, Minnesota 55455, USA. The deadline for receipt of the application and supporting material is **February 29, 1996.** The successful candidate is expected to assume the postion September 1996.

The University of Minnesota is committed to the policy that all persons shall have equal access to its programs, facilities, and employment without regard to race, color, religion, national origin, sex, age, marital status, disability, public assistance status, veteran status, or sexual orientation.

GEOLOGY-OCEANOGRAPHY INSTRUCTOR

MiraCosta Community College District, located in North San Diego (CA) County, is recruiting for a full-time, tenure-track Geology-Oceanography Instructor, beginning August 1996 (subject to available funding). A Master's degree or the equivalent is required. To request an application form and job announcement: leave your name, address, and *title* of the position on the Job Line Tape (619) 757-2121, ext. 8071; or reply by e-mail on the Internet to: jobs@micracosta.cc.ca.us (Website: http://www.miracosta.cc.ca.us). The closing date is March 8, 1996.

MiraCosta College is an equal employment opportunity and affirmative action employer and seeks to enhance its staff diversity by specifically inviting and encouraging qualified minorities and women to apply. MiraCosta College, Attn: Human Resources, One Barnard Drive, Oceanside, CA 92056.

Services & Supplies

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

Opportunities for Students

JOI/USSAC Ocean Drilling Fellowships. JOI/U.S. Science Advisory Committee is seeking doctoral candidates of unusual promise and ability who are enrolled in U.S. institutions to conduct research compatible with that of the Ocean Drilling Program. Both one-year and two-year fellowships are available. The award is $20,000 per year to be used for stipend, tuition, benefits, research costs and incidental travel, if any. Applicants are encouraged to propose innovative and imaginative projects. Research may be directed toward the objectives of a specific leg or to broader themes. The award aims to encourage student participation on board ODP's drillship, *JOIDES Resolution.*

April 15, 1996 is the shipboard fellowship application deadline for the following legs: Leg 170 Costa Rica, Leg 171 Barbados LWD - Blake Nose, Leg 172 NW Atlantic Sediment Drifts, Leg 173 Iberia, Leg 174 New Jersey Margin, and Leg 175 Benguela Current.

Staffing for these legs will begin during the next few months. Students interested in participating as shipboard scientists must apply to the ODP Manager of Science Operations in College Station, TX. A shipboard scientist application form and leg descriptions are included in the JOI/USSAC Ocean Drilling Fellowship application packet. For more information and to receive an application packet, contact: Andrea Johnson, JOI/USSAC Ocean Drilling Fellowship Program, Joint Oceanographic Institutions, Inc., 1755 Massachusetts Ave., NW, Suite 800, Washington, DC 20036-2102 (telephone: (202) 232-3900, ext. 213; Internet: ajohnson@brook.edu).

Interdisciplinary Graduate Study in Hydrology. The Cincinnati Earth System Science group announces the availability of graduate traineeships from the National Science Foundation for research and education leading to a Ph.D. degree. We seek highly motivated and creative individuals with a strong interest in understanding, characterizing, and modeling the occurrence, distribution, transport, and quality of water in the natural environment from an earth system science perspective.

Five NSF graduate research traineeships will be awarded during the 1996-97 academic year. The total amount of each traineeship award is $33,964 per year that includes a monthly stipend, full-tuition, cost-of-education allowance, and a three-month sabbatical at a national laboratory. Applicants must have a bachelors or masters degree in one of the hydrology interfacing disciplines including, but not limited to, atmospheric sciences, biology, engineering, geography, geology, mathematics, and physics. Students will have the option to earn a Ph.D. in their primary discipline, in environmental science, or in interdisciplinary hydrologic science. Although the NSF program is limited to U.S. Citizens and permanent residents, other funding opportunities are available for international students. For more information and to request an application package, please contact: Dr. Shafiqul Islam, The Cincinnati Earth System Science Program, P.O. Box 210071, University of Cincinnati, Cincinnati, OH 45221-0071; E-mail: hydro@fractals.cee.uc.edu. For more program information, including participating faculty and study areas, please see http://www.cee.uc.edu on the WWW.

Traveling Fellowship: Interdisciplinary Research Training Group (RTG) in ecology, geology, archeology, geography, and soils. Graduate students are invited to Minnesota for up to 3 months to enhance training in "Paleorecords of Global Change." Stipend (provided for citizens, nationals, or permanent residents of the U.S.), travel and living allowance, and tuition. Application deadline April 1 (for travel July 1 – December 31) and October 1 (for travel January 1 – June 30). For application contact RTG, University of Minnesota, Ecology, Evolution and Behavior, 1987 Upper Buford Circle, St. Paul, MN 55108. Phone: (612) 624-4238; FAX: 612/624-6777. An Equal Opportunity Educator and Employer.

Final Announcement Additions

Attending the 1996 Northeastern Section Meeting?

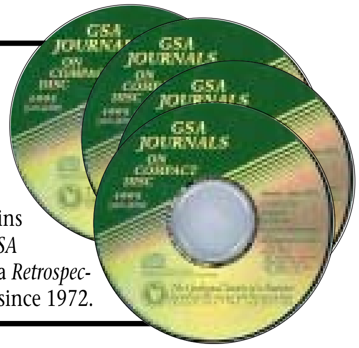
On Friday, March 22, the Northeastern Section is hosting a **Reception and Light Supper** at the **Buffalo Museum of Science** from 6:00 to 9:30 p.m. During this event the museum's exhibit areas will be open, including items of special paleontological interest—dinosaurs, Green River fossils, eurypterids, systematic arrays of minerals—and more. The special traveling exhibit "Our Weakening Web" explores all aspects of biological extinction, past and present.

This special event includes round-trip bus transportation between the Hyatt Regency and the museum as well as an Italian buffet with salad, main course, dessert, and coffee or tea. A cash bar will be open. For more information call the University of Buffalo Office of Conferences and Special Events, (716) 645-2018; be sure to indicate you are with the GSA Northeastern meeting. Please preregister using the form found on page 255 of the December 1995 issue of *GSA Today*. Cost: $15.

Sigma Gamma Epsilon Luncheon

Friday, March 22, 12:00 noon to 1:15 p.m. This lunch will feature a presentation on the use of new technology and real data sets in teaching the earth sciences—CD-ROMS and more. We will demonstrate AGI's *Portrait USA*. Cost: $15; preregistration is required (use the preregistration form in the December 1995 issue of *GSA Today*).

GSA JOURNALS ON COMPACT DISC



A CD-ROM publication of the Geological Society of America. Published since 1992, each annual CD contains a full year of articles from *GSA Bulletin, Geology,* and *GSA Today,* plus the current year's *GSA Data Repository* and a *Retrospective Electronic Index* to GSA's journal articles published since 1972. You can search the full text of articles, or view, print, or export from them. Viewable, printable graphical images of all pages are included and all photographs are provided in high-resolution, linked to the text. Now published twice annually, with new Acrobat technology that permits you to print complete pages with photos in place (since 1995, except color photos). The viewable, printable Data Repository, and any inserts, are available as scanned images, without searchable text.

GSA Journals on CD is available for DOS, MS Windows (1995/96 editions only), and Macintosh as follows:

- JCD001. 2-year, 2-CD introductory package (1992 & 1993), 6,000+ pgs. Net price: GSA Members $99, all others $125.
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- JCD005. 1-year, 2-CDs (1995), 3,000+ pgs. Net price: GSA Members $89, all others $125.
- JCD006. 1-year, 2-CDs (1996), 3,000+ pgs. Jan–Jun in July 1996; Jan–Dec in February 1997. Net price: GSA Members $89, all others $125.

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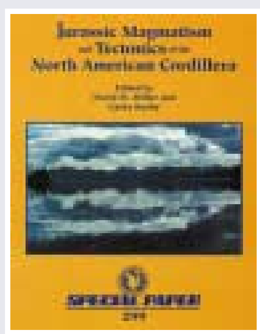
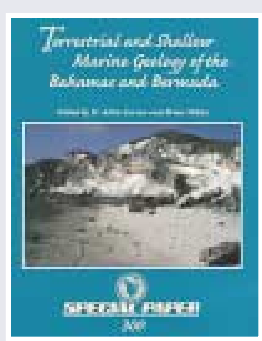


JURASSIC MAGMATISM AND TECTONICS OF THE NORTH AMERICAN CORDILLERA

edited by D. M. Miller and C. Busby, 1995

There is a growing realization that in about mid-Jurassic time, both magmatism and tectonism were widely initiated in the western North American continental crust, earlier subduction-driven magmatism and tectonics being localized near the plate margin. The 19 papers in this book discuss diverse approaches to characterize the Jurassic tectono-magmatic event, identify variations in its timing and other characteristics from region to region, and consider its ultimate origin in terms of lithospheric processes. Crucial aspects of the Jurassic tectonic events from the Yukon to southernmost United States are described. The lead paper presents a broad synthesis of Cordilleran subduction cycles, and is followed by papers arranged in three groups, from north to south: Canadian Cordillera; U.S. Great Basin; and southwestern U.S. desert regions. Within each group, papers are arranged from magmatic arc eastward to craton. This is an important look into now-eroded initial subduction-driven orogeny of the Cordillera, the precursor to later events that so strongly shaped present geology. Most papers are data-intensive first-order studies, although some fresh synthesis studies are also present.

SPE299, 432 p., indexed, ISBN 0-8137-2299-3, $95.00



TERRESTRIAL AND SHALLOW MARINE GEOLOGY OF THE BAHAMAS AND BERMUDA

edited by H. A. Curran and B. White, 1995

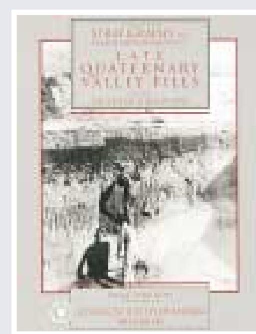
The authors review the current knowledge of the Quaternary geologic history of the Bahama Archipelago and Bermuda, an area with unique terranes for the study of carbonate rocks, sediments, and environments. The exposed stratigraphic sequences of the islands reveal much about the history of global sea-level changes during Quaternary time. The focus is an interpretation of the characteristics of Bahamian and Bermudan rocks units, their fossil faunas and floras, and the karst surface features of the islands. Information from studies of the modern shallow marine environments are used to help understand the rock record. Up-to-date summaries of the geologic history are presented along with models of stratigraphic development. Other articles cover a broad spectrum of subdisciplines, from paleontology to carbonate systems geochemistry. Chapters are case-book examples of the investigation of important aspects of carbonate island geology.

SPE300, 428 p., indexed, ISBN 0-8137-2300-0, $93.00

STRATIGRAPHY AND PALEOENVIRONMENTS OF LATE QUATERNARY VALLEY FILLS ON THE SOUTHERN HIGH PLAINS

V. T. Holliday, 1995

Reports on a five-year study of the late-Quaternary history of ten dry valleys or "draws" on the Southern High Plains of Texas and New Mexico. This record is a key to understanding the paleoenvironmental evolution of the region, important because of the long history of human occupation and because of the climatic extremes of the High Plains. Sections are included on geomorphic characteristics and evolution, stratigraphy of the valley fill (the focus of the volume), and paleontology, paleobotany, and stable isotopes. The stratigraphy along and between draws is broadly synchronous and remarkably similar in lithologic and pedologic characteristics, suggesting that each draw underwent a similar, sequential evolution of the dominant depositional environments. The changing depositional environments suggest shifts in regional vegetation and climate, but there also were distinct local variations in environmental evolution.



MWR186, 142 p., indexed, ISBN 0-8137-1186-X, $54.00

Volumes are 8-1/2 x 11". Price includes shipping & handling.

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