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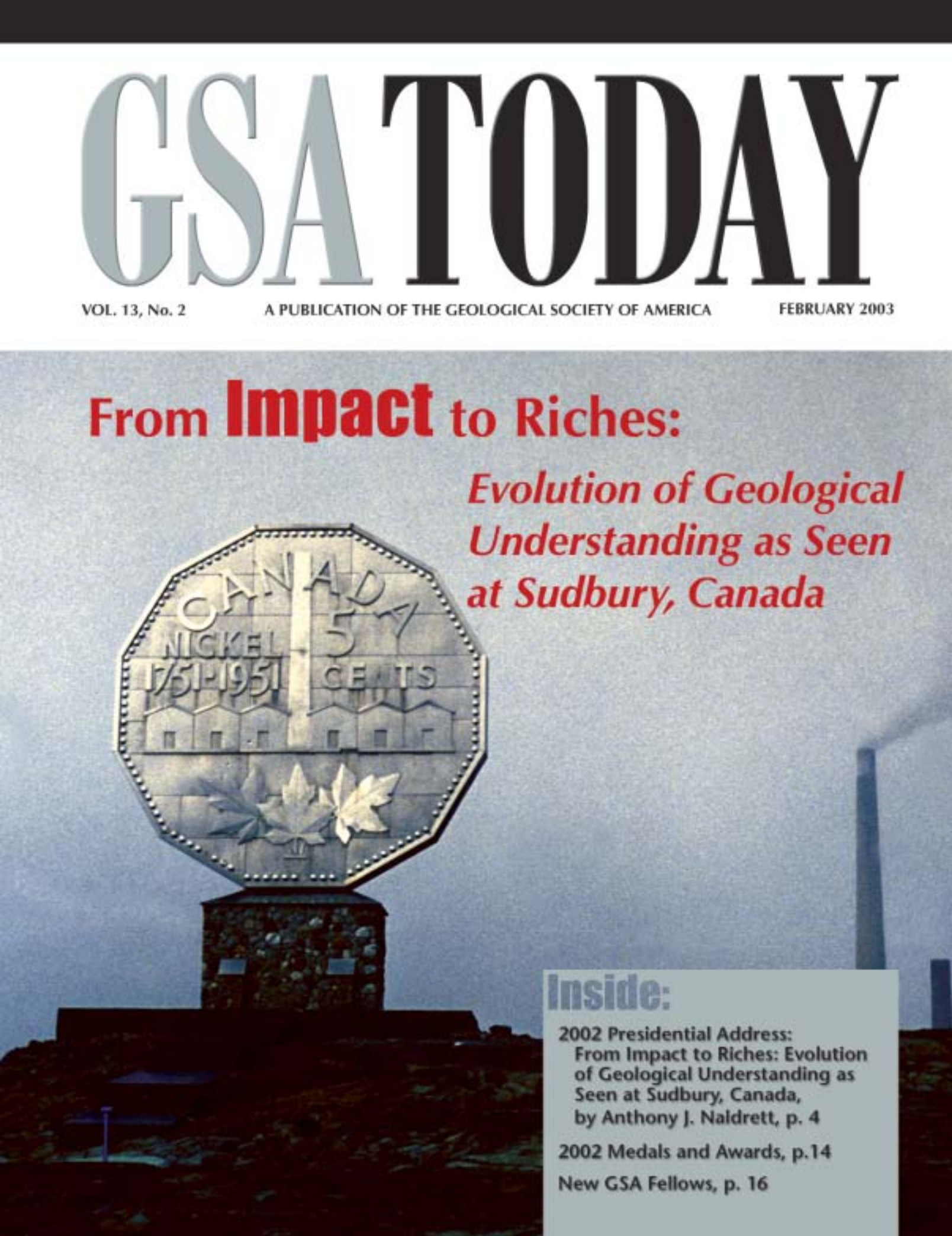
From Impact to Riches:

Evolution of Geological Understanding as Seen at Sudbury, Canada



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ON THE COVER: The Big Nickel, symbol of Sudbury, the world's nickel capital since 1905, with the INCO superstack in the background. Photo by Tony Naldrett. See "From Impact to Riches: Evolution of Geological Understanding as Seen at Sudbury, Canada," p. 4–10.

"But honestly, I once got one this big!" Bob Dietz with a whole field of shatter cones at Sudbury. Photo by John McHone.

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SCIENCE ARTICLE

From Impact to Riches:
Evolution of Geological Understanding as Seen at Sudbury, Canada

Anthony J. Naldrett, *University of Toronto*

As I thought about a topic for this address, I decided that I should pick something that has been a major factor, perhaps *the* major factor in my professional life—the world's nickel capital, Sudbury, Ontario. On setting out in July 1957 from Britain to make a life in North America, I was fortunate to obtain a job with Falconbridge Nickel Mines Limited in one of their mines at Sudbury. In my subsequent career as a graduate student, postdoctoral fellow, and academic, I have been lucky enough to stay in close touch with the new developments in Sudbury geology as they have occurred over the intervening 45 years. The developments have been startling and I believe provide an object lesson as to how progress in our particular science commonly occurs. Therefore my intention in this address is not to discuss every aspect of the geology, but to give you a personalized view of the major jumps in our understanding about Sudbury, how they came to be made, and how one led to the other.

First, a little history. The presence of sulfides was initially reported at Sudbury in an 1856 Geological Survey of Canada Report as documented in the following quotation (Report of Alexander Murray, Geological Survey of Canada, 1853–1856, p. 180–181):

> Previous to my visit to Whitefish lake, I had been informed by Mr Salter that local attraction of a magnet had been observed by himself while running the meridian line and he expressed it to be his opinion that the presence of a large body of iron ore was the immediate cause. When therefore, I came to the part indicated by Mr Salter, I made a very careful examination not only in the direction of the meridian line but for a considerable distance on each side of it, and the result of my examination was that the local attraction, which I found exactly as described by Mr Salter, was owing to an immense mass of magnetic trap. Specimens of this trap given to Mr Hunt for analysis and the result of the investigation shows that it contains magnetic iron ore and magnetic iron pyrites generally disseminated throughout the rock, the former in very small grains: titaniferous iron was found associated with the magnetic ore, and a small quantity of nickel and copper with the pyrites.

These remarks were not followed up. It was only after sulfides were revealed in a new railway cutting in 1883 as a result of the building of Canada's first transcontinental railroad, the Canadian Pacific, that a prospecting and staking rush started in the area. The first production at Sudbury occurred in 1886 (Fig. 1). During the late nineteenth and early twentieth centuries, laterites in New Caledonia satisfied the majority of the world's demand for nickel, but by 1905 the sulfide mines at Sudbury had overtaken New Caledonia as the principal source of supply. Thereafter, Sudbury production waxed and waned according to demand. The early companies soon merged into what eventually became INCO Limited, but in 1928 another significant company, Falconbridge Nickel Mines Ltd., appeared on the Sudbury scene and has continued to this day. The slackening in the growth rate that is shown in Figure 1 as having set in during the 1960s, and having continued to this day, coincides with the discovery of the Talnakh deposits of the Noril'sk area, which exceed Sudbury in terms of their grade and resources of Ni, Cu, and platinum group elements (PGE).

Turning to the geology, the principal aspects are summarized in chronological order in Table 1 and are illustrated in the simplified geological map appearing as Figure 2. An Archean hinterland comprising granites and felsic gneisses (shown in pink in Fig. 2) was affected by 2.46 Ga rifting that gave rise to a southern ocean. The northern margin of the rift is shown in red in Figure 2. The Huronian Supergroup, shown in yellow, comprises greenstones, greywackes, and quartzites that were deposited along the margin of the rift. North of the northern margin, the Huronian rocks form a thin shelf cover on

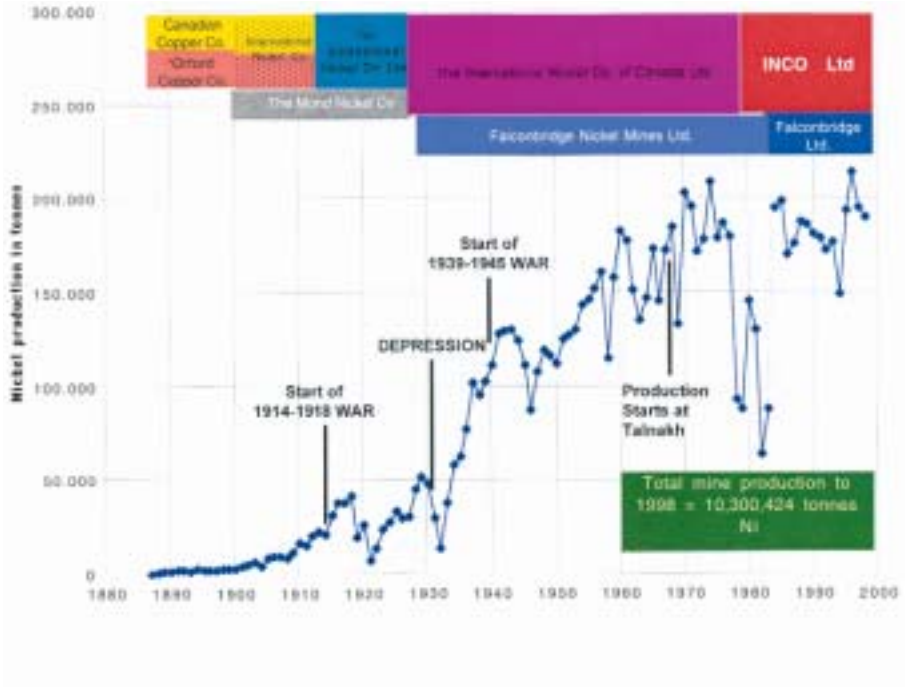

Figure 1. Production of Ni metal in tonnes from 1886 to 1998. The principal mining companies operating at Sudbury are shown at the top of the diagram.

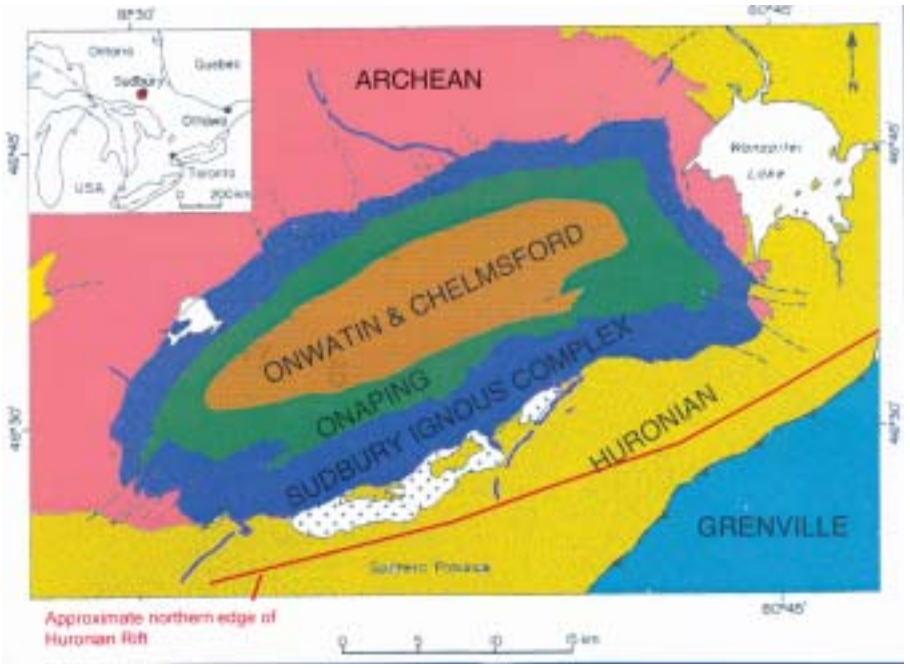

Figure 2. Simplified geological map of the Sudbury area showing the approximate northern edge of the Huronian rift.

the Archean hinterland, but they thicken rapidly southward into the rift. A suite of gabbroic sills (not shown in Fig. 2) intruded the Huronian Supergroup and underlying Archean rocks at 2.22 Ga. It is possible that these sills, which are referred to as Nipissing Diabase, were feeding flood basalts at surface, but if so, no traces of the basalts remain. Closure of the ocean during the 1.9–1.8 Ga Penokean orogeny folded the Huronian rocks. It was during this orogeny that the Sudbury event occurred at 1.85 Ga. Apart from an intervening dike swarm (the Sudbury dikes), the last major geological event to affect the Sudbury region was the Grenville metamorphism and deformation at 1.2–1.0 Ga. The Sudbury structure straddles the boundary between the Archean and the Huronian, and rocks belonging to it are exposed principally in a 60×30 km elliptical basin.

The Sudbury event has left us with a wide variety of rock types, many of which are indicative of an enormous release of energy in the area (see schematic representation in Fig. 3). They include irregular vein-like bodies in country rocks forming the footwall to the basin that are known as Sudbury Breccia. Sheet-like bodies of smashed up and partially melted country rocks line the bottom of the basin and often form the host for sulfides that appear to have settled out of the overlying Sudbury Igneous Complex. Discontinuous lenses of sulfide-rich noritic rocks containing inclusions of country rocks, including, in some areas, a suite of mafic-ultramafic cumulates ranging from dunite to olivine gabbro, are

Figure 3. Schematic diagram showing main units resulting from the Sudbury "event." SIC—Sudbury Igneous Complex.

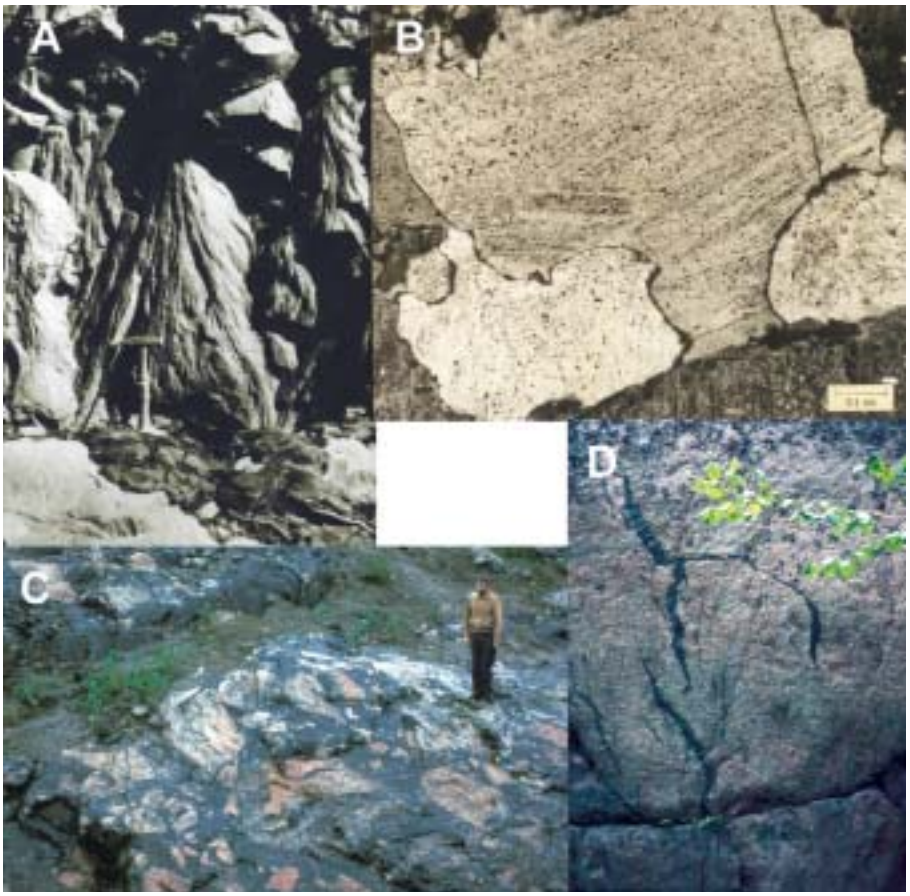

Figure 4. A: A shatter cone from the site south of Kelly Lake, Sudbury, where Bob Dietz first identified them (from Dietz, 1964). **B:** Shocked quartz showing at least two orientations of original lamellae of thetamorphic glass (photo thanks to Bevan French). **C:** Large area of Sudbury Breccia (photo thanks to Burkhardt Dressler). **D:** Thin veinlets of Sudbury Breccia cutting Archean granite (photo thanks to Burkhardt Dressler).

TABLE 1. PRINCIPAL GEOLOGICAL EVENTS IN THE SUDBURY AREA

Age in Ga	Event
>2.6	Formation of Archean greenstones, granite, and felsic gneiss
2.46	Onset of rifting, opening of Southern Ocean Deposition of Huronian Supergroup
2.22	Intrusion of gabbro sills (Nipissing Diabase)
1.9–1.8	Penokean Orogeny
1.85	Sudbury event
1.25	Intrusion of Sudbury dikes
1.1–1.0	Grenville Orogeny

present at intervals along the footwall of the Sudbury Igneous Complex and are referred to as Sublayer. The main body of the complex ranges from quartz-norite at the base through gabbro to granophyre at the top. The uppermost unit associated with the Sudbury event is a series of breccias known as the Onaping Formation.

The principal elements of Sudbury geology were appreciated very early on. A.P. Coleman's 1913 map is remarkably similar to Figure 2. Much of the debate during the first 70 years of mining operations at Sudbury centered on why there was so much granophyre in relation to mafic rock. Some simply accepted Sudbury Igneous Complex as an unusually felsic sill, others explained it as the result of incomplete exposure of a funnel-shaped lopolith, and yet others proposed that it was the result of two separate, ring dike-like injections of magma. Nearly all geologists held that the sulfides had settled out of the overlying norite as magmatic droplets (see summary in Hawley [1962]), although there were a few voices arguing that they were deposited from hot aqueous solutions (Wandke and Hofmann, 1924). Everyone who visited Sudbury was impressed by the enormous energy involved in producing the breccias, and most believed that the source of this energy was volcanic.

With this background, I'm coming to the main focus of my address, which is an account of the major breakthroughs that have come in our understanding of Sudbury, how they came about, and what they led to.

My story begins in May 1962 when Robert Dietz presented himself at the Mine Geology office of Falconbridge Nickel Mines Ltd. near Sudbury, and asked to be taken into the field. Dietz was a U.S. Navy oceanographer who, apart from his other accomplishments in the field of plate tectonics, had developed an interest in shatter cones and their relationship to meteorite impact craters (Dietz, 1959). Because of this, he was making a systematic study of circular, or nearly circular structures on Earth's surface that were visible via remote imagery. He had been working on the Vredefort dome in South Africa and had convinced himself that this was an impact site. His first line of evidence was shatter cones (Fig. 4A): his argument was that the development of the cones required a shock wave more powerful than that normally developed by terrestrial processes and he came to Sudbury to look for these. Sad to say, he was taken to the wrong place on this first visit, a location inside the Sudbury basin. (As an aside, I should know because I was the junior geologist designated by my superiors to take him into the field.) Fortunately for science, he was not put off by this first failure. He decided that he should be looking outside the structure, not inside, returned the next year, and was successful. The shatter cone in Figure 4A is from the locality where he first identified them in quartzites some 7 km south of the southern margin of the Sudbury Igneous Complex. Dietz wrote up his discovery and conclusions in 1964 (Dietz, 1964), suggesting that Sudbury was an astrobleme and that the nickel present came from an iron meteorite. The first suggestion immediately led to debate, controversy, and a great deal of new research. His second suggestion has been largely discounted over the intervening years. For example, there is as much Cu at Sudbury as Ni, the relative proportions of siderophile elements are terrestrial, not chondritic, and the osmium isotope systematics indicate a major crustal component. The research stimulated by Dietz's article soon showed that shatter cones are present all around the Sudbury structure (Fig. 5).

The late 1960s were the years when NASA was preparing to visit the moon, and NASA scientists showed a strong interest in developments in Sudbury geology. In the course of their training, the Apollo astronauts came to study analogues of the impact structures that they were likely to find on the moon. One of the NASA scientists who became involved with Sudbury geology at this time was Bevan French. He had been studying deformation in minerals that was the result of shockwaves generated by impact. Amongst other features, shock effects on

Figure 5. Distribution of shatter cones in the Sudbury area (after Dressler, 1984).

minerals include kink banding in biotite; shock lamellae in quartz and plagioclase; the diaplectic melting of quartz and plagioclase; and the development of the high-pressure SiO_2 polymorphs, coesite and stishovite. Experimental data has shown (Horz, 1968; Muller and Defourneaux, 1968) that shockwaves of 100 kb and more peak pressure produce planar structures in quartz, and that the number of orientations of these structures increases with increasing pressure. In the case of plagioclase, pressures below ~100–150 kb do not produce planar features. Between 150 and 300 kb, planar features and isotropisation occur, and between 300 and 500 kb, whole plagioclase crystals become converted to diaplectic glass (von Engelhardt et al., 1967). French reported the discovery of shock features at Sudbury (Fig. 4B) and noted that they strongly supported Dietz's hypothesis (French, 1967). Work conducted in the 1970s and 1980s has shown that shocked quartz extends up to 7 km from the outer contact along the northern rim of the Sudbury Igneous Complex.

Soon after Dietz's 1964 paper, attention was drawn to the similarity between the Sudbury breccia present outside the Sudbury structure (Figs. 4C and 4D) and pseudotachylites present at the Vredefort ring, which is interpreted as a large impact structure in South Africa (Wilshire, 1971). These breccias, which consist of local country rock fragments in all stages of comminution from 2 to 5 m diameter on downward, in a fine grained flour apparently also derived locally, are another consequence of the passage of a shockwave. The development of Sudbury Breccia closely mimics the outline of the Sudbury Igneous Complex (Fig. 6).

Concurrent with studies at Sudbury, German scientists were unraveling the geology of the rocks present at the well-documented Riess impact structure near Nordlingen, Bavaria (von Engelhardt et al., 1969). Similarities between impact breccias exposed in outcrop and drill core there and units at Sudbury, particularly the Onaping Formation, became apparent. French (1970), and Peredery (1972) interpreted different members of the Onaping as a series of breccias caused by impact. Avermann (1999) has presented the latest synthesis of the Onaping Formation in the light of the impact hypothesis (Fig. 7). In this synthesis, the units range from a basal breccia and impact melt rock up through a ground surge breccia and then suevite to one that is interpreted as due to the collapse of a plume fireball. Breccias around the

Figure 6. Distribution of Sudbury Breccia in the Sudbury area (after Fedorowich et al., 1999).

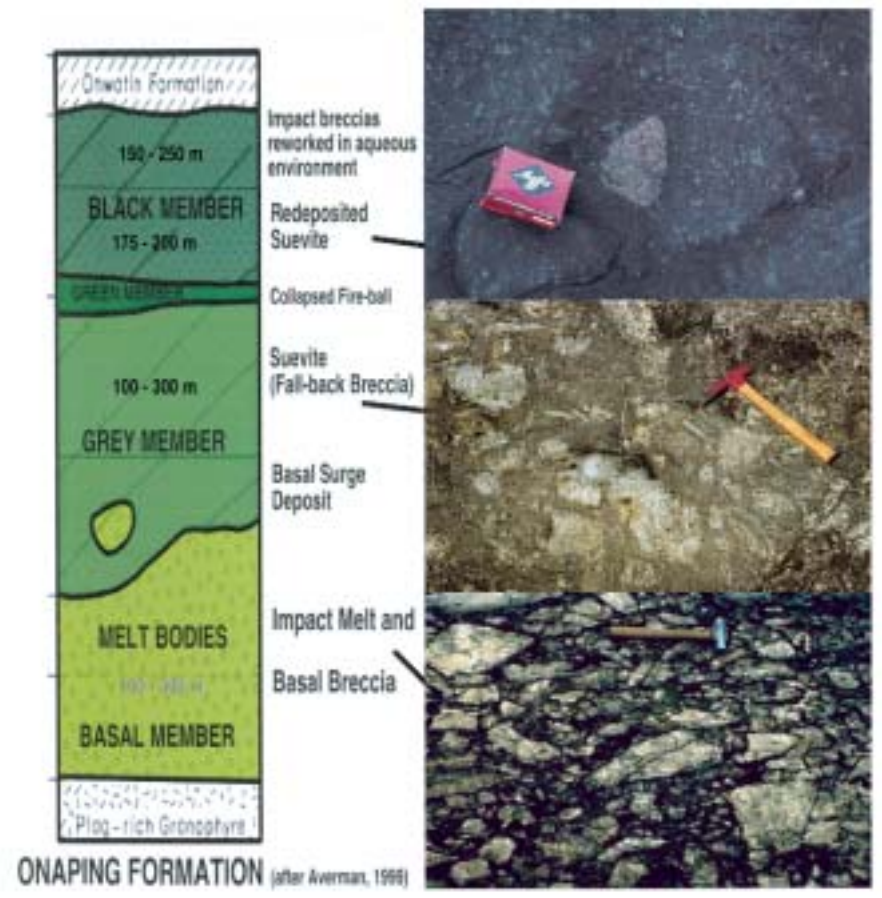

Figure 7. Avermann's (1999) synthesis of the Onaping Formation. Upper photo from Bevan French, middle and lower photos from Burkhardt Dressler.

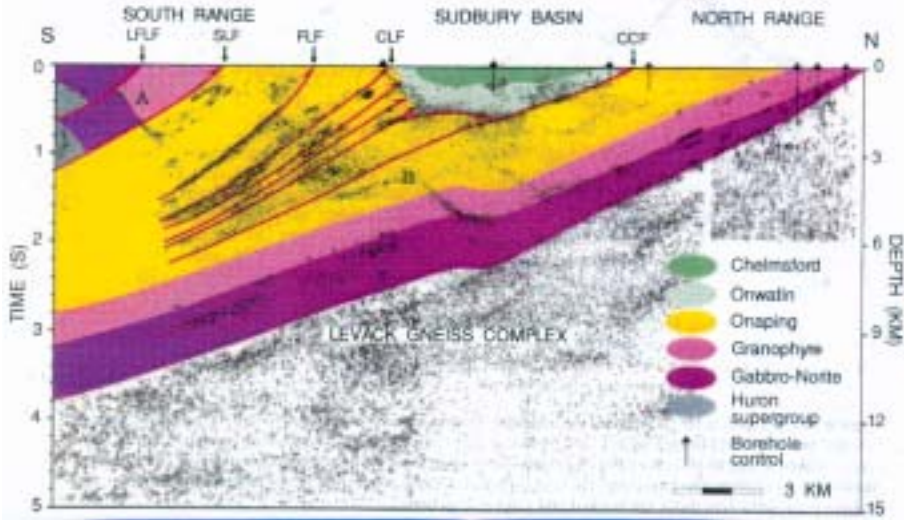

Figure 8. Interpretation of vibroseis data for the Sudbury structure modified after Milkereit et al. (1994).

structure have been reworked and swept into the center of the crater and now form the carbon-rich Black Onaping member, which is the uppermost unit. All of these units contain highly shocked inclusions of country rocks.

The latest evidence for ultrahigh pressure during the Sudbury event is the report by Masaiitis et al. (1999) of micro-diamonds in the Black Onaping. These are the most ancient of all impact diamonds discovered so far.

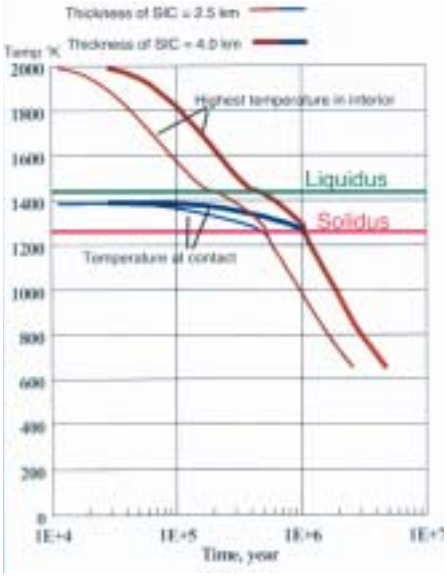

Figure 9. Cooling with time for an impact melt sheets with thicknesses of 2.5 km (thin lines) and 4 km (thick lines). Temperatures at the contact are shown in blue and at the hottest point in the interior in red. Modified after Ivanov and Deutsch (1999). SIC—Sudbury Igneous Complex.

The next definitive advance in understanding arose as a result of Canada's LITHOPROBE program. This comprised a series of seismic transects around the nation analogous to the Co-Corps program conducted in the United States. Sudbury was proposed and selected for a vibroseis survey, and the first transects were conducted in 1990. Part of the motivation had been to determine whether the basal contact of the Sudbury Igneous Complex, along with its rich deposits, was close to the surface beneath the center of the structure. This would have been expected if Sudbury had been affected by the central uplift that characterizes most large impact craters. As seen in Milkereit et al.'s 1994 interpretation (Fig. 8), far from showing a central uplift, the vibroseis data indicate that the northern perimeter of the structure dips smoothly south to beyond the present perimeter of the southern limb. The southern limb has been thrust northward an unknown amount over the northern limb. Current estimates of the original diameter of the transient crater are of the order of 100–200 km, far larger than the present 30 × 60 km surface outline of the basin.

Grieve (1994) showed that the newly recognized very large size of the Sudbury structure was consistent with all of the Sudbury Igneous Complex being an impact melt. Part of his argument was that Sudbury lies on the extension of the trend of numerous terrestrial impact craters in a plot of volume of impact melt against crater transient diameter. Faggart et al. (1985) had been the first to suggest on the basis of Nd isotope data that the Complex was entirely due to impact melting. Subsequent trace element and isotopic studies (Naldrett et al., 1986; Lightfoot et al., 1997a, 1997b) had shown that either their suggestion was correct, or that a mantle-derived magma had been contaminated by a very large proportion of impact melt or impact-heated country rock. The question as to whether the Sudbury Igneous Complex has incorporated any primitive, mantle-derived magma at all is still being argued. However, there is a growing body of isotopic evidence that the complex is an impact melt that incorporated Ni-, Cu-, and PGE–bearing mafic and/or ultramafic rocks that were already present in the target area (Keays and Lightfoot, 1999; Cohen et al., 2000).

The most recent major contribution to our understanding of Sudbury comes from the use of a modified version of computer code developed at Los Alamos (Amsden et al., 1980) to simulate the behavior and temperature of target rocks during a cratering event. Ivanov and Deutsch (1999) applied this to Sudbury and then used heat flow equations to estimate temperature variations in the resulting impact melt. Their plot of temperature in degrees Kelvin versus time for two hypothetical melt sheets is shown in Figure 9. The thinner lines represent a sheet with the present 2.5 km thickness of the Sudbury Igneous Complex, and the thicker lines a sheet 4 km thick. Blue lines are temperatures at the contact, red lines at the hottest point in the interior. Their calculations indicate that the maximum temperature within a 2.5-km-thick impact melt sheet would be about 2000 °K at the time of impact and that the temperature would remain above 1450 °K, which is the approximate liquidus, for 250,000 years.

This extended period of superheat explains many features observed at Sudbury, including the extensive local contamination that is seen at the margins of the Sudbury Igneous Complex. It also explains the distribution of the sulfide ore. When one looks at other deposits of magmatic Ni-Cu sulfide, one finds that very commonly, the sulfides do not settle to the base of the overlying igneous body, but remain suspended as a cloud

amongst cumulus silicate minerals. The Duluth Complex in Northern Minnesota is a case in point: very large zones of sparsely disseminated sulfide occur above the footwall along the northwestern margin of the intrusion. In contrast, deposits of massive sulfide are usually associated with feeder channels to lavas and intrusions, where hydrodynamic forces have caused the sulfides to concentrate (Naldrett, 1999). An example is the Voisey's Bay deposit on the coast of Labrador (see papers in *Economic Geology*, v. 95, no. 4). Here sulfides developed in a lower intrusion as a result of interaction with sulfide-bearing country rock. The sulfide-bearing magma flowed up a connecting dike into an upper intrusion. Sulfides become concentrated within swellings in the conduit and along the line of its entry into the upper intrusion. Ironically, Sudbury, which has so often served as the type model for exploration for magmatic sulfides, is the exception in which the sulfides have segregated very completely from the intrusion to concentrate within basal embayments. The high temperature and thus low viscosity of the superheated magma, coupled with the long time for which it remained superheated, account well for the unusually complete settling of the sulfides.

In summary, my story started 150 years ago with the discovery of a layered intrusion and associated Ni-Cu sulfides. Certain aspects bothered people for the next 110 years, including the huge amount of breccia and the very high proportion of felsic rock within the intrusion. Subsequent events are an object lesson on how progress is often made in our branch of science. Most of the basic facts had been known for 70 years as a result of the precise, hard work of generations of geologists. Other facts, such as shatter cones and shock deformation structures had undoubtedly been seen, but had not been appreciated for what they were. It took Robert Dietz's lateral mind to come up with a concept, for him to find time to look for critical evidence, and to propose a theory on the basis of this evidence. This was what was needed to bring many workers, with backgrounds that would never have drawn them to take an interest in a layered intrusion and its nickel deposits, to come to Sudbury and apply their special knowledge. As a result, a remarkable evolution in our geological understanding has occurred over the past 40 years. We are not there yet. The Sudbury Igneous Complex is strongly differentiated whereas most melt sheets, including that in the 200 km diameter Chicxulub crater, are not. Sudbury also appears to lack the central uplift characteristic of most large impact craters. I suspect that the answer to these questions may come from a realization that the initial Sudbury crater was even larger than current estimates.

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G&PP Committee Accepting Comments on Position Statement

GSA Council has approved a proposal from the Geology & Public Policy Committee to develop a statement on GSA's position on "The Importance of Teaching Earth Science in the Public Schools." This statement is intended to encourage the teaching of earth science throughout elementary and secondary schools to promote scientific literacy in general.

The Council's decision to proceed with the development of this important statement on the importance of teaching earth science in the public schools is an achievement of the presidency of Anthony Naldrett in 2002. GSA President Clark Burchfiel appointed and charged the panel chair and members according to GSA policy. The final version of this statement will be presented for the Council's approval.

This panel is now accepting comments from Council and GSA members. The Proposed Public Policy Statement on "The Importance of Teaching Earth Science in the Public Schools" is on GSA's Web site at www.geosociety.org/aboutus/position.htm. Please submit your comments electronically on this issue by April 1, 2003, to Rachel Burks, rburks@towson.edu.

A Message from Tony Naldrett, 2001–2002 GSA President

The presidential address and awards ceremony, coming at the end of a presidency, is the only occasion on which a president has a chance to speak in person to the Society at large, and I feel that I can't step down as president with a clear conscience without a few remarks about GSA's future.

We all know too well that the year 2000 brought about a major change in the way in which our investments have been appreciating. This has affected societies just as seriously as individuals. Traditionally, the principal sources of GSA income have been publications, membership dues, meetings, the GSA Foundation, and prudent cultivation of our investments. As with all societies, the downturn in the market has seriously affected the income that we can derive from our investments. Looking to the future, those of you who have been following the recent Dialogue columns in *GSA Today* will know that the preservation of our publications at the leading edge of science depends on their being incorporated, along with publications of other earth science societies, in an integrated, hyperlinked aggregate of online journals. No one can predict what the future will bring in terms of return of revenue to member societies of the aggregate, but we cannot assume that revenue will continue as before.

The result of these changes is that we have to plan for a very different financial future, with the budget for each financial year no longer cushioned by return on investment and net publication revenue. In recognition of this, I inaugurated an ad hoc committee, under the leadership of Tom Fouch, President of the GSA Foundation. The committee is composed of members from the private sector, not-for-profit institutions, and GSA staff with the charge that they advise us on how to provide for the future. I asked them to focus strongly on the budget bottom line and the bottom line of every future enterprise that we might become involved in.

Their deliberations are helped enormously by our strengths—our superbly talented headquarters staff led by Jack Hess, our network of sections and divisions, our scientific reputation, and above all by the talents and dedication of you, our members. Contrary to many other scientific societies, whose membership has been declining recently, our membership has grown steadily over the past seven years, showing a 7% jump in just this last year.

There is little doubt that the turn of the millennium has brought a drastic change in our environment. Geologists more than all others know that evolution in the face of a changing environment is the key to survival, a survival of the fittest. I call on each of you, our members, the very heart of GSA, to contribute your ideas, your time, and your understanding to ensure that GSA remains amongst the fittest, that the future GSA is a leaner, tougher, and much more entrepreneurial body than the GSA of the past.

UPCOMING DEADLINES

Applications for the GSA Coal Geology Division's **Antoinette Lierman Medlin Scholarship in Coal Geology*** are due February 15, 2003, to Leslie F. Ruppert, Coordinator, A. Lierman Medlin Scholarship Committee, U.S. Geological Survey, 956 National Center, Reston, VA 20192, (703) 648-6431, lruppert@usgs.gov. For details, see the December 2002 issue of *GSA Today* or visit www.geosociety.org. Go to "Grants, Awards & Medals."

Nominations for the **John C. Frye Environmental Geology Award*** are due March 31, 2003. Nominations for the following national awards are due April 30, 2003: **William T. Pecora Award, National Medal of Science, Vannevar Bush Award,** and **Alan T. Waterman Award.** Details and nomination procedures for these awards are posted at www.geosociety.org. Go to "Grants, Awards & Medals." You may also contact Program Officer, Grants, Awards, and Medals, (303) 357-1037, awards@geosociety.org, P.O. Box 9140, Boulder, CO 80301-9140, or see the October 2002 issue of *GSA Today*.

For details on the following awards, see the January issue of *GSA Today* or visit www.geosociety.org. Go to "Sections and Divisions."

- **Don J. Easterbrook Distinguished Scientist Award,* Quaternary Geology and Geomorphology Division:** Nominations due by April 1, 2003, to J. Steven Kite, Dept. of Geology & Geography, West Virginia University, 425 White Hall, Morgantown, WV 26506-6300, (304) 293-5603, ext. 4330, jkite@wvu.edu.
- **Farouk El-Baz Award for Desert Research,* Quaternary Geology and Geomorphology Division:** Nominations due by April 1, 2003, to Ellen Wohl, Dept. of Earth Resources, Colorado State University, Fort Collins, CO 80523-1482, (970) 491-5298, ellenw@cnr.colostate.edu.
- **Laurence L. Sloss Award for Sedimentary Geology,* Sedimentary Geology Division:** Nominations due by March 1, 2003, to Paul Karl Link, Treasurer, Sedimentary Geology, via e-mail (with attachments) to linkpaul@isu.edu.
- **Gilbert H. Cady Award,* Coal Geology Division:** Nominations due by February 28, 2003, to Leslie F. Ruppert, U.S. Geological Survey, National Center, MS 956, Reston, VA 20192, (703) 648-6431, fax 703-648-6419, lruppert@usgs.gov.

*Funds supporting these awards are administered by the GSA Foundation.

Call for Nominations:

Twelfth Annual

BIGGS AWARD

for Excellence in Earth Science Teaching for Beginning Professors

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

Eligibility

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

Award Amount

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

Deadline and Nomination Information

Nomination forms for the 2003 Biggs Earth Science Teaching Award are posted at www.geosociety.org (go to "Grants, Awards & Medals," then "GSA Awards"). Or, contact Program Officer, Grants, Awards & Medals (303) 357-1037, awards@geosociety.org. Nominations must be received by May 1, 2003.

Mail nomination packets to:

Program Officer, Grants, Awards, and Medals
GSA, P.O. Box 9140, Boulder, CO 80301-9140.

Science at the Highest Level

GSA 2002 Annual Meeting & Exposition

Denver proved to be yet another successful venue for the GSA Annual Meeting. More than 6,200 people attended technical sessions, field trips, and short courses, visited the GSA bookstore, took advantage of the GSA Employment Services, and had a great time in the Mile High City! The week was filled with thought-provoking Pardee Keynote Symposia sessions presenting cutting-edge science. Denver 2002 saw a record number of technical sessions with 246 sessions. And, this was the first year that GSA instituted a complete networked computer system for electronic presentations, which provided a smooth process for speakers using the audiovisual equipment in each technical session room. Also, many colleges and universities participated in the Graduate School Information Forum and held fun alumni parties in the evenings.

2002 Meeting Statistics

Total attendance:	6,263
Abstracts submitted:	3,364
Number of technical sessions (including oral and poster sessions):	246
Number of short courses and field trips:	27
Number of exhibit booths:	236
Number of exhibiting companies:	177

Employment Service

Number of interviews scheduled:	278
Number of applicants on-site:	150 +
Number of employers using the on-site service:	31
Number of positions advertised: (48 in academics; 8+ in consulting and petroleum)	56
Number of new GSA members signed up:	352

Come to Seattle!

Why not make the GSA Annual Meeting an annual event to attend? Start planning now to attend the 2003 meeting in the beautiful Emerald City!

Geoscience Horizons: Seattle 2003 will be yet another exciting time to learn about new scientific theories and facts and to network with your colleagues. The Seattle meeting will be held November 2–5, 2003. ***See you there!***

2002–2003 Division Officers & Past Chairs

Archaeological Geology
Vance T. Holliday—Chair
David L. Cremeens—First Vice-Chair
Vacant for 2002–2003—Second Vice-Chair
Andrea K. Freeman—Secretary-Treasurer
Christopher I. Hill—Past Chair

Coal Geology
Stephen F. Greb—Chair
R.M. (Marc) Bustin—First Vice-Chair
Gretchen K. Hoffman—Second Vice-Chair
Thomas D. Demchuk—Secretary
Peter D. Warwick—Past Chair

Engineering Geology
Judy Ehlen—Chair
William C. Haneberg—Chair-Elect
Robert H. Fakundiny—Secretary
Terry R. West—Past Chair

Geobiology and Geomicrobiology
Christopher M. Fedo—Chair
Sherry L. Cady—First Vice-Chair
Jack D. Farmer—Second Vice-Chair
Gordon Southam—Secretary
Kurt O. Konhauser—Treasurer
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Geophysics
James H. Knapp—Chair
Mousumi Roy—Vice-Chair
G. Randy Keller—Secretary-Treasurer
Alan G. Jones—Past Chair

Geoscience Education
Thomas C. Walker—Chair
Susan M. DeBari—First Vice-Chair
Elizabeth Wright—Second Vice-Chair
William Slattery—Secretary-Treasurer
Bonnie A.B. Blackwell—Past Chair

History of Geology
Roger D.K. Thomas—Chair
Charles W. Byers—First Vice-Chair
Edward J. Rogers—Second Vice-Chair
William R. Brice—Secretary-Treasurer
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Ralph K. Davis—Secretary-Treasurer
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Mark Cloos—First Vice-President
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Bruce F. Molnia—Secretary-Treasurer
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Elizabeth H. Gierlowski-Kordesch—Chair
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Tracy K.P. Gregg—Chair
Michael S. Kelley—First Vice-Chair
Eric B. Grosfils—Second Vice-Chair
R. Aileen Yingst—Secretary-Treasurer
Susan E.H. Sakimoto—Past Chair

Quaternary Geology and Geomorphology
J. Steven Kite—Chair
Ellen E. Wohl—First Vice-Chair
Alan R. Gillespie—Second Vice-Chair
Janet L. Slate—Secretary
Scott F. Burns—Treasurer
William C. Johnson—Newsletter Editor/Web Manager
Deborah R. Harden—Past Chair

Sedimentary Geology
Douglas W. Burbank—Chair
Carol B. de Wet—First Vice-Chair
Laura J. Crossey—Second Vice-Chair
Paul K. Link—Secretary-Treasurer
Steven G. Driese—Past Chair

Structural Geology and Tectonics
Martha O. Withjack—Chair
Elizabeth R. Schermer—First Vice-Chair
David R. Lageson—Second Vice-Chair
Peter J. Vrolijk—Secretary-Treasurer
Laurel B. Goodwin—Past Chair

THE GEOLOGICAL SOCIETY OF AMERICA
2002 MEDALS AND AWARDS

PENROSE MEDAL
Presented to Walter Alvarez
Eldridge Moores, Citationist

Walter Alvarez

ARTHUR L. DAY MEDAL
Presented to Richard G. Gordon
Kenneth P. Kodama, Citationist

Richard G. Gordon

YOUNG SCIENTIST AWARD
(DONATH MEDAL)
Presented to Ariel D. Anbar
Heinrich D. Holland, Citationist

Ariel D. Anbar

GSA PUBLIC SERVICE AWARD
Presented to John A. McPhee
Eldridge Moores, Citationist

John A. McPhee

GSA DISTINGUISHED SERVICE AWARD
Presented to Samuel S. Adams (Anthony Naldrett, Citationist), David E. Dunn (Sharon Mosher, Citationist),
and John W. Geissman (Sharon Mosher, Citationist)

Samuel S. Adams

David E. Dunn

John W. Geissman

RIP RAPP ARCHAEOLOGICAL
GEOLOGY AWARD
Presented to Paul Goldberg
Rolfe D. Mandel
and Vance T. Holliday, Citationists

Paul Goldberg

GEORGE P. WOOLLARD AWARD
Presented to G. Randy Keller Jr.
Alan Levander, Citationist

G. Randy Keller Jr.

HISTORY OF GEOLOGY AWARD
Presented to Dennis Dean
R.H. Dott Jr., Citationist

Dennis Dean

2002 Speeches are Online

The full text of citations and responses is posted at www.geosociety.org.
Go to "Grants, Awards & Medals," then to "Current Recipients."
Or, go to "Publication Services," then to the February 2003 issue in "*GSA Today* Archive."

THE GEOLOGICAL SOCIETY OF AMERICA
2002 MEDALS AND AWARDS

E.B. BURWELL, JR., AWARD

Presented to Tom Eastler, Paul Fisher, and Don Percious
Judy Ehlen, Citationist

Tom Eastler

Paul Fisher

Don Percious

STRUCTURAL GEOLOGY & TECTONICS CAREER CONTRIBUTION AWARD

Presented to Robert E. Wallace
Robert Yeats, Citationist

Robert E. Wallace

KIRK BRYAN AWARD

Presented to Mark T. Brandon and Frank J. Pazzaglia
Peter L.K. Knuepfer, Citationist

Mark T. Brandon

Frank J. Pazzaglia

GILBERT H. CADY AWARD

Presented, posthumously, to Ronald W. Stanton
Brenda S. Pierce, Citationist

Ronald W. Stanton

LAURENCE L. SLOSS AWARD

Presented to
Allison R. "Pete" Palmer
Paul Karl Link, Citationist

Allison R. "Pete" Palmer

O.E. MEINZER AWARD

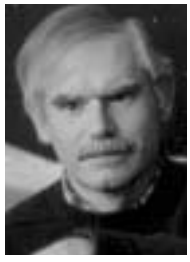
Presented to Thomas C. Winter
Donald I. Siegel, Citationist

Thomas C. Winter

For a paper copy of any or all of the citations and responses, please contact Program Officer Grants, Awards, and Medals GSA, P.O. Box 9140 Boulder, CO 80301-9140, awards@geosociety.org, (303) 357-1037.

G.K. GILBERT AWARD

Presented to James W. Head III
Sean C. Solomon, Citationist



James W. Head III

2002 HONORARY FELLOW

John Francis Lovering
Victoria, Australia

THE GEOLOGICAL SOCIETY OF AMERICA

GSA Fellows Elected in 2002

Julie Brigham-Grette
Professor, University of Massachusetts

Julie Brigham-Grette has brought tremendous energy and vitality to resolving questions of the paleoclimatic record of Beringia. She has developed a network of colleagues and students working in marine and non-marine deposits on both sides of the Bering Sea in order to figure out the chronology of glaciation and sea level response. Her recent "discovery" of El'gygytgyn and the achievement of the coring of this lake is both a commendable physical accomplishment and scientific coup.

Kerry D. Cato
Project Consultant, Earth Consultants International

Kerry Cato was nominated for outstanding contributions to the profession while serving as co-editor of *Environmental & Engineering Geoscience*.

Eric H. Christiansen
Professor, Brigham Young University

Eric Christiansen is the consummate professor. Every aspect of the professorial career is attacked with thoroughness and tireless energy and effort. His incisive intellect and interest and intimate knowledge of an exceptionally broad spectrum of geology is recognized by everyone—students, fellow faculty, and colleagues outside of BYU.

Allen J. Dennis
Professor and Chair, University of South Carolina

Allen Dennis is an outstanding geologist who has made significant contributions to the profession in education, service, research, and outreach.

Yildirim Dilek
Associate Professor, Miami University

Yildirim Dilek is nominated for his published contributions to the geology of ophiolites, their relationship to oceanic crust, the tectonic evolution of the western United States and the eastern Mediterranean regions, and for his editorial contributions and organization of international meetings concentrating on these issues.

Thomas E. Eastler
Professor, University of Maine

Recipient of 2002 E.B. Burwell, Jr., Award (Engineering Geology Division)

Judy Ehlen
Geologist, USA Engineer Research & Development Center

Judy Ehlen is nominated for her outstanding effort at promoting military geology with GSA and within the general geologic community.

Charles H. Fletcher III
Professor, University of Hawaii

Charles Fletcher is an international expert on coastal process and has contributed significantly in creating innovative studies of coastal hazards, coastal change studies, coastal sediment budget analyses, and applying coral reef histories to unraveling Pleistocene and Quaternary records of sea level and paleoclimatic change. Particularly noteworthy are Fletcher's pioneering efforts in developing new methods including the use of portable submarine drills for coring individual coral heads and multi-spectral mapping of coral reefs.

Karen S. Harpp
Assistant Professor, Colgate University

Karen Harpp has been a pioneer in integrating analytical chemistry into the geosciences, and she is a remarkable mentor and has won many teaching awards. She has planned and developed an outreach program where undergraduates from Lawrence and Colgate visit K–12 schools with hands-on geological and chemical experiences, and she participates actively in several professional organizations.

W. Burleigh Harris
Professor, University of North Carolina at Wilmington

W. Burleigh Harris is well known for his contributions to Coastal Plain stratigraphy, particularly in the areas of geochronology and sequence stratigraphy. He is an outstanding teacher with an excellent record of service to the profession (e.g., on the North American Stratigraphic Commission and through editorial activities) and of administration of graduate education.

Kirk R. Johnson
Curator of Paleontology and Head of Earth Science Department, Denver Museum of Nature & Science

Kirk Johnson is a highly productive and dedicated researcher who has contributed greatly to the science of paleobotany. He has an envious publication record and certainly ranks as world class in paleobotanical research. His diligence and energy know no limits. His work on the effect of the asteroid impact on the plant community at the Cretaceous-Tertiary boundary has changed fellow scientists' understanding of the resulting devastation.

Jeffrey D. Keith
Professor, Brigham Young University

What sets Jeffrey Keith apart is his exceptional acuity of observation and insights into geologic process. He realized the role of sulfur solubility in mixed mafic and silicic magmas and its bearing on the origin of magmatic sulfide and porphyry copper deposits.

Allan Kolker
Research Geologist, U.S. Geological Survey

Allan Kolker is an expert in trace element geochemistry, microanalysis, and coal geochemistry, and has become a key player in the environmental arena. His work on coal quality, groundwater quality, and human health issues has gained recognition within these respective communities.

Bart J. Kowallis
Professor, Brigham Young University

Bart Kowallis has made significant contributions to fission track dating, time scale calibration, paleostress analysis, and Mesozoic tectonics. His careful work in radiometric dating has clearly defined what have been long-standing controversial Mesozoic stratigraphic and chronologic boundaries in western North

America. Earlier work on microcracks with Herb Wang helped define paleostress directions in rocks from Iceland and North America. In collaboration with several American and Mexican geologists, his current geochronological work in Mexico is directed toward fuller understanding of Cenozoic paleontology and stratigraphy of North America.

Chia-Yu Lu
Professor, National Taiwan University

Chia-Yu Lu is a leading geologist and the most prominent structural geologist in Taiwan. In addition, he is a philanthropist who donates to his alma mater and to the Geological Foundation of Taiwan generously.

Douglas J. Nichols
Research Geologist, U.S. Geological Survey

Doug Nichols' research on palynology of the Cretaceous-Tertiary boundary has resulted in the discovery of four important localities in unexplored areas and the compilation of a massive database from detailed studies at localities across western North America. Due in large part to his work, the bolide-impact theory of the K-T boundary event is now firmly supported by palynologic data and is widely accepted by the geologic community. His research on the palynology of coals has led to new insights into the origin, evolution, and characteristics of coal deposits of the Rocky Mountain, northern Great Plains, and Gulf Coast regions.

Carrie Jennings Patterson
Senior Scientist, Minnesota Geological Survey

Carrie Patterson has combined field studies of the dynamics and sediments of modern glaciers in Alaska, Greenland, and Sweden with the mapping of glacial sediments in Minnesota to better interpret the Pleistocene sediments. She has contributed significantly to development of a concept of rapidly moving ice streams to explain some of the glacigenic sediments at the southwestern part of the Laurentide ice sheet. She has participated actively and enthusiastically in professional societies, serving on management and editorial boards of GSA and helping organize field trips for AMQUA and INQUA. She has worked on projects at both the collegiate and K–12 levels to encourage women and girls to consider careers in science-related fields. She has also helped educate public officials and the public on the significance of Quaternary sediments in their everyday lives.

Frank J. Pazzaglia
Associate Professor, Lehigh University

Recipient of the 2002 Kirk Bryan Award (Quaternary Geology and Geomorphology Division)

Gerald M. Ross
Research Scientist, Geological Survey of Canada

GSA Councilor, 2001–2003

William W. Simpkins
Associate Professor, Iowa State University of Science & Technology

William Simpkins is a leader in understanding the linkages between the geology and ground water flow systems of tills, the redox geochemistry, and the potential impacts of nitrogen cycling in the Midwest. He has successfully developed a hydrogeology program at Iowa State University, mentored students, and provided leadership to GSA.

Barbara J. Tewksbury
Professor, Hamilton College

GSA Councilor, 2000–2002

H.L. Vacher
Professor, University of South Florida

H.L. Vacher is a well-published researcher in the area of hydrogeology, with specializations in the hydrogeology of carbonate islands and also the quantification of hydrogeologic relationships. He spends considerable of his creative efforts toward applying principles of fluid flow through porous media to practical problems, especially in carbonate platform reservoirs.

Terry R. West
Professor, Purdue University

Terry West is known for both his applied research and for his role as an educator and mentor. His research in the geological and physical properties of construction aggregate is well known within the industry, both in the United States and internationally.

Thomas C. Winter
Research Hydrologist, U.S. Geological Survey

Recipient of the 2002 O.E. Meinzer Award (Hydrogeology Division)

GEOLOGY from THE HILL: Final Report

Chester F. "Skip" Watts, *GSA–USGS 2001–2002 Congressional Science Fellow*

My tour as the GSA–U.S. Geological Survey Congressional Science Fellow came to a close on November 1, but the effects will last a lifetime. I've come to see the world in an entirely new light, and I've gained a deeper understanding of the complex world of public policy. I've changed in many ways, but then so has everyone since September of 2001. It's been an honor to serve the profession in this way. I thank GSA and the USGS for making the opportunity available.

In my last report, I promised a glimpse into the day-to-day activities of congressional fellows. Experiences on the Hill vary from year to year and with the offices that fellows enter, but many facets remain common to all. I knew very little of what lay ahead when I arrived in Washington and I felt some understandable apprehension. Now I leave knowing at least one office on Capitol Hill where always I will feel at home.

For background, congressional fellows are funded by outside sources, including professional societies and government agencies, like the Environmental Protection Agency, to serve as assistants or advisors to congressmen or their committees, at no cost to congress. Fellows become fully integrated "staffers" with all of the duties and responsibilities. They are authorized to assist and represent their member of congress in countless capacities. Importantly, neither the fellow nor the funding bodies may have their own agendas. Fellows are to remain unbiased in their work, providing technical support for what we all hope are informed political decisions. In addition to the GSA–USGS fellowship, the American Geological Institute, the American Geophysical Union, and the Soil Science Society of America also sponsor geoscience fellows.

I met fellows representing chemistry, physics, biology, meteorology, astronomy, medicine, and pharmacology. And there were fellows in law, economics, political science, military science, education, and many other disciplines. Fellows comprise a remarkable group of motivated and accomplished individuals, and I am lucky to have worked among them. For example, I was proud to serve on Senator Joseph Lieberman's personal staff alongside fellow Adrian Erkenbrack. Erkenbrack was in the Pentagon during the morning of September 11, 2001. Months later, the senator presented a medal from the U.S. Army—its highest award for non-combat heroism—to Erkenbrack for his part in rescuing victims at considerable personal risk.

However, more typical activities include researching policy issues, seeking input from established experts, meeting with lobbyists, meeting with constituents, briefing the congressman on issues, writing news releases and opinion editorials, arranging and staffing meetings for the member, and drafting position papers.

Given the title of Legislative Fellow in the Lieberman office, I essentially served as a science and technology advisor. With my background in consulting for various state highway departments, I found myself handling all of the transportation issues. I dealt with not only highways but with ferries, trains, buses, airlines, and even bike paths. The issues ranged from appropriations for bridge repairs, to arming pilots in the cockpit, to preparing for reauthorization of federal transportation funding.

When it was learned that I taught courses in computer applications, I also became the "computer policy guy." I was asked to produce a whitepaper detailing the history, technology, policies, and projected economic impact of the coming age of truly high-speed Internet. I am grateful that the report was praised on Capitol Hill and in industry as a notable contribution to legislative discourse. And I had the fascinating task of actually drafting a bill, which came to be called the *National Broadband Strategy Act of 2002*. In the senator's absence, I carried the bill to the Capitol and introduced it to the Senate, although protocol dictated that I do it quietly at the cloakroom door and certainly not on the floor.

It would be impossible to recount here the meetings, luncheons, and press conferences, or do justice to the serious geological and environmental issues that arose. My intent is to provide some of the flavor. But I must say that among the most fascinating events to me as a geologist were briefings on geology and the war in Afghanistan. I'm still trying to convince certain folks across the river that understanding the distribution and nature of geologic structures is vital to predicting the behavior of landscapes subjected to ordnance. But that's another story.

Now I begin a new adventure as the Jahn's Distinguished Lecturer, sponsored by GSA and the Association of Engineering Geologists. I have technical lectures planned on topics in rock mechanics, as well as a general lecture on geology and public policy. My message is simple. Congressional fellows are invaluable on the Hill for informing politicians, but in reality the public influences politicians even more with votes. There are many ways for each of us to reach out and help educate the public. Look for them. In the meantime, I hope to see you in your hometown sometime during the next year.

Submitted for publication by Chester F. Watts, 2001–2002 GSA–USGS Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and by the USGS, Department of the Interior, under Assistance Award No. 1434-HQ-97-GR-03188. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government.

GSA Foundation Update

Donna Russell, *Director of Operations*

Support for Education & Outreach Programs

The Foundation proudly supports the following Education & Outreach Programs. These programs are supported either fully or in part from funds held and administered by the GSA Foundation.

- Roy J. Shlemon Mentor Program in Applied Geoscience
- Subaru Distinguished Earth Science Educator Program
- GeoCorps America Program
- Earth Science Week
- Geology in Government Student Luncheon
- Geology and Ecosystem Field Course

Future issues of *GSA Today* will focus on other Education & Outreach programs. An article on the Shlemon Mentor Programs was published in the January issue (page 18).

Update on Subaru Distinguished Educator Program

Christine McLelland has been busy the first semester of her appointment as the 2002–2003 Subaru Distinguished Earth Science Educator. Sponsored by Subaru of America, Inc., and offered to a qualified earth science teacher, the Subaru teacher provides leadership in the continued development of GSA education programs as presented on the GSA Web site. McLelland's accomplishments so far this year include the following.

- Restructured the GSA Education Web page to include downloadable lesson plans, links to lesson plans, and information on additional resources in a wide range of topics for earth science teachers of K–12 students. Geoscience teachers, visit www. geosociety.org/educate, and please contribute your lesson plans today!
- Developed "What Materials are in My Subaru" lesson plan for the Subaru Rendezvous in Syracuse, New York, September 2002.
- Developed the lesson plan and rock kit "If You Bit a Rock," a program modeled after a NASA lesson plan for meteorites called "Edible Rocks." The rock kit was distributed to teachers in more than 18 states.
- Designed a contest for interested high school students to attend the 2002 GSA Annual Meeting in Denver. The "Subaru Teacher's Choice Award" went to Kristen Fuchs from Cheyenne Mountain High School, Colorado Springs, Colorado.
- Developed a CD-ROM with 12 earth science lesson plans which are included in the rock kit.

McLelland will attend the National Science Teachers Association National Convention in Philadelphia in March, and will complete the "GSA Junior Rock Hound" program. For more information about the Subaru Educator, please visit www.geosociety.org/educate.

Most memorable early geologic experience

1950, Magdalena Valley: Rounding a bend in a box canyon, I abruptly confronted a Braham bull. Talk about big! No time for fright! We split!

—Jack B. Mills

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ROCK STARS

James Dwight Dana (1813–1895): Mineralogist, Zoologist, Geologist, Explorer

James H. Natland, *Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, FL 33149, USA*

To many of his contemporaries, James Dwight Dana was the foremost American geologist of the nineteenth century. His *Manual of Geology*, in its fourth edition when he died in 1895, was on the shelf of almost every American geologist, and he used it to teach two generations of students while a professor in the Sheffield Scientific School at Yale. Dana was celebrated for his *System of Mineralogy* (1837), for his report on the geology of the U.S. Exploring Expedition (1849), for monographs on crustaceans and corals, and for a seminal text on volcanology he wrote in his 70s.

Dana came from a religious family. His father owned a hardware store in Utica, New York, and Dana, the eldest of four children, became adept with tools. He was musical—piano and guitar—and artistic. His mother ran the household, and her emphasis on religiosity had a lifelong influence on Dana. He liked to "tramp" and began collecting rocks, plants, and insects at an early age. He entered the sciences when opportunities for both travel and communication grew in response to the industrial revolution, and in his case, with the size, wealth, and influence of his own nation.

Dana trained in several disciplines at Yale under his future father-in-law, Benjamin Silliman, founder and editor of the *American Journal of Science*. After Yale, Dana served as an instructor on a U.S. Navy vessel that sailed to the Mediterranean, where he saw Vesuvius in eruption and pursued entomological studies. His account of the eruption in a letter, published by Silliman in the *Journal*, was Dana's first scientific paper. In 1834, Dana returned to Yale, where he developed a new mineral classification based on chemistry and crystallography and using Silliman's cabinet of minerals and his own childhood collection. The resulting *System of Mineralogy*, published when Dana was just 24, ran to four editions in his lifetime.

Dana took up geology mainly when he became geologist and mineralogist of the U.S. Exploring Expedition (1838–1842). This expedition was charged with charting islands in the Pacific—potential way stations for American clipper ships and whalers—and venturing to Antarctica. Besides Dana, the civilian "scientifics" included specialists in botany, vertebrate zoology, conchology, and philology, plus two artists. Dana, however, felt deficient in geology and looked on the expedition as an opportunity to learn it and other branches of natural history. The expedition took Dana to the Andes, to the atolls and reefed volcanic islands of the Pacific, and to the active volcano of Kilauea in Hawaii.

Dana was only 25 when the expedition sailed in August 1838, under Acting Captain Charles Wilkes. For American science, the expedition was without precedent—the first blue-water oceanographic expedition funded by the U.S. Navy. With six ships, it was far larger than earlier European ventures to the Pacific. It was also the first American exploration on land or sea to make systematic geological observations. Only Darwin, whose career Dana's paralleled in many ways, had done geological work on volcanic islands and reefs (on the *Beagle* a few years earlier). On sailing, Dana had Darwin's *Journal of Researches*, now usually called *Voyage of the Beagle*, but it provided only glimpses of geology in South America and elsewhere. The Pacific was still virtually terra incognita and a magnificent opportunity for a young scientist.

The trip was not always convivial. In one letter, Dana described it as "Naval servitude," and the imperious Wilkes eventually sent one scientist home after a disagreement and ordered Dana to assume his responsibilities. The expedition was also hazardous. Dana's ship was nearly lost in a storm in the Straits of Magellan. Unfriendly natives daunted the work in Fiji. Later, another vessel had to be abandoned, along with many of Dana's samples, after running aground at the mouth of the Columbia River. On Dana's return, his adventurous tales charmed the 19-year-old Henrietta Silliman, and within a month they were engaged.

James Dwight Dana at the time when he was most actively engaged in coral reef research (from W.M. Davis, 1928, The Coral Reef Problem: American Geographical Society Special Publication 9, Fig. 1).

Dana's Pacific synthesis is presented in several chapters of his expedition report on geology, which Dana drew on for the rest of his career. The expedition's scale prompted him to think globally. Each facet of Pacific geology—atolls, the radially dissected volcano of Tahiti, the islands of Samoa that are studded with small volcanic cones, the grand natural theater of the cauldron at Kilauea—is given a chapter, and the whole is concluded almost from the perspective of one looking at a globe in a study. The islands occur in concentric chains, each active only at one end. Toward the other end, the deeply eroded volcanoes eventually disappear beneath the waves. Only tiny coral resists, and sustains a reef, first at the shore of the volcano, then farther away, and finally bounding only the waters of an atoll lagoon. Darwin, of course, said this first, as Dana always acknowledged, but Dana actually had the idea independently, and in Sydney, Australia, he was nonplussed to read a newspaper account of Darwin's first publication on the evolution of reefs.

Dana, however, added key facts, establishing that embayments of the volcanic stumps within the lagoons are drowned, deeply subsided remnants of river valleys that could not have been carved by

waves. Also, the corals finally die, and the atolls slip beneath the waves. Later, in his volume on corals, Dana predicted the existence of deeply submerged, drowned atolls, today's guyots, in the far western Pacific. In 1849, Dana also contrasted the linear chains with the arcuate ones bounding the Pacific basin, which generally occur in regions of uplift, and are active all along their lengths.

Dana was adept at grand geological synthesis. His four most important concepts were: (1) understanding the patterns of age progression and subsidence of linear volcanic chains in the Pacific based on extents of erosion and relationship to offshore reefs; (2) the geological distinction between continents and ocean basins, and the doctrine that both are permanent features of the globe; (3) the place of geosynclines (a term he coined) in orogeny; and (4) the concentric accretion of mountain belts about the ancient interior of the North American continent. All of these are foreshadowed in his report *Geology*.

To Dana, the principal physiographic features of the Pacific basin are geologically young, although they rest on ancient rock, and there are two dynamic domains. One is in the middle of the basin—the linear, volcanically active ridges; the other is at the edges of the continents—the arc volcanoes and active mountain belts. The arcs bound much older, inactive interiors. The arrangement results from contraction of a cooling globe. The Pacific basin is that portion of the globe where hot volcanic material has long vented to the surface and is resisting contraction; the continents are cold and disrupted at their margins, where the surface of Earth is currently taking up the shrinkage. Continental interiors carry the ancient history of this process and gradually increased in area as Earth shrank throughout geological time. The ocean basins and continents are thus separate, permanent, and very different geologically. Dana doubted the existence of submerged continents beneath the great oceans, believing them to grow outward at their edges *toward* the ocean basins, which are mainly basaltic constructs. This was decidedly at odds with contemporary thinking, and even with much later tectonic theory, especially that of the eminent Austrian tectonicist, Eduard Suess.

With the decade-long writing of the expedition reports, Dana established the program for his life's work. Still to come were the documentation of accretion of continental crust, formation of geosynclines at the disrupted continental margins, and a role in the complicated Taconic controversy. He wrote thousands of pages, preparing many of the illustrations himself. He suffered vicissitudes of health, including a physical breakdown in his late 40s. Nevertheless, he recovered and actively pursued his science, returning (in more comfort) to Hawaii in his 70s to prepare for his volume on volcanoes, revising his texts, answering a huge correspondence, and writing papers until a few days before he died.

Even with the hindsight of plate tectonics, Dana's concepts are surprisingly modern. He contributed the core observations that form the basis of the Wilson-Morgan hypothesis of the passage of plates over hot spots, producing linear island chains in their wake. Only after his death did geophysics firmly dispose of the idea of contracting Earth. After that, no other tectonic hypothesis held as much sway until the advent of plate tectonics. Plate tectonics confirmed the contrast in age and structure between continents and ocean basins, and their permanent, albeit shifting, configuration. It finally involved the distinctive character of the ocean basins in a truly global synthesis.

Dana held no strictly uniformitarian view of Earth history. A devout Christian, Dana had a New Englander's properly Protestant view of the direction of Earth history. At one scale, he saw this in the progressive volcanism, erosion, and subsidence of linear volcanic chains. At another, the continents themselves have grown, and life itself has changed form in many ways; always, in Dana's view, becoming more complex, accordingly as the area of land increased and global climate became more rigorous. This was plan, not chance. The paleontologist in Dana saw this, from a very nineteenth century phrenological perspective, in the growth and shape of the skulls of vertebrates. Thus a benevolent creator, whom Dana termed the "Power Above Nature," prepared Earth for the benefit of His children, who are at the present end point of history. Such sentiments pervade Dana's writing, as one might expect from a man who led Bible studies, played the piano for his church choir, and prayed with his family over meals.

One's system of beliefs often contributes to scientific hypothesis. Dana had outlooks that are difficult to reconstruct and experiences that are impossible to re-create. Dana's work is remarkable because he was able to make so much out of what we today would consider so little. His mind arched broadly and with great discipline over many topics. Within his final, chosen field of geology, his influence was pervasive and extends even to us today.

Acknowledgments

This summary is drawn mainly from Gilman (1899), Prendergast (1978), Viola and Margulis (1985), and Dana's Geology (1849) of the Exploring Expedition. I thank Michele Aldrich, R.H. Dott, Gerard Middleton, and R.N. Ginsburg for thoughtful comments on the manuscript.

Further Reading

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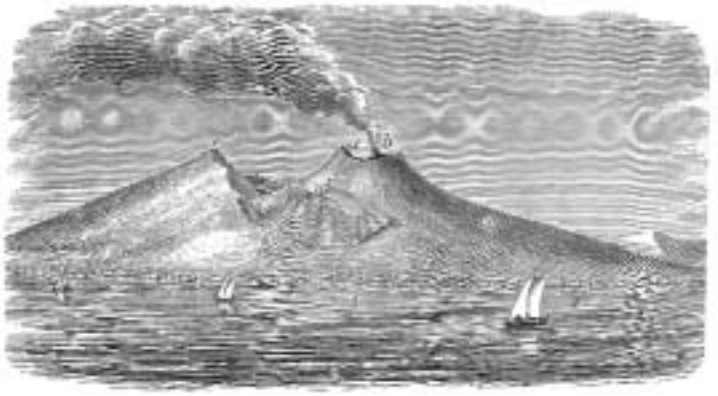
"Rock Stars" is produced by the GSA History of Geology Division. Editorial Committee: Robert Dott, Robert Ginsburg (editor of this profile), Gerard Middleton, and Peter von Bitter.



James Dwight Dana's 1834 drawing of Vesuvius, which inspired a lifelong interest in volcanology. From Dana's *Manual of Geology*, 4th Edition, 1896, p. 266, Fig. 225.

GeoVentures

NEW!

Flatirons in Boulder. Photo by John Karachewski.

GeoClass
Tilted Rocks, Mountain Roots, and Ancient Oceans: A Newcomer's Guide to the Geology of the Front Range

June 27–30, 2003
Williams Village Dormitory
University of Colorado, Boulder

Scientific leader: Alan Lester, University of Colorado, Boulder. Lester, a recipient of multiple teaching awards at the University of Colorado, is a research associate and senior instructor in the Department of Geological Sciences. His research interests include Laramide magmatism, Front Range kimberlite emplacement, and Eocene sedimentary rocks of southwest Wyoming.

Experience three days of scenic geology excursions along the eastern margin of the Colorado Front Range, south-central Rocky Mountains. Situated at the foot of the Front Range, Boulder is a picturesque and convenient vantage point from which to launch explorations. In Boulder, home of the University of Colorado, participants, spouses, and family will find ample opportunities for dining and shopping. Our excursions, although geological in focus, will also be wonderful opportunities for bird and wildlife watching.

Description

An astonishing array of rocks and geologic structures literally "rise from the plains" along the eastern margin of the Front Range, south-central Rocky Mountains, Colorado. In this GeoClass, a combination of lectures, discussions, and field excursions will be used to reconstruct the rich and complex—nearly two billion year—geologic story of this unique region. The class will encounter a wide variety of rock types (metamorphic, intrusive, volcanic, sedimentary), observe a range of geologic structures and erosional features, and become familiar with local stratigraphy.

The GeoClass begins early Friday evening with a welcoming reception at the University of Colorado campus. On Saturday morning, a lecture and slide presentation on the local geology will be followed by a field trip to nearby Flagstaff Mountain, taking us into the heart of the picturesque Flatirons—rocks that hold clues to two distinct periods of ancient mountain building. Stops include: the "Great Unconformity," where one can place a finger on nearly 1.5 billion years of missing time; a Late Cretaceous sill harboring information on Laramide rotation and mountain building; and a visit to the Green Mountain Kimberlite (the southernmost occurrence in the Colorado-Wyoming kimberlite province).

On Sunday's all-day field excursion to Rocky Mountain National Park, we'll immerse ourselves in the Precambrian roots of the continent, hiking amongst jewel-like glacial lakes, soaring ridges, and snow-capped peaks. The geology of the park highlights two ends of the geologic story in this area: uplifted ancient metamorphic rocks and the effects of relatively recent glaciation. The GeoClass will end Sunday evening with a farewell dinner.

Fees and Payment: $525 for GSA members; $600 for nonmembers. A $200 deposit is due with your reservation and is refundable through May 1, less a $20 processing fee. Total balance is due May 1. Minimum: 12; maximum: 22. **Included:** Classroom programs and materials; field trip transportation; lodging for three nights (single occupancy or double for couples in dormitory style rooms, shared bath); breakfast on Saturday, Sunday, and Monday; boxed lunch on Saturday and Sunday; and welcoming and farewell events. **Not included:** Transportation to and from Boulder, Colorado; transportation during hours outside field trips; alcoholic beverages; and other expenses not specifically included.

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Pingora Peak in the Cirque of the Towers, Wind River Range. Photo by Sherrie Landon.

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GeoHostel
Geology of the Southern Wind River Range and Wind River Basin, Wyoming

July 12–17, 2003
Pronghorn Inn
Lander, Wyoming

Scientific Co-leaders: Sheila Roberts, University of Montana—Western, Dillon, Montana. Sheila has taught geology at the University of Montana—Western for the past eight years. She worked in Wyoming for nine years, first as a petroleum geologist for Gulf Oil in Casper and then as editor and publications manager at the Geological Survey of Wyoming, on the campus of the University of Wyoming in Laramie. She edited approximately 100 publications on Wyoming geology while at the survey, including the two-volume 1992 classic, *The Geology of Wyoming,* which was a cooperative venture with the University of Wyoming Department of Geology and Geophysics. Roberts' experience with Wyoming geology includes about everything from the Archean to the Recent, but her primary interest for this trip is the Pleistocene glacial record. **Rob Thomas,** University of Montana—Western, Dillon, Montana. Thomas is a professor of geology in the Department of Environmental Sciences at the University of Montana—Western. He developed an interest in the geology of central Wyoming while working on Cambrian mass extinction boundaries as a doctoral student at the University of Washington. He currently works on a diverse array of geologic problems, including the processes that form mixed carbonate-siliciclastic systems, Cenozoic extensional tectonism and sedimentation in southwestern Montana, applied fluvial geomorphology, and geoscience education. His passion is to make geology accessible to the public. **Sherrie Landon** graduated from the University of Montana—Western in 1998 with a B.S. in environmental science. She received a master's degree in geology in 2001 from the University of Wyoming. Currently an environmental protection specialist with the Bureau of Land Management in Farmington, New Mexico, Landon has participated in the past eight GeoHostels in various capacities, including co-leader, liaison between the GSA staff, trip leaders, and attendees, and as a van driver extraordinaire.

Description

The geology of central Wyoming is some of the most interesting in the Rocky Mountain region. From Archean basement rocks to Pleistocene alpine glaciation, the geology of this region is diverse and beautiful. The GeoHostel will focus on the geologic history of the southern Wind River Range and adjacent Wind River Basin, with special emphasis on the geology of the Laramide uplifts and associated oil fields. We'll investigate granitic rocks and uranium deposits in the Granite Mountains region, see the spectacular Paleozoic and Mesozoic stratigraphy of the Wind River Canyon, tour the Tertiary geology of central Wyoming, and discuss Pleistocene glaciation at the type locality of the Bull Lake glacial event. In addition, we'll stop at the famous Thermopolis Hot Springs as well as a dinosaur museum and dig site. Most trips will be full day, but some leisure time will be available to enjoy the quaint town of Lander and the spectacular scenery and history of central Wyoming!

Fees and Payment: $1,475 for GSA members; $1,575 for nonmembers. A $200 deposit is due with your reservation and is refundable through June 1, less a $20 processing fee. Total balance is due June 1. *Firm* minimum: 25; maximum: 32. **Included:** Classroom programs and materials; field trip transportation; lodging for six nights (single occupancy or double for couples); breakfast and lunch daily; and welcoming and farewell events. **Not included:** Transportation to and from Lander, Wyoming; transportation during hours outside field trips; alcoholic beverages; and other expenses not specifically included.

GeoTrip

Costa Rica: A Student Only—Oriented GeoTrip

July 31–August 15, 2003
San José, Costa Rica

Scientific leader: James Reynolds, Brevard College, Brevard, North Carolina. Reynolds is a magnetostratigrapher with interests in Neogene volcanism and foreland basins who has been leading international field trips since 1996.

Description

GSA's second student-oriented GeoTrip will take on a tropical flavor. Restricted to students, this trip will visit the classical geological localities of Costa Rica on a trip that rivals any adventure tourism excursion. Costa Rica offers a rich variety of national parks and nature preserves upon which most of our trip will focus. Participants will stay in quality hotels and eat excellent Costa Rican cuisine. Approximately 50 km of hikes will take us through spectacular volcanic highlands, tropical rain forests, and coastlines. The extreme changes in elevation on the volcanic slopes will allow us to visit all of the major ecological zones, seeing their plants, mammals, birds, and reptiles. For the first time, students will have the opportunity to receive transfer course credit.

This 15-day expedition through the country begins in San José, Costa Rica. We'll visit five active volcanoes, including Arenal, which is erupting. Our ascent of the 3400-m-high Turrialba volcano will be accomplished on horseback up a winding dirt track. Near Fortuna, we'll be whisked into the jungle canopy to investigate the flora and fauna from ziplines and catwalks. We'll also snorkel in both Pacific and Caribbean coral reefs with two nights of camping on the Caribbean shore, and we'll paddle 27 km of whitewater on a raft trip over Class III and IV rapids on the Río Pacuare, rated as one of the world's most scenic rivers. The trip goes through virgin rain forest where we will examine Neogene volcanic strata. About mid-way, we'll stop to spend the night at a remote but elegant jungle camp where our experienced guides will prepare a tropical feast. Hot springs, waterfalls, a musical soirée on the beach, and ample opportunity for cross-cultural interaction are also planned for our trippers.

A pristine shoreline on the Caribbean coast at Cahuita National Park. Photo by Jim Reynolds.

Fees and Payment: $2,900 for GSA student members; $3,000 for nonmembers. A $450 deposit is due with your reservation and is refundable (less $225) through May 1. Total balance is due May 1. *Firm* minimum: 16; maximum: 35. **Included:** Lodging, based on double occupancy; 15 breakfasts, 11 lunches, 11 dinners; field trip transportation; tents for camping nights; and guidebook and map. **Not included:** Airfare to and from San José, Costa Rica; sleeping bags and pads; alcoholic beverages; and other expenses not specifically included.

GEOVENTURES 2003

for GSA Members & Friends

For complete details on GeoVentures or for full itineraries, contact Edna Collis, Program Officer, 1-800-472-1988, ext. 1034, fax 303-357-1072, ecollis@geosociety.org, or visit www.geosociety.org (go to "Meetings and Excursions" then to "GeoVentures"). Participants must be 21 or older and in good health. Any physical condition requiring special attention, diet, or treatment must be reported in writing when reservations are made. We'll do our best to accommodate special needs, including dietary requirements and physical disabilities. Deposits and payments are refundable less a processing fee, up to the cutoff date. Termination by an individual during a trip in progress for any reason will not result in a refund, and no refund will be made for unused parts of trips. For details on accommodations and occupancies, see trip descriptions or contact Edna Collis.

Reminder: GeoTrip

Basalts, 'Beests, and Bee-Eaters: The Geologic and Natural History of the Kenya Rift and Environs, Kenya and Northern Tanzania GeoTrip

July 30–August 14, 2003

Co-Leaders: Timothy F. Lawton, New Mexico State University, Las Cruces, and **Brenda J. Buck,** University of Nevada, Las Vegas

Description

This GeoTrip to the Kenya rift explores the geologic and natural history of this unique tectonic province and its associated spectacular

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environments, supporting a variety of bird and wildlife habitats. Participants will have the opportunity to hike and view ice-sculpted landscapes on glaciated Mount Kenya, Kenya's highest peak, situated squarely on the equator; visit saline internally drained lakes in the rift itself; boat immense Lake Victoria, the second largest freshwater lake in the world in the topographic sag between the rift valleys; traverse the Precambrian shield on the north edge of the Serengeti Plains; explore the spectacular Ngorongoro Crater, an intra-rift caldera; visit Olduvai Gorge, the cradle of humankind; and ponder the great Kilimanjaro, Africa's highest peak.

Don't miss this unforgettable adventure in exotic geology and wildlife!

Fees and Payment: $5,650 for GSA members; $5,750 for nonmembers. A $500 deposit is due with your reservation and is refundable (less $300 cancellation fee) through June 1. Balance is due June 1. Fee is based on double occupancy. Single supplement, based on availability, is an additional $895. Minimum number of participants (*firm*): 15; maximum: 40. **Included:** Accommodations in twin bedded rooms; all meals on tour beginning August 1; flights within East Africa; guidebook; all tips and gratuities to drivers/guides, hotel, and camp staff; temporary membership in the Flying Doctors Service; government taxes and levies. **Not included:** Airfare to Nairobi and return from Tanzania; optional tours; lunch in Nairobi on August 9; entry visa fees to Kenya and Tanzania (approx. $100); alcoholic beverages; and other expenses not specifically included.

For complete information on this fabulous GeoTrip, see the December 2002 issue of *GSA Today*, visit www.geosociety.org (go to "Meetings and Excursions" then to "GeoVentures"), call (303) 357-1034, or e-mail ecollis@geosociety.org.

Mount Kilimanjaro. Photo by Toni Rottenberg.

Increased registration fees: Due to the current financial realities, GSA must cover all of its costs for providing GeoVentures programs.

REGISTER TODAY!

Send a deposit to hold your reservation; please pay by check or credit card. You will receive further information soon.

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City/State/Country/ZIP

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2003 GSA GeoVentures, Member Services
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Fax 303-357-1071

MAKE CHECKS PAYABLE TO: GSA 2003 GeoVentures

GeoHostel: Geology of Coastal Southern Maine

July 13–18, 2002

Leader: Arthur M. Hussey II, Bowdoin College (retired)

Co-Leaders: Walter Anderson, State Geologist, Maine Geological Survey (retired); Joseph T. Kelley, University of Maine—Orono; Thomas K. Weddle, Maine Geological Survey; David P. West Jr., Middlebury College

"The whole trip was well-rounded, covered a great variety of subjects. You couldn't have found a better bunch of leaders! All were extremely knowledgeable of their topics and they were excellent speakers who explained things well. This was indeed a great experience!"—Irene and Al Boland, Rock Hill, South Carolina

Maine GeoHostel gang. Photo by D. West.

GeoTrip Iceland: Fire and Ice

August 1–15, 2002

Leader: Haraldur Sigurdsson, University of Rhode Island

"The Iceland trip was incredible! Haraldur did a great job leading it, and all the people on the trip were interesting and enthusiastic. Every day we saw textbook examples of glaciers and volcanoes that were spectacular. Had a great time, even on the days it rained!"—Martha McRae, Houston, Texas

Left to right: Hugh Dresser, Gunnar Gunnarsson, James Eagen, Kenneth Aalto, Martha McRae, Haraldur Sigurdsson, Peter La Delfe, John Cochran, Carol La Delfe, Barbara Cochran, Miguel Carrillo (front), Doug Dresser (back), Fred Farwell, and Mary Emma Wagner. Photo by P. La Delfe.

Iceland: A Student Only–Oriented GeoTrip

August 1–15, 2002

Leader: James Reynolds, Brevard College

"Our journey to Iceland was a once-in-a-lifetime experience that was enjoyed by all. The group of students came together from diverse backgrounds but we were soon making lifelong friendships. Our fearless leader, Jim Reynolds, led us through some of the most fascinating landscapes we will ever see. Geology is best learned in the field, and we learned far more in two weeks than could have been possible from a month of classroom instruction. We are all glad to have had that opportunity, and I think every person on the trip would do it again if they had the chance. I know I would."—Brian Hynek, Washington University

Student GeoTrippers at Eldgja, Iceland. Photo by C. Billmayer and J. Reynolds.

Make Your Next Vacation an Adventure—a GeoVenture!

GSA's GeoVentures are adult educational and adventure experiences known for superior scientific leadership. The GeoVentures program is a special benefit created for GSA members, but the trips are also open to guests and friends.

GeoTrips last anywhere from one to three weeks, and the itinerary covers a wide variety of destinations. These educational programs serve professional geologists who enjoy their geology and the company of colleagues in a field setting. GeoHostels and GeoClasses are usually three- to five-day, campus-based programs.

Ads (or cancellations) must reach the GSA Advertising office one month prior. For 2003, the April and May issues will be combined; deadline is March 3. Contact Advertising Department, (303) 357-1053, 1-800-472-1988, ext. 1053, fax 303-357-1073, acrawford@geosociety.org. Please include address, phone number, and e-mail address with all correspondence.

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GEOLOGIST SCIENCE APPLICATIONS INTERNATIONAL CORPORATION (SAIC)

Science Applications International Corporation (SAIC) is an industry leader in providing environmental and engineering services to the DoD, DOE, EPA and other federal and commercial clients, nationwide. Within its environmental sector, SAIC has 1,600 employees and a network of over 30 offices in the US, providing environmental compliance, restoration, impact studies, natural resources & planning, health & safety, information management, water resources, engineering (environmental and utility), technology evaluation, and optimization to a diverse client base.

SAIC is looking for junior and mid level geologists in the Brea California area. Candidates must have a Bachelor's Degree in geology, hydrogeology, or geophysics and 0-5 years of experience and bachelors degrees or better. Ideal candidate will have some experience with site assessments, remedial systems, sampling, and installation. Familiarity with all types of sampling (i.e., air, soil, and ground water) is desired.

Please visit www.saic.com to learn more about SAIC's business areas, growth history, core values and employee ownership culture. We are an Affirmative Action employer who values cultural diversity in the workplace. Please forward resume to Carol.L.Teran @saic.com if you are interested.

DEPARTMENT OF ENGINEERING SCIENCE AND PHYSICS ASSISTANT PROFESSOR/GEOLOGY

The Department of Engineering Science and Physics of the College of Staten Island/CUNY seeks candidates for an anticipated tenure-track position as assistant professor of geology, beginning September 2003. Required: PhD in geology, and a demonstrated commitment to research and teaching. Postdoctoral experience preferred. Responsibilities include teaching undergraduate geology courses to liberal arts students, teaching graduate courses in environmental science, performing department and college service, and engagement in an active and productive research agenda. The successful candidate will present credentials appropriate for appointment to the doctoral faculty of the CUNY Graduate School. Salary range: $47,331–$61,111, commensurate with qualifications. Review of applications will begin immediately and continue until the position is filled. Send a letter of application describing teaching experience and research interests, a curriculum vitae, and the names, addresses, and telephone numbers of at least three references to Prof. A. Ohan, Chair, Geology Search Committee, Department of Engineering Science and Physics, College of Staten Island/CUNY, 2800 Victory Blvd., Staten Island, NY 10314. EEO/AA/ADA employer.

CHEMICAL OCEANOGRAPHY/COASTAL HYDROLOGY FLORIDA STATE UNIVERSITY

The Department of Oceanography at Florida State University is expanding. One of our new positions is a tenure track Assistant Professor in Chemical Oceanography/Coastal Hydrology. We are particularly interested in a person with a research focus in the flux of freshwater, nutrients, or toxic materials into the coastal zone, especially from a modeling perspective. Other qualified persons in similar fields are encouraged to apply. Applicants must have earned the PhD, and some postdoctoral experience is preferred. We expect the person we hire to establish a vigorous externally funded research program and to support graduate and undergraduate student research and education. Please send applications to Chemical Oceanography Search Committee, Department of Oceanography, Florida State University, Tallahassee, Florida, 32306-4320. Applications should include a full resume, statement of research and teaching interests, and a list of three or more references. For additional information, please visit our web site: http://ocean.fsu.edu or contact Jeff Chanton, jchanton@mailer.fsu.edu or 850-644-7493. The university is an equal opportunity/access/affirmative action employer.

PLANETARY REMOTE SENSING UNIVERSITY OF TENNESSEE

The Department of Geological Sciences and the Planetary Geosciences Institute invite applications for a tenure-track position in planetary remote sensing at the Assistant or Associate Professor level. This program currently focuses on extraterrestrial petrology and cosmochemistry, has a growing base in spectroscopy and exobiology, and actively participates in planetary exploration via spacecraft. Applicants should have research experience in planetary imagery, spectroscopy, or other remote sensing techniques that complement existing department strengths. The successful candidate is expected to develop an active, funded research program, mentor graduate students, and teach graduate and undergraduate courses. The position requires a PhD in geology, geophysics, or a related discipline, and experience with spacecraft missions and teaching is desirable. Apply with a statement of research and teaching goals, resume, and names and email addresses of three references, by March 1, 2003, to: Dr. Hap McSween, Department of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410, mcsween@utk.edu. Review of applications will begin in early March and continue until the position is filled. The University of Tennessee is an EEO/AA/Title VI/Title IX/Section 504/ADA/ADEA institution in the provision of its education and employment programs and services.

MARSHALL UNIVERSITY/FACULTY POSITION

The Department of Geology at Marshall University invites applications for a temporary teaching position from August 2003 through May 2004. The position will be filled at the Assistant or Associate Professor level. The successful applicant will be expected to teach upper level courses in Geomorphology (Fall 2003) and Environmental Geology (Spring 2004) as well as an introductory course in General or Physical Geology. A Ph.D. is required and several years teaching experience is preferred. The successful applicant will be expected to integrate a strong field component into the environmental and geomorphology courses.

Applicants should submit a letter of application, curriculum vitae, a statement of teaching and research interests, and the names and contact information (including e-mail addresses) for three references. All application materials should be sent to Dr. Ronald Martino, Chair, Department of Geology, Marshall University, Huntington, WV 25755. Review of applications will begin March 15 and continue until the position is filled.

Marshall University is an EO/AA employer. Women and minorities are encouraged to apply. For additional information about the Department of Geology and Marshall University, please visit the website www.marshall.edu.

THE COLORADO COLLEGE

The Department of Geology seeks applicants for a one-year non-tenure track position beginning in August 2003. Ph.D. or ABD is required. Appointment will be at the assistant professor level for a candidate with a PhD. Desired area of expertise is open.

Expectations include teaching Introductory Geology and other courses in the candidates' areas of specialty. Undergraduate research is an integral part of our curriculum, and willingness to advise research in the candidates' areas of expertise would be a distinct advantage. The College is committed to increasing diversity of the com-

PRESIDENT

MILWAUKEE PUBLIC MUSEUM

Established in 1882, the Milwaukee Public Museum is one of the nation's leading educational and research institutions focusing on natural science, anthropology, and history. Its collections of 6.2 million specimens and artifacts are widely used by scholars worldwide. Exhibits and education programs renowned for their innovation and diversity are offered in the 400,000-square-foot facility, which includes an IMAX theater, restaurant, retail shops, courtyard, and other amenities for more than 1 million visitors annually. The museum operates with a budget of $20+ million, a full-/part-time staff of approximately 269, a 27-member board, and more than 400 volunteers. Among the president's responsibilities will be to study the institution, its needs, potential, and priorities and, in concert with staff and board, develop and implement its strategic agenda for the next decade. The candidate must have demonstrated success as a visionary leader and a strong, effective manager; have excellent fundraising, external relations, revenue generation, and interpersonal skills; and enthusiasm for public education and scientific research. At least 10 years' experience as a senior executive gained in a similarly complex institution and an advanced degree (preferably Ph.D.) in a relevant field are desired. All communication will be held in the strictest confidence. Address inquiries and resumes to:

Search Committee, Milwaukee Public Museum
800 West Wells Street, Milwaukee, WI 53233-1478
fax: 414-278-6104, email: schmeling@mpm.edu

EOE

munity and curriculum. Candidates who can contribute to that goal are particularly encouraged to apply.

Applicants must be committed to high-quality innovative undergraduate teaching, including field-oriented courses. The Block System of education at Colorado College, in which professors teach and students take only one course at a time for 3-1/2 weeks, lends itself to field and project-based teaching. The Department has excellent field and laboratory facilities for teaching and research in both hard-rock and soft-rock geology.

Send statement of teaching and research interests, curriculum vitae, and names and letters from three referees to: Dr. Paul Myrow, Chair, Department of Geology, Colorado College, Colorado Springs, CO 80903, pmyrow@coloradocollege.edu. Review of applications will begin March 15, 2003. Applications will be accepted until the position has been filled.

The Colorado College welcomes members of all groups, and reaffirms its commitment not to discriminate on the basis of race, color, age, religion, sex, national origin, sexual orientation, or disability in its educational programs, activities, and employment practices.

EQUAL OPPORTUNITY EMPLOYER.

ENVIRONMENTAL SCIENCE INSTITUTE AT THE UNIVERSITY OF TEXAS AT AUSTIN FACULTY SEARCH

The Environmental Science Institute (ESI) at UT-Austin (www.geo.utexas.edu/esi) seeks to hire two individuals to join the ESI-affiliated Jackson School of Geosciences and the School of Biological Sciences, with one appointment to be made in each school at the Assistant Professor level. Each successful candidate will have demonstrated both ability and interest in a vigorous research and teaching program that crosses traditional disciplinary boundaries. A degree in geological or biological sciences is preferred. For each position, we seek candidates with expertise in one of the areas listed:

Position 1: Jackson School of Geosciences: Integrated watershed science, including one or more of the following: hydrology, ecohydrology, biogeochemistry, anthropogenic impacts, climate-system interactions, remote sensing, soils, and geomorphology.

Position 2: School of Biological Sciences: Environmental biology, including one or more of the following: microbial ecology, ecosystem processes, climate change, and human impacts on natural communities.

These hires represent two of five new faculty positions authorized over the next five years to further ESI's mission of conducting outstanding interdisciplinary research and education in environmental science. The ESI also provides opportunity for interaction with excellent UT-Austin programs in engineering, policy, and social sciences.

Applicants should send an application including a statement of research and teaching interests, vita, names and contact information for five references, and reprints of three pertinent publications to: Faculty Search (indicate BIO or GEO), Environmental Science Institute, The University of Texas at Austin, 1 University Station C1100, Austin, Texas 78712-0254. Review of applications will begin February 15, 2003, and will continue until the positions are filled. The University of Texas is an Equal Opportunity/Affirmative Action employer.

GEOLOGICAL OCEANOGRAPHER: SEDIMENT TRANSPORT THE UNIVERSITY OF SOUTHERN MISSISSIPPI

The University of Southern Mississippi's Department of Marine Science at Stennis Space Center seeks to hire a sedimentologist at the tenure-track, Assistant Professor level. Applicants must hold a Ph.D. in geological oceanography or a related field, and have demonstrated field and research experience in depositional processes and transport, preferably in shelf and coastal environments. Post-doctoral experience is desirable. The successful candidate is expected to conduct an active research program and teach graduate courses. Expertise in field observation in concert with numerical or laboratory modeling and knowledge of GIS and/or remote sensing applications are desirable. Research interests in morphodynamic substrate evolution, hydraulics and sediment transport, sediment budgets, high-resolution effects of events and/or processes on subsurface architecture are highly desirable. The position requires interactions with ecologists, acousticians, physical oceanographers, stratigraphers, paleoclimatologists, geochemists, and hydrographers to address multidisciplinary problems in neritic environments. Information is available on-line about the Department at http://www.marine.usm.edu.

Candidates must submit, preferably by electronic mail, a curriculum vita with a research plan; a statement of teaching philosophy; and names, mailing addresses, and e-mail addresses of four referees to Charlotte Brunner, Chair of Search Committee, Department of Marine Science, University of Southern Mississippi, 1020 Balch Blvd., Stennis Space Center, MS 39529 (FAX: 228-688-1121; e-mail: Charlotte.Brunner@usm.edu). Review of candidates will begin February 15 and will continue until the position is filled.

The University of Southern Mississippi's Department of Marine Science is home to a multidisciplinary program of graduate study and research in marine environments. The department offers a Master of Science and Ph.D. in Marine Science and a Master of Science in Hydrographic Science. Located at Stennis Space Center, USM's Department of Marine Science is strategically situated at the single largest concentration of oceanographers and hydrographers in the world. Thirteen on-site faculty conduct research and teach courses in biological oceanography, marine chemistry, geological oceanography, physical oceanography, bio-optics, remote sensing, numerical modeling, hydrography, and underwater acoustics to ~45 full time graduate students. Faculty also interact with research scientists at government agencies located on site including the U.S. Navy, EPA, NOAA, USGS, and NASA. On April 23, 2002, the USM Department of Marine Science broke ground for a new $3 million, 17,000-square-foot marine science laboratory building that will be the first permanent University facility constructed at Stennis Space Center.

USM is an AA/EO employer.

ISOTOPE GEOCHEMISTRY LABORATORY SPECIALIST EARTH AND SPACE SCIENCES AT UCLA

The Department of Earth and Space Sciences at UCLA has an immediate opening for an analytical chemist/geochemist to manage its laboratory operations in support of a new multiple-collector inductively coupled plasma-source mass spectrometer (MC-ICPMS). The person to fill this position will be involved in the development of new isotopic systems for applications in cosmochemistry and geochemistry. Responsibilities include oversight of day-to-day operations of the laboratories and technique development in collaboration with faculty and students. Duties require familiarity with ion exchange chromatography and acid digestion techniques. An advanced degree in chemistry or geochemistry is preferred. Experience in the field of isotope geochemistry or cosmochemistry would be an asset. Deadline for submission: February 28, 2003 or until position is filled. The University of California is an equal opportunity employer. Contact and/or send resume to: A.C. Search, Department of Earth and Space Sciences, University of California at Los Angeles, 595 Charles Young Drive East, P.O. Box 952567, Los Angeles, CA 90095.

FACULTY POSITION DEPARTMENT OF EARTH SCIENCES UNIVERSITY OF OTTAWA

The Department of Earth Sciences, University of Ottawa invites applications for a tenure-track faculty position, beginning July 1, 2003. We seek a dynamic individual with an exceptional research record in Earth System Evolution, using geochemical and isotopic techniques. Applicants must hold a PhD and must satisfy the criteria for potential membership in the Canadian Institute for Advanced Research http://www.ciar.ca/. Rank for the hiring is open and competitive start-up funding will be available. The Department of Earth Sciences houses the world-class G.G. Hatch isotope geochemistry facility http://www.isotopes.science.uottawa.ca/. Information on the department can be found at http://www.science.uottawa.ca/EST/. Under the auspices of the Ottawa-Carleton Geoscience Centre http://www.earthsci.carleton.ca/OCGC/index.html, our department shares a joint graduate studies and research institute with the Department of Earth Sciences at nearby Carleton University. The University of Ottawa is a bilingual (English/ French) institution and the ability to teach in both languages is considered an asset, though not a precondition. Applicants should submit their curriculum vitae, a statement of teaching and research interests, a selection of representative reprints, and the names and contact information for at least three potential referees to: Chair, Faculty Search Committee, Department of Earth Sciences, University of Ottawa, 140 Louis-Pasteur Street, Ottawa, ON K1N6N5, Canada. Applications should be received by February 28, 2003. In accordance with Canadian immigration policies, preference will be given to Canadian citizens and permanent residents of Canada; however, all qualified candidates are strongly encouraged to apply. Equity is a University policy.

NORTHEASTERN UNIVERSITY INSTRUCTOR IN GEOLOGY (FALL '03–SPRING '04)

Instructor one-year position to teach undergraduate courses (i.e. Soil Science, Glacial Geology, Geomorphology, Mineralogy, Geophysics, or Engineering Geology) and introductory courses. Some flexibility in courses. See www.casdn.neu.edu/~geology. Send resume to Prof. Peter Rosen, Chair, Department of Geology, 14 Holmes Hall, Northeastern University, Boston, Massachusetts 02115-5000; p.rosen@neu.edu.

GEOLOGY AND GEOGRAPHY, DEPAUW UNIVERSITY

GEOLOGY. Three-year entry-level position in Geology beginning August 2003. Rank and salary commensurate with credentials and experience. Candidates broadly trained in geosciences capable of teaching many courses from among Physical Geology, Physical Geography, Historical Geology, Environmental Geoscience, Sedimentology/Stratigraphy, Oceanography, and a geoscience-related First-Year Seminar preferred. The department is housed in newly renovated Julian Science and Mathematics Center with excellent facilities to support undergraduate teaching and research. For more information about the department, visit http://www.depauw.edu/acad/geology. DePauw has exceptional faculty development programs, including funding for conference travel and professional and curriculum development activities (see http://www.depauw.edu/admin/acadaffairs/facdev.htm). Submit letter of application, curriculum vitae, contact information for three references, transcripts, a statement of teaching interests/philosophy, and a statement of research interests to Dr. James G. Mills, Jr., Search Committee Chair, Department of Geology and Geography, DePauw University, Greencastle, IN 46135. Review of applications begins February 1, 2003 and continues until position is filled. DePauw University is an Equal Opportunity/Affirmative Action Employer; Women and Minorities are strongly encouraged to apply.

THE JOSEPH P. OBERING POSTDOCTORAL FELLOWSHIP DARTMOUTH COLLEGE

The Department of Earth Sciences seeks outstanding candidates for the Joseph P. Obering Postdoctoral Fellowship in Earth Sciences at Dartmouth College. This competitive fellowship provides two years of full-time salary and a research allowance, with a third year contingent upon performance and funding. In concert with Dartmouth's philosophy that scholarship and teaching are inseparable facets of academic life, this fellowship provides recent Ph.D. recipients the opportunity to pursue independent research as well as develop a teaching portfolio. Candidates will be expected to collaborate with one or more Dartmouth Earth Sciences faculty members, taking advantage of existing resources and facilities, and will teach one course (quarter system) per year. The starting date is negotiable, but could be as early as July 1, 2003. Details about our program can be found at www.dartmouth.edu/~earthsci.

Candidates should submit a cv, statements of research and teaching interests, and selected reprints by March 1, 2003. Applications should be sent to: Obering Postdoctoral Fellowship Committee, Department of Earth Sciences, Dartmouth College, 6105 Fairchild Hall, Hanover, NH 03755. In addition, applicants should arrange for three letters of recommendation to be sent directly to the above address. Dartmouth College is an EO/AA Employer.

GEOMORPHOLOGY/SURFICIAL PROCESSES & GIS COLLEGE OF CHARLESTON

The College of Charleston Department of Geology and Environmental Geosciences (www.cofc.edu/~geology) is accepting applications for a tenure-track Assistant Professor position to begin in August of 2003. We are looking for a dynamic geomorphologist with a commitment to undergraduate education and research excellence, who will develop an active research program involving undergraduate students in support of the College's 4th Century Initiative.

Preference will be given to those with teaching experience at the college level and demonstrated research potential, especially in areas that blend geomorphology and GIS. The successful candidate will be expected to teach introductory geology courses, introductory and advanced GIS, and one or more related courses in their field of specialty. He or she is expected to develop his/her own research program and seek outside funding for that research. A Ph.D. is required at the time of employment. Salary is dependent upon experience.

To apply, send a letter of interest, current curriculum vitae, a statement of research goals, a statement of teaching goals, and arrange for at least three letters of reference to be sent to: Dr. Cassandra Runyon, Chair, Geomorphology/GIS Search Committee, Department of

continued on p. 30

continued from p. 29

Geology, College of Charleston, 66 George Street, Charleston, SC 29424 (843-953-8279), runyonc@cofc.edu.

Applications will be accepted through February 28, 2003. For additional information contact the Department Chair, Dr. Mitchell Colgan: (843-953-5589), colganm@cofc.edu.

The College of Charleston is an equal opportunity/affirmative action/equal access employer. Women and minorities are strongly encouraged to apply. Those persons requiring reasonable accommodation under the Americans with Disabilities Act should contact Dr. Cassandra Runyon at the mail or email addresses above.

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Opportunities for Students

Ph.D. Student Assistantships. Oregon State and Portland State Universities are offering fifteen Ph.D. research assistantships to explore all aspects of the Earth's subsurface microbial biosphere. Tuition and stipend are provided by the NSF IGERT program and the two universities. Students will work in interdisciplinary teams of engineers, oceanographers, microbiologists, microbial ecologists, geologists, soil scientists, and chemists to solve environmental problems, to understand global chemical cycles, and to determine the impact of subsurface microorganisms on surface ecosystems. More information can be found at: http://oregonstate.edu/dept/igert/, or Martin R. Fisk, College of Oceanic and Atmospheric Sciences, Oregon State University, mfisk@coas.oregonstate.edu

Students from all scientific backgrounds are encouraged to apply to departments represented by IGERT faculty at either institution. U.S. citizens or permanent residents can be supported by IGERT funds, however students of all nations can participate in the program. Review of applications starts 2/1/03. Oregon State and Portland State Universities are committed to equality in education.

Environmental and Engineering Geosciences/M.S. The Department of Geology at Radford University has funded opportunities for M.S. students to study a variety of topics in applied geology, including physical and chemical hydrogeology, groundwater modeling, contaminant transport, soil and rock mechanics, engineering geophysics, and geographic information systems. Interested students are encouraged to contact: Dr. Stephen W. Lenhart (slenhart@radford.edu), P.O. Box 6939, Department of Geology, Radford University, Radford, VA 24142; Tel: (540) 831-5257. Additional information about this graduate program can be found at http://www.radford.edu/~geol-web/grad.htm. Radford University is an equal opportunity, affirmative action employer. Minorities and women are encouraged to apply.

Graduate Assistantships, Department of Geosciences, the University of Tulsa. A limited number of teaching assistantships are available for the fall 2003 term in The University of Tulsa Department of Geosciences. The assistantships carry a full tuition waiver plus a monthly stipend, and require 20 hours of work per week Assistantships are awarded on a competitive basis. The Department offers both M.S. and Ph.D. programs in Geology, Geophysics and Geochemistry. Faculty expertise in the Department includes petroleum geochemistry, sequence stratigraphy and clastic depositional systems, petroleum seismology, mantle geochemistry and igneous petrology, environmental geology and structural geology. The Department offers an exceptional graduate experience in a setting where students work closely with their advisors and committee members throughout their graduate program. The Department is exceptionally well equipped with state-of-the-art research and computer labs. For more information on the Department see: http://www.geo.utulsa.edu. For admissions information see: http://www.utulsa.edu/graduate/Files/Graduate Admissions/appl.htm. To request more information, please contact: Graduate Advisor, Department of Geosciences, University of Tulsa, 600 S. College Ave., Tulsa, OK, 74014-3189, Phone: (918)-631-2517, FAX: (918) 631-2091, jbt@utulsa.edu.

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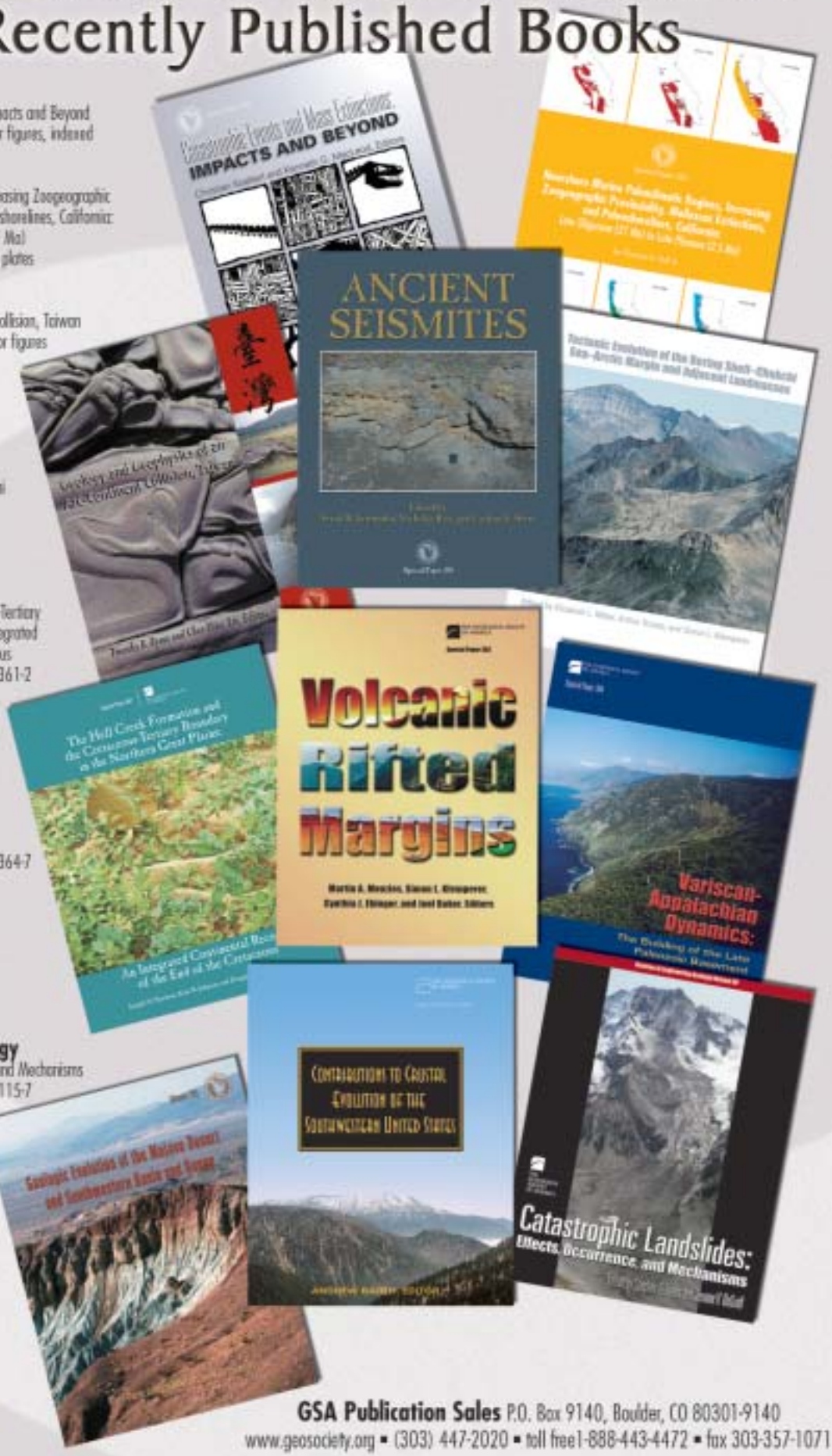

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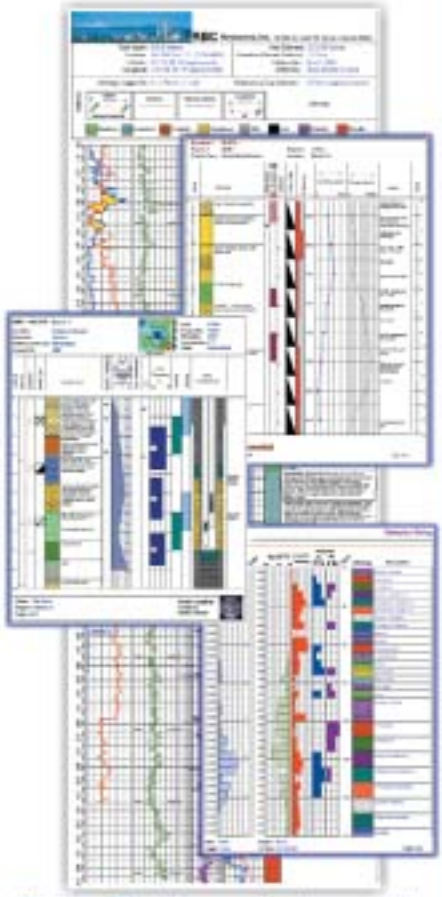

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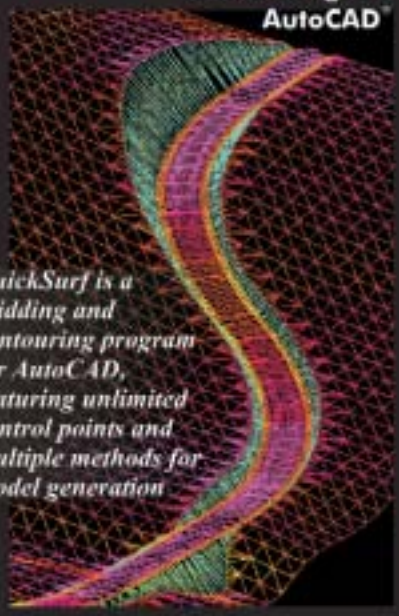

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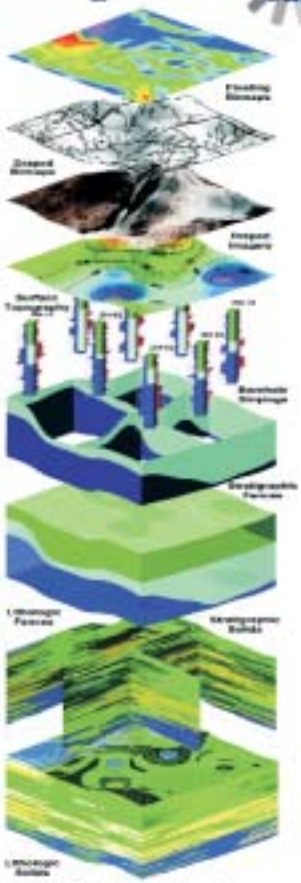

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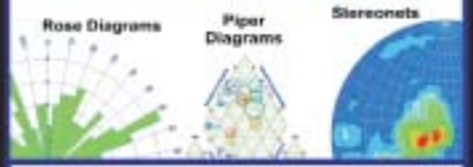

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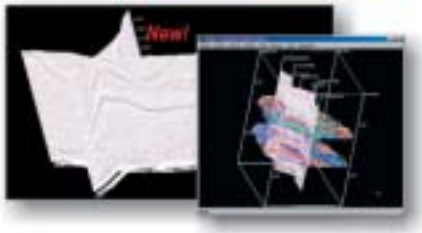

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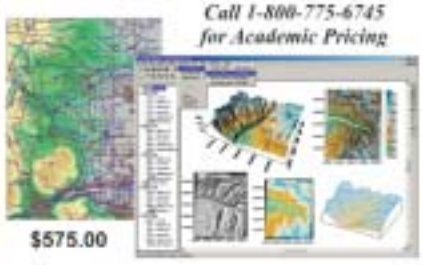

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