GSA news & information

SUPPLEMENT TO GEOLOGY MAGAZINE

DECEMBER 1976

GSA members contribute to AGI minority scholarships

Individual members of the Geological Society of America contributed $3,354 to the $33,500 in scholarships awarded by the American Geological Institute to 37 minority geological-science college majors for the academic year 1976–1977. The students assisted by GSA members, other individual contributors, AGI member societies, and corporations are

Michael Almeda, Mexican-American geology junior at New Mexico Highlands University
Manuel Berumen, Mexican-American geology graduate student at University of Texas at Austin
Ronald Bowser, Black geology senior at Elizabeth City State University
Michael Carroll, Black geology graduate student at University of New Orleans
William Comeaux, Black meteorology sophomore at Kean College
Angel Curet, Puerto Rican geology graduate student at University of California at Santa Barbara
James Davis, Black geology graduate student at University of Southern Mississippi
Celeste Diggs, Black geology junior at Howard University
Luis Fernandez, Puerto Rican geology graduate student at North Carolina State University
Manuel Fernandez, Mexican-American geology graduate student at University of Southern California
Elliott Fisher, Black geophysics junior student at York College (designated the Seismological Society of America Scholar)
Patricia Ford, Black geology freshman student at University of New Orleans
Ernest Gomez, Mexican-American geology graduate student at Northern Arizona University
Eduardo Gonzales, Mexican-American geology junior student at University of Washington
Lou Gonzales, Mexican-American geology senior student at Boise State University
Sylvia Gutierrez, Mexican-American geology junior student at Texas Southern University
Frank Hall, Black geology junior student at Kean College
Toya Horn, Black geology graduate student at University of Washington
Wayne Hunt, American Indian geology senior student at Campbell College
Anthony Johnson, Black geology sophomore student at University of Texas at Austin
Michael Mallette, Black geology senior student at University of Miami (Florida)
Abdul Malik, Black geology junior student at Wright State University
Ademar Martin, Black geology senior student at Howard University
Daniel Martinez, Mexican-American geology senior student at Sul Ross State University
John Martinez, Mexican-American geophysics junior student at Metropolitan State College, Denver
Wilbert Mathews, Black geology graduate student at University of Kansas
Brenda Outler, Black geology senior student at Florida State University
Kim Perez, Mexican-Japanese-American geology graduate student at University of Wyoming
Robert Quintanar, Mexican-American geology senior student at New Mexico State University
Peter Ramirez, Mexican-American geology senior student at University of California at Santa Cruz
Bonnie Robinson, Black geology graduate student at University of California at Santa Cruz
Rudy Rodriguez, Mexican-American geology junior student at Texas Southern University
Phyllis Rutherford, American Indian geology senior student at Southern Oregon State College
Alejandro Soto, Puerto Rican geology graduate student at Stanford University
Kenneth Thornton, Black geology senior student at California State College (Pennsylvania)
Ron Trujillo, Mexican-American geology junior student at Colorado State University
Nickie Williams, Black geology sophomore student at Virginia State College

L. C. Pakiser, *Chairman,* ad hoc Committee
on Minority Group Members in the Earth Sciences

GSA OFFICERS AND COUNCILORS FOR 1977

Charles L. Drake, *President*	Peter T. Flawn, *Vice-President*
William B. Heroy, Jr., *Treasurer*	Robert E. Folinsbee, *Past-President*

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Ninth International Congress of Carboniferous Stratigraphy and Geology

The United States will be the host country for the ninth International Congress of Carboniferous Stratigraphy and Geology. The first Carboniferous Congress was held in Herleen, Netherlands, in 1927. From an originally small group concerned with correlations in northern Europe, the Congress has grown in scope and has also been held in various places (V in Paris, France; VI in Sheffield, England; VII in Krefeld, Germany; and VIII last year in Moscow). In 1979 the Congress will leave Europe for the first time.

Field trips play a key role. It is planned that in early May 1979, interested participants will assemble in Pittsburgh to view type and reference sections of Pennsylvanian strata. Following these trips, subcommission meetings and an opening Plenary Session will be held in Washington, D.C. Technical Sessions will be May 21–25 in Urbana, Illinois. Post-Congress trips to examine the type Mississippian will follow the technical sessions.

Many additional field trips, both pre- and post-meetings will be offered. A wide and varied technical program will be prepared of interest to both academic and commercial groups. Both coal and oil from Carboniferous rocks, as well as other mineral products of this age, will be discussed in depth.

For further information, contact Dr. Ellis L. Yochelson, Secretary-General, IX International Congress of Carboniferous Stratigraphy and Geology, Room E-501, Museum of Natural History, Washington, D.C. 20560.

Geodynamics Project notes

1. *Geodynamics: Progress and Prospects* was prepared by the Inter-Union Commission on Geodynamics and issued as a paperback volume by AGU in July 1976 (238 pages, soft cover, list price $7.50). This book was prepared under the guidance of the Geodynamics Commission and its Working Group chairmen as an attempt to draw together contributions from the international Working Groups that would reflect current thinking and research and would provide a background for subsequent activities under the Project. There are 38 articles by 67 authors.

2. The U.S. Geodynamics Committee issued *Geodynamics Project: U.S. Progress Report — 1976* in July 1976 (75 pages). This second progress report of the U.S. Geodynamics Committee is devoted almost entirely to the activities and progress of the 14 reporters designated by the U.S. Geodynamics Committee to encourage implementation of the priorities established by the Committee. Copies have been widely distributed nationally and internationally, including to the Geodynamics Project Correspondents, one each in some 170 geoscience departments throughout the United States. Copies of the report are available upon request (while the supply lasts) from: U.S. Geodynamics Committee, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

3. Albert P. Bally (Shell Oil Company), Arthur L. Boettcher (UCLA), and William R. Muehlberger (University of Texas, Austin) became members of the U.S. Geodynamics Committee in September 1976. In keeping with policy of the National Academy of Sciences, there is rotation in a portion of the membership of the U.S. Geodynamics Committee each year.

4. James R. Balsley, U.S. Geological Survey, became chairman of the Committee on the International Geodynamics Project of the Federal Council on Science and Technology, replacing former chairman A. P. Crary.

Digital bathymetric data for coastal regions of the United States

As part of a program by NOAA's National Ocean Survey (NOS) to automate the nautical chart production process, water depths (soundings) and supplemental data from approximately 3,200 survey sheets are being digitized and transferred to magnetic tapes. The National Geophysical and Solar-Terrestrial Data Center (NGSDC) will serve as the agency to make these digitized nautical charting (hydrographic data available for general use as they are released by NOS.

They have announced the availability of 166 magnetic tapes representing data from 125 1x1 degree areas off the Atlantic, Gulf, and Pacific Coasts of the United States. The digitized data are from surveys completed between 1930 and 1965; post-1965 data are to be digitized in the near future. Data from all United States coastal waters, including Alaska and Hawaii, will be available within the next several years.

Digital Data. Most of the data (approximately 97%) contained on the magnetic tapes are soundings; the remainder of the data are bottom characteristics (that is, soft, hard, rock, mud, and so forth) and dangers to navigation (that is, rocks, wrecks, pilings, and so forth). All data records contain the registry number of the survey sheet from which they were extracted, the date of completion of the survey, and the latitude and longitude to the nearest 0.01 second. The available data have been digitized from survey sheets of scales 1:2,500 to 1:40,000. Survey scales 1:40,000 to 1:200,000 will be digitized in the near future.

In general, one 1600-BPI tape contains data from one square degree of area; however, in certain cases there are up to eight tapes for one square degree. The master magnetic tapes are 1600 BPI, 9-track, blocked, 5,120 characters per block. The data also can be made available in 9-track (800 BPI) or in 7-track (556 or 800 BPI). More tapes generally will be required for 7-track requests.

Analog Products. Various plotter products are also available in addition to data on magnetic tape. These include: plots of soundings, bottom characteristics, dangers to navigation, bottom profile plots, and various statistical plots (that is, average depth per unit area and depth ranges per unit area).

Address all orders and inquiries to

National Geophysical and Solar-Terrestrial Data Center
Code D621, EDS/NOAA
Boulder, Colorado 80302
Phone: (303) 499-1000, ext. 6338. (FTS 323-6338)

A Reminder:
Two new reports from the Committee on Environment and Public Policy are available

Geologic Constraints in the Urban Environment. *Prepared by a panel under the chairmanship of Wallace R. Hansen that included Donald R. Coates, James R. Dunn, I. Beach Leighton, Andrew M. Spieker, Robert E. Wallace, and Stanley D. Wilson.*

The 12-page report contains discussions under the following topics: *Water, Solid Waste, Building Foundations, Landslides, Construction Materials, Earthquake Hazards, Geologic Constraints and Open Space,* and *Ultimate Responsibility of the Community.* As pointed out in the Foreword, the report is designed as an information paper for decision makers in the broad field of land use.

Impact of Barrier-Island Development—Geologic Problems and Practical Solutions. *Prepared by a panel under the chairmanship of Robert A. Morton that included Cyril J. Galvin, Jr., James D. Howard, Joe C. Moseley, Orrin H. Pilkey, Limberios Vallianos, and James A. Veltman.*

The 8-page report contains, in addition to an introductory discussion, sections titled: *Beach and Barrier-Island Dynamics, Important Environmental Considerations, Other Constraints, Impact of Human Activities,* and *Alternatives to Coastal Problems.* The focus of this information paper is on the coastal areas of the Gulf of Mexico and the Atlantic Ocean.

Members of GSA may secure copies free of charge of either or both of these reports by writing to headquarters and requesting copies; or, if you prefer, you may check the special box in the order blank for *Bulletin* separates near the end of the News & Information section.

The membership of the Committee on Environment and Public Policy is as follows: John H. Moss, Chairman; Helen L. Cannon; George B. Maxey; John D. Moody; Peter H. Given; Howard R. Waldron; M. Genevieve Atwood; Donald D. Runnells; Nathaniel Rutter; and Harold E. Malde, Conferee.

Circum-Pacific volume available to GSA members at reduced price

Papers from the first Circum-Pacific Energy and Mineral Resources Conference have been published as AAPG Memoir 25, *Circum-Pacific Energy and Mineral Resources*, edited by Michel T. Halbouty, John C. Maher, and Harold M. Lian. Because of GSA's role as a cooperating society, AAPG is making this publication available to GSA members at the AAPG member price of $32.00. Any member wishing to order at this discount rate must indicate GSA membership and place the order with AAPG Headquarters, Box 979, Tulsa, Oklahoma 74101. Otherwise, he will be charged the nonmember price.

Memorials available on request

We have a supply of the following memorials available upon request:

Arch Addington, Hans Ahlmann, Frederick Alcock, Ernst Antevs, Esther Applin, Leslie Barrett, Richard Bayley, Charles Brown, Francis Cameron, Anthony R. Cariani, Frank Clark, John Douglas, Helen M. Duncan, Maurice Ewing, Elliot Gillerman, George Goodspeed, William Ham, Henry Howe.

William Irwin, Philip Jennings, Glenn Jepsen, George Knebel, L. Don Leet, Gerald MacCarthy, Phil Martyn, Gordon Merriam, Walter Pond, Gordon Rittenhouse, Robert Sitler, Anna Stose, Alexander Stoyanow, George Swingle, Garvin Taylor, Francis Van Tuyl, Merton Williams, and Robert Vernon.

Necrology

Notice has been received of the following deaths: Richard F. Boss, Houston, Texas; Donald F. Hewitt, Toronto, Ontario; Thomas P. Ahrens, Denver, Colorado; Leslie M. Clark, Alberta, Canada; Eugene R. Eller, Pittsburgh, Pennsylvania; Walter L. Moreman, Oklahoma City, Oklahoma; Jon N. Weber, University Park, Pennsylvania; Eugene J. Wilson, Denver, Colorado.

BOOK BRIEFS

This feature is included occasionally in the News & Information section to keep members informed of recent books published by the Society.

Subduction of Aseismic Oceanic Ridges: Effects on Shape, Seismicity, and Other Characteristics of Consuming Plate Boundaries

SPECIAL PAPER 172 — by P. R. Vogt, A. Lowrie, D. R. Bracey, and R. N. Hey. 1976. iv + 60 pages, 48 figures. $7.50.

Aseismic ridges on underthrusting oceanic plates commonly trend into cusps or irregular indentations in the trace of the subduction zone. For example, the Hawaii-Emperor Ridge trends into the Kuril-Aleutian cusp, and the Marianas arc is bounded by the Marcus-Necker Ridge on the north and the Caroline Ridge on the south. This paper, worldwide in scope, develops the previous proposal of Vogt that many of these complexities of consuming plate boundaries are caused by the relative buoyancy of aseismic ridges on the downgoing plate. These ridges would resist being subducted; therefore, they would also preferentially inhibit back-arc or interarc extension of a type now reasonably well established, at least for the younger marginal basins of the western Pacific. (Island arcs may, therefore, acquire their curvature by additional constraints other than the Earth's curvature.) The authors also examine the seismicity, volcanism, and morphology of the arc-trench gap to determine whether these features of subduction zones have been affected in a systematic way where ridges are being subducted. The discussion does not in general depend on the mode of origin of the aseismic ridges—whether they are, for example, hot-spot traces, fracture ridges, or remnant arcs—nor does it depend on the physical processes responsible for the back-arc extension.

The geology of about 15 cusp areas is examined for evidence to test the hypothesis that cusps were caused by subducted aseismic ridges. This hypothesis applies only to cases where extensional basins lie behind the arcs. There also appear to be cases in which the trace of the subduction zone has been modified not by inhibiting back-arc spreading but by splintering of the overthrusting and possibly the underthrusting plate as well. Extremely high, massive aseismic ridges might induce arc polarity reversals and thereby assume the role of protocontinental nuclei.

There are several examples of reduced seismicity where aseismic ridges are being subducted that cannot be explained as effects of insufficient sampling time. By modifying the geometry of the subduction zone, the downgoing ridges necessarily affect seismicity. In addition, the plate containing the ridge may be thinner and hotter and more likely to deform by creep. There is no systematic increase or decrease in the number of andesite volcanoes where the ridges are subducted. However, lines of volcanoes and sometimes other kinds of geologic and seismic provinces may stop or start at the arc-ridge intersections. This is attributed to segmenting of the lithosphere into distinct tongues, each tongue acting more or less independently. Aseismic ridges would act as lines of weakness along which the downthrust slab becomes detached.

Dunnage Melange and Subduction of the Protacadic Ocean, Northwest Newfoundland

SPECIAL PAPER 175 — by Marshall Kay. 1976. vi + 50 p., 17 figures, 1 plate: one-sheet map, in color, folded in back pocket. $8.00.

Marshall Kay intended that this paper and its accompanying map summarize the results of many years of painstaking field work in the New World Island area, which lies at the northeastern end of the complex Central Volcanic Belt of Newfoundland. His intent was to document the field relations of the perplexing rocks of the Dunnage melange. The map, which is multi-colored (scale 1:50,000), and its legend point out and describe nearly eighty important geologic localities.

The Dunnage melange crops out in a band 10 km wide between the Dildo and Holmes Point faults on the north and south and is truncated eastward by the northeast-trending Reach fault. The matrix of laminated black and greenish argillite has interbeds of graded graywacke, tuff, and lava. A limestone layer has Middle Cambrian fossils. Olistostromes are interbedded. Boulders are mainly graywacke and pillow lava, with less abundant plutonic and volcanic rocks, chert, and dolomite; spheroidal masses exceed diameters of 10 m; facings are rather random. Southeast-dipping cleavage is isoclinally folded; primary structures (including bedding) rarely are apparent.

Northward on New World Island between the Dildo and Lukes Arm faults lie several sequences of Ordovician volcanic and sedimentary rocks and Silurian sedimentary rocks, separated by angular unconformity. South of the Holmes Point fault are volcanic and sedimentary rocks of the Campbellton sequence. The Lukes Arm and Reach faults, which are transcurrent, may have displacements of scores or hundreds of kilometres.

Ordovician and Devonian stocks intrude the melange.

Devonian Acadian folding affected all the earlier rocks and was succeeded by intrusions of plutonic granitic batholiths. Some or all of the steeply dipping faults are later Paleozoic or early Mesozoic, preceding the intrusion of mafic dikes in Jurassic time.

The Campbellton sequence may contain oceanic crust; the New World Island sequences contain island-arc associated rocks. In the Dunnage Formation north of the Holmes Point fault, abundant olistostromes give it the character of a melange. Deposition in a large submarine trough or basin is required by the lamination of the argillite, minute-pustulate surfaces of pillows, flysch nature of graywacke interbeds, and the olistostromes with large olistoliths. Slabs of continental rise sediment slid from the margins of the basin. Neither the direction of transport nor the age of the plutonic boulders has been determined. The volcanic rocks that lie to the north, particularly those in the Virgin Arm sequence, suggest an island-arc association above a subduction zone (Dewey).

The Dunnage melange is interpreted as forming in a northwest-dipping subduction zone along the margin of the Ordovician Protacadic Ocean; olistostromes and olistoliths moved from the island-arc terrane situated to the northwest. The melange was not made chaotic within the subduction zone. The chaotic character of the bouldery mudstone came from the transport and subsequent tectonic disturbance rather than from kneading in a subduction zone. There is no suggestion of deep burial of the melange. The intrusions seem to be hypabyssal and nearly contemporaneous. If dacite boulders at the base of the Dildo sequence on the north are from the intrusions, the Dunnage terrane was raised and eroded soon after intrusion. If the melange related to a subduction zone, it was the part at or near the surface, marking the close of subduction movement.

Many problems remain to be resolved. Within the structural sequences and blocks, successions are well established in some, but tenuously reported in others. Even if the successions in each block were satisfactorily known, there remains the problem of palinspastic restoration of fault-displaced segments of Protacadic Ocean crust elsewhere.

December BULLETIN briefs

Brief summaries of articles in the December 1976 GSA Bulletin *are provided on the following pages to aid members who chose the lower dues option to select* Bulletin *separates of their choice. The document number of each article is repeated on the coupon and mailing label in this section.*

☐ 61201—Rheological implications of the internal structure and crystal fabrics of the West Antarctic ice sheet as revealed by deep core drilling at Byrd Station. *Anthony J. Gow and Terrence Williamson, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire 03755 (present address, Williamson, J. S. Cummings, Inc., Bangor, Maine 04401)* (13 p., 11 figs.)

Crystalline textures and fabrics of ice cores from the 2,164-m-thick ice sheet at Byrd Station, Antarctica, reveal the existence of an anisotropic ice sheet. A gradual but persistent increase in the *c*-axis preferred orientation of the ice crystals was observed between the surface and a depth of 1,200 m. This progressive growth of an oriented crystal fabric is accompanied by a twentyfold increase in crystal size between 56 and 600 m, followed by virtually no change in crystal size between 600 and 1,200 m depth. A broad vertical clustering of *c* axes develops by 1,200 m. Between 1,200 and 1,300 m, the structure transforms into a fine-grained mosaic of crystals with their basal glide planes now oriented substantially within the horizontal. This highly oriented fine-grained structure, which persists to 1,800 m depth, is compatible only with a strong horizontal shear deformation in this part of the ice sheet. Rapid transformation from single- to multiple-maximum fabrics occurs below 1,800 m. This transformation, accompanied also by the growth of very large crystals, is attributed to the overriding effect of relatively high temperatures in the bottom layers of old ice at Byrd Station rather than to a significant decrease in stress.

The zone of single-maximum fabrics between 1,200 and 1,800 m also contains numerous layers of volcanic dust. Fabrics of the very fine grained ice associated with these dust bands indicate that the bands are actively associated with shearing in the ice sheet.

Some slipping of ice along the bed rock seems likely at Byrd Station, since the basal ice is at the pressure melting point and liquid water is known to exist at the ice-rock interface. The textures and fabrics of the ice indicate that plastic deformation (intracrystalline glide) in the zone of strong single-maximum fabrics and movement of ice along discrete shear planes situated well above bed rock are also major contributors to the flow of the ice sheet. Any extensive shearing at depth could seriously distort stratigraphic records contained in the ice cores, such as climatic history as inferred from stable isotope analysis. Also, the common practice of using simplified flow models to approximate the depth-age relationships of deep ice-sheet cores may need to be revised in light of the deformational features and fabrics observed in the Byrd Station ice cores.

☐ 61202—Species diversity of deep-sea benthic Foraminifera from the central Arctic Ocean. *Martin B. Lagoe, Department of Geology and Geophysics, University of Wisconsin, Madison, Madison, Wisconsin 53706 (Present address: Atlantic Richfield Company, P.O. Box 360, Anchorage, Alaska 99510)* (6 p., 5 figs., 2 tbls.)

The species diversity of benthic Foraminifera contained in 67 sediment samples from the central Arctic Ocean is investigated to determine diversity patterns in a deep-sea, high-latitude environment. The samples range in depth from 1,069 to 3,709 m. Species diversity and equitability, as measured by the number of species, S, the Shannon-Wiener index, $H(S)$, the Buzas-Gibson index, E, and the Lloyd-Ghelardi index, e, decrease with depth in this interval. Comparison with previously published data suggests that species diversity decreases with depth throughout the entire depth range of the Arctic Ocean.

The diversity of the deep Arctic benthic Foraminifera is less than that of faunas from comparable depths at lower latitudes. Current theories of species diversity do not completely explain the observed diversity patterns. The youthfulness of the Arctic ecosystem and instability of resource supplies may be important contributing factors.

☐ 61203—Recumbent folding in the base of the Barnes Ice Cap, Baffin Island, Northwest Territories, Canada. *P. J. Hudleston, Department of Geology and Geophysics, University of Minnesota, Minneapolis, Minnesota 55455* (9 p., 9 figs.)

Recumbent folds exposed in an ice cliff at the southeast side of the Barnes Ice Cap occur in banded ice and have hinges subparallel to the glacier margin. The folds appear similar in shape and attitude to others expressed on the glacier surface as a series of irregular lenses of white ice that are elongate parallel to the margin and are surrounded by blue ice. Such lenses are all around the margin of the south dome of the ice cap. Both sets of folds are thought to have a common origin.

Fold geometry and fabric studies suggest that the ice is behaving homogeneously on the scale of the folds and that the banding is essentially passive. Flow considerations indicate that banding or foliation will tend to become parallel to the particle paths near the glacier base and toward the margin under steady-state conditions. However, departures from the steady state in the form of minor advances or retreats may change the flow pattern sufficiently for the particle paths to depart from parallelism with the banding, which may then become passively deformed and eventually folded. For this to occur, the bedrock surface must be appropriately irregular. A simple mathematical model describes this process and successfully accounts for the geometrical features of the folds observed. This theory is consistent with earlier observations of the Barnes Ice Cap, which suggest that there have been fluctuations in the position of the ice-cap margin in the last few centuries.

☐ 61204—Anatomy of an assemblage zone. *J. G. Johnson, Department of Geology, Oregon State University, Corvallis, Oregon 97331; W. W. Niebuhr II, Department of Paleontology, University of California, Berkeley, Berkeley, California 94720* (11 p., 8 figs.)

The upper Lower Devonian *pinyonensis* Zone, named by Merriam in central Nevada, is an assemblage zone based on brachiopods. It encompasses a high diversity fauna, most of whose members migrated into central Nevada shortly after the distinctive and favorable *pinyonensis* Zone environment came into existence. The *pinyonensis* Zone coincides in space and time with the equally distinctive Bartine Limestone lithofacies, which is a member of the McColley Canyon Formation.

The assemblage zone comprises several communities that existed side by side during all or part of *pinyonensis* Zone time. The brachiopods of these communities migrated in regular, nonrandom patterns within the *pinyonensis* Zone environment in response to changes in water depths, energy levels, and circulation. The assemblage as a whole ceased to exist when its favorable environment disappeared, judging from the coincidence of the *pinyonensis* Zone with the Bartine lithofacies.

The fauna of the *pinyonensis* Zone represents an indivisible aggregate, or naturally "packaged" group of coexisting species that underwent little evolution once they were assembled in a favorable environment. The formation of the distinctive fauna and its demise can both be attributed to geological events that altered the environment. It appears that assemblage zones form when and where geological events cause pronounced environmental changes and that they tend not to form in environments in which changes are small and continual.

Loss of the environment of an assemblage zone, or of a large percentage of its total area, evidently causes large-scale speciation and (or) extinction of the fauna which previously had attained a relative stability and which is the reason that an assemblage zone, when fully known, is a viable chronostratigraphic unit.

☐ 61205—Sliding stones, Racetrack Playa, California. *Robert P. Sharp, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, California 91125; Dwight L. Carey, Department of Geology, University of California at Los Angeles, Los Angeles, California 90024* (14 p., 21 figs., 5 tbls.)

Twenty-eight of 30 monitored stones on the southern part of Racetrack Playa moved within a 7-yr interval, leaving distinct tracks. Movements occurred principally during the winters of 1968-1969, 1972-1973, and 1973-1974. Some stones moved in all three episodes, some only in one or two, and a few on other occasions. Movement is clearly related to wet stormy weather.

Greatest cumulative movement, 262 m, and greatest single-episode movement, 201 m, were by a small, 250-g stone. Other monitored stones weighing as much as 25 kg moved cumulative distances of 60 to 219 m. Net direction of movement was north-northeasterly with deviations to east and southeast on occasions by some stones. Movement most likely occurs within one to several days after playa wetting, and velocities on the order of 0.5 to 1 m/sec are inferred from track characteristics.

Thin sheets of ice form in winter on this playa, and eyewitness accounts of ice sheets, some with infrozen stones, being driven by wind across other southern California playas indicate that stone tracks may be made in this manner, as earlier advocated. However, movement of stones out of an encirclement of iron stakes, large changes in neighboring stone separation during movement, disproportionate corresponding reaches within contemporaneous tracks of neighboring stones, and other relationships strongly suggest that monitored stone movements occurred without the aid of extensive ice sheets.

Wind acting directly on the individual stones is considered the prime moving force. A critical element promoting movement may be deposition of a thin layer of fine slippery clay, the material that last settles from suspension after playa flooding.

☐ 61206—Geology of Crater Elegante, Sonora, Mexico. *James T. Gutmann, Department of Earth and Environmental Sciences, Wesleyan University, Middletown, Connecticut 06457* (12 p., 5 figs., 1 tbl.)

Crater Elegante is a circular, flat-floored, volcanic depression 1.6 km in diameter located in the Pinacate volcanic field, northwestern Sonora, Mexico. Exposed in its steep walls is an eruptive sequence of late Pleistocene age that is made up of numerous flows and pyroclastic units of porphyritic alkali basalt and hawaiite. Rapid alternation of effusive and pyroclastic activity is evident. The forms of intravolcanic sills and dikes are displayed in vertical cross section in the crater walls, as are structural relationships between flows and pyroclastic layers deposited on them while the flows were still mobile.

Eruptive activity at Crater Elegante culminated catastrophically with ejection and base-surge dispersal of large quantities of pyroclastic materials. These form a blanket of tuff breccia and contain vesicular juvenile ash as their dominant constituent at the crater rim. Fine-grained accidental ejecta in the tuff breccia deposits increase in relative abundance with distance from the rim. The volume of accessory debris in the ejecta blanket is much smaller than the volume of the crater. Although the diameter of the original vent is not known, it must have been much smaller than the diameter of Crater Elegante. The crater formed chiefly by wholesale collapse of the volcanic edifice following eruption of ultravesiculating magma and evisceration of a large chamber located within fine-grained, water-bearing sediments beneath the volcanic pile. Thus, Crater Elegante in some respects resembles a maar but is in fact a small collapse caldera.

☐ 61207—Stable isotope geochemistry, geothermometry, and geochronology of speleothems from West Virginia. *Peter Thompson, Department of Physics, University of Alberta, Edmonton, Alberta T6G 2J1 Canada; Henry P. Schwarcz, Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1 Canada; Derek C. Ford, Department of Geography, McMaster University, Hamilton, Ontario L8S 4M1 Canada* (9 p., 8 figs.)

Some speleothems (cave-deposited travertine formations) from two caves in West Virginia were formed in isotopic equilibrium with seepage waters during the interval 200,000 B.P. to the present. Deuterium/hydrogen ratios in fluid inclusions from these speleothems indicate that $\delta^{18}O$ values of waters from which they were deposited did not change appreciably during at least part of that interval. From these and other data, we infer that $\delta^{18}O$ of calcite increased with decreasing temperature of deposition. Deposition rates appear to be greatest during summer and may have fallen to zero during glacial advances. Curves of relative paleotemperature, based on secular changes in $\delta^{18}O$ of calcite as dated by the $^{230}Th/^{234}U$ method, are presented. Maxima in this record correspond to maxima in summer insolation in the Northern Hemisphere as calculated by Vernekar, as well as to high sea stands marked by raised coral reefs and to thermal maxima observed in speleothems from other regions of North America.

☐ 61208—Mineral reactions in the sedimentary deposits of the Lake Magadi region, Kenya. *Ronald C. Surdam, Department of Geology, University of Wyoming, Laramie, Wyoming 82071; Hans P. Eugster, Department of Earth and Planetary Science, Johns Hopkins University, Baltimore, Maryland 21218* (14 p., 11 figs., 11 tbls.)

The authigenic minerals, principally zeolites, in the Pleistocene to Holocene consolidated and unconsolidated sediments of the Magadi basin in the Eastern Rift Valley of Kenya have been investigated. Samples were available from outcrops as well as drill cores. The following reactions can be documented: (1) trachytic glass + H_2O → erionite, (2) trachytic glass + Na-rich brine → Na-Al-Si gel, (3) erionite + Na^+ → analcime + K^+ + SiO_2 + H_2O, (4) Na-Al-Si gel → analcime + H_2O, (5) calcite + F-rich brine → fluorite + CO_3^-, (6) calcite + Na-rich brine → gaylussite, and (7) magadiite → quartz + Na^+ + H_2O. Erionite is the most common zeolite present, but minor amounts of chabazite, clinoptilolite, mordenite, and phillipsite were also recognized. Erionite can form directly from trachytic glass by the addition of H_2O only. It is characteristic of the Magadi basin because of the low content of alkaline earths in the volcanic glasses and in the solutions interacting with them.

Analcime is common in outcrops of the High Magadi and Oloronga Beds. It forms from erionite by a reaction probably initiated by a lowering of the silica activity, which results from the transformation of magadiite to chert. Analcime in the drill-core samples grew at the expense of a Na-Al-Si gel. This gel forms at the lake shore and is washed into the lake during flooding conditions.

Fluorite is common in the core samples and can be explained by reaction of the fluoride-rich brines with calcium in the sediments, principally detrital calcite. Authigenic albite and potassium feldspar were not recognized, probably for reasons of reaction kinetics.

The presence of authigenic minerals can be accounted for by considering the chemical compositions of the starting materials, mainly volcanic glasses, and the brines they come in contact with. Lake Magadi represents a unique opportunity for studies of diagenesis because authigenic minerals are forming there at the present time and because the evolution of its waters is well known.

☐ 61209—Origin of the late Paleozoic plutonic massifs in Morocco. *Thomas A. Vogel, E. Ruth Williams, John K. Preston, Bruce M. Walker, Geology Department, Michigan State University, East Lansing, Michigan 48824* (10 p., 5 figs., 7 tbls.)

Throughout northwestern Africa are small (less than 200 km^2) late Paleozoic massifs. These are shallowly emplaced into unmetamorphosed Paleozoic sediments and always produce a well-defined contact metamorphic aureole. The Tichka massif is the only well-exposed massif with over 2,000 m of vertical relief developed. In contrast, the other massifs have been barely unroofed.

The Tichka massif contains basic rocks surrounding teardrop-shaped granitic pods. At the contact of the massif with the overlying sediments, large masses of granite occur. On the basis of field relationships, two models can be proposed: the rock types are related to a common parent, or the dioritic and granitic magmas are independent melts. A least-squares approximation test, using all available chemical data, is consistent with the latter model.

The granitic massifs approximate a "minimum-temperature melt" composition, which suggests that these rocks originate by fractional fusion of the crustal rocks. The heat source is proposed to be caused by emplacement of mantle-derived gabbroic melts. In some massifs the granitic material was generated and emplaced without intermingling with the gabbroic melts, and it is these massifs that are associated with relatively large negative gravity anomalies (-40 mgal). The chemistry and mineralogy of these massifs are statistically identical. In contrast the Tichka and Midelt massifs are not associated with negative gravity anomalies, and the granitic rocks from these two massifs are statistically identical; but each is statistically different from the massifs with negative gravity anomalies. The Tichka massif contains abundant, possibly mantle-derived, basic rocks and it is inferred that the Midelt massif does also.

There is no evidence that supports a subduction zone model for the origin of these late Paleozoic massifs. It is proposed that the massifs of Morocco may be a response of the continental crust to initial spreading and rifting of North America from Africa. The origin of the granitic rocks is suggested to be the result of fractional fusion of the lower crust, with the heat source caused by sporadic upwelling of mantle-derived gabbroic material associated with the initial extension and thinning of the lithosphere. On the basis of the ages of these massifs, the initial activity began about 320 m.y. B.P.

☐ 61210—Unconformity at the Cardenas-Nankoweap contact (Precambrian), Grand Canyon Supergroup, northern Arizona. *Donald P. Elston and G. Robert Scott, U.S. Geological Survey, Flagstaff, Arizona 86001 (Present address, Scott: Division of Geosciences, University of Dallas, Dallas, Texas 75320)* (10 p., 4 figs., 1 tbl.)

Red-bed strata of the Nankoweap Formation unconformably overlie the ∼1,1100-m.y.-old Cardenas Lavas of the Unkar Group in the eastern Grand Canyon. An unconformity and an apparent disconformity are present. At most places the upper member of the Nankoweap overlies the Cardenas, and locally an angular discordance can be recognized that reflects the truncation of 60 m of Cardenas. This unconformity also underlies a newly recognized ferruginous sandstone of probable local extent that underlies the upper member and that herein is called the ferruginous member of the Nankoweap. Truncation of the Cardenas beneath the ferruginous and upper members locally may have been as much as 300 m. Basal conglomeratic sandstone of the upper member locally overlies the ferruginous member with apparent disconformity, reflecting a probable hiatus in deposition.

Stratigraphic and structural relationships indicate that a ferruginous weathered zone was developed on an erosionally truncated section of the Cardenas before, and perhaps during, the time of deposition of the ferruginous member. Erosion of the ferruginous weathered zone provided material for the ferruginous member of the Nankoweap. The ferruginous weathered zone locally was faulted against unweathered Cardenas before deposition of the upper member of the Nankoweap.

The Nankoweap Formation is disconformably overlain by marine strata of the Chuar Group. Three distinct units separated by unconformities (the Unkar Group, Nankoweap Formation, and Chuar Group) thus are recognized in the Grand Canyon Series of Walcott. Following current stratigraphic practice, the Grand Canyon Series is herein redesignated the Grand Canyon Supergroup.

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☐ 61211—Low-temperature serpentinization of peridotite fanglomerate on the west margin of the Chiwaukum graben, Washington. *Susan M. Cashman and John T. Whetten, Department of Geological Sciences and U.S. Geological Survey, University of Washington, Seattle, Washington 98195* (4 p., 5 figs.)

Peridotite clasts in fanglomerate on the west margin of the Chiwaukum graben have rims of serpentine (lizardite) that formed after deposition. Interbedded sedimentary rocks are incompletely altered to laumontite and other low *P-T* phases. Serpentinization must have occurred under *P-T* conditions no higher than zeolite facies, probably less than 100°C.

☐ 61212—Petrology of McKinney Basalt, Snake River Plain, Idaho. *W. P. Leeman, Oregon State University, Department of Geology, Corvallis, Oregon 97331; C. J. Vitaliano, Indiana University, Department of Geology, Bloomington, Indiana 47401* (16 p., 9 figs., 10 tbls.)

The McKinney Basalt, a composite pahoehoe and pillow lava unit in the Snake River Plain, has been studied by petrographic, chemical, strontium-isotopic, and experimental methods in an attempt to define its origin and evolutionary history. Differences in the compositions of olivine and plagioclase phenocryst cores and in the whole-rock composition of different samples are interpreted as evidence that McKinney Basalt erupted as sequential surges of lava that represent different degrees of fractional crystallization of an olivine tholeiite parental magma. Olivine and plagioclase geothermometry and experimental studies indicate that McKinney pillow lava erupted at a temperature of about 1190° to 1200°C. Compositions of iron-titanium oxides and plagioclase/glass europium partition coefficients indicate that as McKinney lava cooled, oxygen fugacity was buffered near the quartz-fayalite-magnetite buffer.

Experimental studies and chemical compositions of McKinney samples suggest that the parental magma underwent significant crystallization only at relatively low pressures (<8 kb). Theoretical calculations involving silica and alumina activities suggest that McKinney parental magma was formed likely by partial fusion of spinel peridotite or aluminous pyroxene peridotite mantle at depths of about 50 to 60 km. Under anhydrous conditions, melting would have occurred at this depth at a minimum temperature of about 1300°C. Under water-undersaturated conditions, melting would have occurred at a significantly lower temperature, whose value would depend on the water content of the magma.

Strontium isotopic data suggest that McKinney Basalt, like all other Snake River olivine tholeiites, was derived from a mantle region that is more radiogenic than typical suboceanic mantle.

☐ 61213—Geological Society of America Bulletin: Contents, Volume 87, 1976; Subject and Author Index to Volume 87, No. 1-12, 1976.

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