New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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December 15, 1980

TO: Board of Regents, New Mexico Institute of Mining & Technology
Bruce King, Governor of New Mexico
Kenneth W. Ford, President, New Mexico Institute of Mining & Technology
Larry Kehoe, Secretary, New Mexico Energy and Minerals Department

We have the honor of transmitting to you the Annual Report of the New Mexico Bureau of Mines and Mineral Resources for the fiscal year July 1, 1979 through June 30, 1980, as required by law (Section 3, Chapter 115, Eighth New Mexico Legislature, approved March 14, 1927).

In this, our 53d year of service and applied research, the Bureau provided information concerning exploration, development, and conservation of New Mexico's geology and mineral resources, as detailed in this report. Ongoing programs were continued; investigations in applied research in coal, uranium, and petroleum were increased.

The Bureau's service to New Mexico is based on the expertise and dedication of our staff. During the fiscal year we lost 16 percent of our professional staff, mainly younger employees. With the increasing demand for geologists and engineers and the higher salaries paid by industry and the federal government, hiring and retaining quality professionals continues to be a significant problem.

Charles E. Chapin, Senior Geologist, was awarded the van Diest Gold Medal by the Colorado School of Mines. This medal is given to an outstanding alumnus who has made significant contributions in the field of mineral-resources geology. Corale Brierley, Chemical Microbiologist, cochaired the Mineral Waste Stabilization Liaison Committee meeting in Santa Fe. Frank Kottlowski was elected Councilor for the Geological Society of America. Other staff members, also, in many ways, assisted professional and scientific organizations and worked in varied state programs, including our cooperative and complimentary liaison with the New Mexico Energy and Minerals Department.

A continuing feature of these Annual Reports are scientific and technical papers, some of which present interesting summaries of project results.

New Mexico is rich in mineral resources, especially energy materials. Thus, the emphasis of our program will continue to be in aiding and encouraging the exploration, development, and prudent handling of these resources -- while striving, always, for technical and scientific excellence that accrues the greatest benefit to the State.

Respectfully submitted,

Frank E. Kottlowski
Director

George S. Austin
Deputy Director

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

ANNUAL REPORT

for the Fiscal Year
July 1, 1979, to June 30, 1980

by
Frank E. Kottlowski
and staff

SOCORRO 1981

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Purpose and functions

INTRODUCTION

For 53 years, the New Mexico Bureau of Mines and Mineral Resources has served New Mexico in its legislatively assigned role of investigating and reporting on the geology, mineral resources, and energy resources of the state. From March 14, 1927, the Bureau has given technical and scientific assistance in the exploration, development, production, and conservation of New Mexico's mineral wealth. Most of the Bureau's investigations have been reported in the 107 bulletins, 37 memoirs, 172 circulars, 10 ground-water reports, 4 hydrologic reports, 1 hydrogeologic sheet, 49 geologic maps, 12 scenic-trip guidebooks, 10 progress reports, 10 resource maps, and 119 open-file reports. In addition, hundreds of articles by staff members have been published in journals of professional and scientific societies. Moreover, staff members have made many scientific and technical presentations to state, national, and international organizations. The Bureau's program of geologic and mineral-resources studies has contributed significantly to New Mexico's position as a leading producer of energy and mineral materials.

In 1979, the value of minerals extracted in New Mexico totaled almost $5.5 billion. Payments from the U.S. Bureau of Land Management and compensatory reimbursement in lieu of taxes totaled $96.5 million; this amount includes the state's share of income from leasing of mineral rights on federal lands administered by the U.S. Bureau of Land Management. State severance and other state taxes collected on minerals extracted in New Mexico during 1979 plus bonuses and royalties were almost $500 million. Thus, New Mexico's mineral industry contributes substantially to the state's economy.

Most of the talent and capital for finding and developing mineral resources in New Mexico comes from private industry. The Bureau contributes actively to these programs by taking the lead in the applied research that insures industry's prudent growth. Serving as a clearinghouse of the best possible scientific and technical information, the Bureau impartially shares its files of basic data with all companies, individuals, agencies, and institutions. An outstanding example is the Bureau's New Mexico Library of Subsurface Data. Oil-well samples and records, secured by companies and individuals at a cost of billions of dollars, are freely accessible at the Bureau; the value of these files increases with the passing of time.

GEOLOGY AND MINERAL RESOURCES

Geologic knowledge is indispensable in the exploration and development of mineral resources. Field investigations, regional geologic reports, structure contour maps, detailed and reconnaissance geologic maps, and stratigraphic studies aid in finding and—eventually—in extracting mineral ores. Many geologists, mining engineers, prospectors, and landowners visit the Bureau to confer on geologic data and interpretations. Most of the Bureau's work is in technical services, but basic and applied geologic research is also important.

The scientific and technical literature generated by the Bureau contributes significantly to mineral exploration. Sales of Bureau publications totaled $49,409 this fiscal year; about 8,500 copies of the new publications were issued free to state officials, libraries, and scientific organizations. Sales performance of a particular publication, however, does not necessarily reflect its ultimate worth to New Mexico; any report or map may contain the clue that leads to the discovery of a huge orebody or a million-barrel oil pool.

Many New Mexicans and most of the tourists visiting the state are not concerned directly with technical geologic investigations but do have a lively interest in our enchanting landscapes. They want to know how the canyons and mountains, the arroyos and mesas, and the volcanoes and desert playas were formed. The popular guides, Scenic Trips to the Geologic Past, explain the geology of local areas and point out scenic and geologic wonders. These books also are designed to keep tourists in the state "that extra day"—so important to New Mexico's economy. Tens of thousands of copies have been distributed, and the demand continues. The Bureau also publishes other more technical guidebooks.

Most of our geologic work constitutes "ground truth" investigations, as demonstrated by the more than 297,000 mi logged by Bureau field vehicles during the fiscal year.

BASIC SERVICES

Citizens of New Mexico and elsewhere, including geologists, engineers, landowners, prospectors, legislators, students, industry personnel, and tourists, sought technical advice from Bureau staff this year. Our records show that 8,750 letters and 6,070 telephone inquiries were answered, and 8,130 office visitors were counseled. Many adults and school children toured the Bureau's mineral museum. More than 4,000 analytical reports were prepared on mineral, ore, metallurgical, and water samples. Staff mineralogists identified hundreds of hand specimens of rocks and minerals brought or mailed to the Bureau.

Direct services to petroleum exploration included making available records of many of the more than 72,000 test wells drilled in New Mexico, including cuttings from selected wells and a variety of borehole logs such as electric, radioactive, and sonic. Up-to-date petroleum exploration maps for most counties are maintained and available.

A number of cooperative projects were continued with state and federal agencies. Staff members served on various government committees and commissions, served as officers of professional organizations, presented papers at scientific meetings, and served New Mexico Tech by teaching, directing graduate studies, and participating in the work of Institute groups.

The worldwide demand for mineral and energy resources this decade has triggered an unprecedented effort to find new domestic deposits—the great search is on. New Mexico, in the midst of a region having high potential, is playing a key role in meeting the nation's needs. New firms have established offices in the region. A growing number of geologists and engineers are combing the state for signs of hidden geologic resources. The demand for scientific information and literature continues to grow.

All of this activity is being countered by other forces that are hampering and inhibiting the necessary mineral exploration and development. One negative aspect that concerns the Bureau directly is the astonishing increase in the number of federal regulations now required in the search for and development of mineral and energy resources. Compliance with federal "red tape" is seriously diverting the activities of our staff; more and more time is being devoted to reviews and commentary in environmental impact statements, land-withdrawal proposals of federal agencies, RARE II proposals by the U.S. Forest Service and the U.S. Bureau of Land Management, and coal surface-mining reclamation plans.

LABORATORIES

Chemistry

The chemistry laboratory at the New Mexico Bureau of Mines and Mineral Resources is primarily a service facility for Bureau personnel. The laboratory is equipped to do geochemical analyses, bulk-rock analyses, metallurgical analyses, water analyses, and fire assays. Equipment includes two atomic absorption spectrophotometers (one with a graphite furnace attachment), a direct-reading emission spectroscope, and a fire-assay furnace. This year the laboratory employed eight New Mexico Tech students on a part-time basis as technicians. Students usually start working in their freshman year, washing dishes and doing clean-up, and continue in the lab throughout their senior year, by which time they have progressed to working independently on a variety of projects.

As a public service the Bureau performs qualitative identifications of economic minerals or elements in submitted samples. If the sample seems to have economic worth, a quantitative assay may be done. When the price of gold was \$32 per oz the economic worth could be easily determined by looking at a sample under the microscope. When the price of gold hovers between \$600–\$700 per oz, an ore that has as little as 0.02 oz per ton gold and that is available in large tonnage can be mined profitably. Gold content in an ore which contains 0.02 oz per ton cannot be determined under a microscope; a chemical assay, usually a fire assay, must be done. Several years ago fire assays for gold and silver were done once a month. Now, because of the tremendous surge in gold and silver prospecting, fire assays must be done three times a week.

Interest in platinum has also increased. Platinum has never been mined nor has its occurrence in economic amounts ever been confirmed in New Mexico; yet, because of its high economic value, several samples are received monthly with requests for platinum analysis. Although individuals claim other laboratories have reported platinum in their samples, some as high as 8 oz per ton, we have not been able to confirm the presence of platinum.

Also as a public service, the Bureau analyzes well, surface, and drinking-water samples for major and minor elements. Samples are limited to two per individual. As much information as possible about the sample should be given: well depth, water level, exact location, and any other details. This information, together with the analyses data, is kept in a public information file that now contains data on over 500 samples.

This past fiscal year 3,685 analyses were completed on 1,234 samples.

Several research projects are underway. One involves the effects of uranium mining and milling on surface water. Because of the demand for fuel for nuclear power plants, uranium mining and related activities in the Grants mineral belt is expected to increase. These activities have the potential to introduce toxic materials into the Rio Grande via the Rio San Jose and Rio Puerco, which both drain the Grants mineral belt. Very little water-quality data on surface water exists for the San Jose–Puerco system, particularly on substances that might be carried by the suspended sediments. Substances associated with suspended sediments may be significant for the Rio Puerco, which has been estimated to contribute less than 16 percent of the water to the Rio Grande while adding more than half of the sediment load.

To determine the physical and chemical characteristics of the water and sediment in the San Jose–Puerco system, six sample sites were chosen along the system. Sampling trips have been made, and now general water chemistries are being determined for each sample. The water and the suspended sediment are being analyzed for mercury, molybdenum, selenium, uranium, vanadium, and zinc. When possible, chromium, lead, and copper are also determined.

Data indicate that uranium, zinc, and vanadium are being carried down with the sediment and that the amounts are increasing. The source and mechanism of transport cannot yet be determined.

Early work was supported in part by a grant from the New Mexico Interstate Stream Commission. Further work is continuing under a grant from the federal Office of Water Research and Technology as well as under Bureau support.

Another area of research involves the study of acid rain in New Mexico. Rain and snow are normally slightly acidic, but rain falling on much of the northeast United States and Scandinavia is more acidic than expected. The explanations are theoretical and sketchy. One theory is that coal burning produces sulfur and nitrogen oxides that dissolve in the rain and lower the acidity. New Mexico's Four Corners area burned over 7 million tons of coal in 1978 and, as a result of the current energy picture, will use more coal in years to come. Until this study, no one has investigated rain in New Mexico to see if acid rain was a problem here or if coal combustion via rain, snow, and aerosols is having an effect on New Mexico surface waters. Work on this project is just beginning. Precipitation samples are being collected and analyzed for pH, metals, and general chemistry. Early work has shown occasional acid rain (pH less than 5) and the presence of significant amounts of some metals.

—Lynn A. Brandvold, Chemist

New Mexico Library of Subsurface Data

The library is an important source of information regarding exploration for petroleum, coal, uranium, and carbon dioxide. It is used by industry and graduate students as well as by Bureau geologists. This year the staff aided 749 visitors and received 603 telephone inquiries.

During the year, 506 boxes of well cuttings (representing 171 wells) were processed; the total number of represented wells is 10,671. Over

1,959 mechanical logs for 660 wells and records for 2,182 new wells were added. Donations of samples, well records, and mechanical logs by individuals, societies, and corporations continue to add to the library's growth.

Metallurgy

The Bureau metallurgy group provides technical assistance to persons and organizations engaged in or planning mineral processing within New Mexico. The aim is to develop processes that will work on ores from New Mexico. Research to develop improved methods of extraction (for coal, silver, gold, barite, potash, and uranium) is conducted under federal, state, and private grants.

The staff assayed 350 ore samples and performed flotation and leach tests as well as flow-sheet development for two new mines in New Mexico. Extensive work such as this flow-sheet development often leads to private grants for further research.

MINERAL MUSEUM

The Bureau Mineral Museum has over 9,000 catalogued display and study specimens. The display collection, with over 2,000 minerals on display, may be viewed from 8:00 a.m. to 7:00 p.m. Monday through Friday. The reference collection, more than 6,000 minerals arranged by mineral groups, is available to the public for study during regular office hours.

During the last year, 14 groups arranged for special tours of the museum. Both students and geologists took advantage of the study collection. Through purchases, donations, and collecting, the museum obtained 106 new specimens valued at approximately $3,500.00. The museum staff also prepared five special exhibits that were shown at mineral and gem club shows around the state.

A "Minerals for Sale" case was initiated to raise money to buy new museum specimens. A variety of minerals are sold in the museum; the number and variety grows as space permits.

SYMPOSIA AND CONFERENCES

A symposium on the reclamation of solid mine waste was held in Santa Fe, July 16–18, 1980. Sponsored jointly by the New Mexico Bureau of Mines and Mineral Resources and Molycorp, Inc., the symposium was attended by about 50 government, academic, and industrial reclamationists from Canada and the United States. The keynote address was delivered by Governor Bruce King, who highlighted New Mexico's efforts to insure prudent development of the mining industry. He commended several mining operators in New Mexico for their achievements in reclaiming mined lands. A field trip to the Molycorp molybdenum mine at Questa was led by Cindy Stark, Environmental Coordinator for Molycorp, Inc. The 10 papers presented at the symposium were edited by symposium organizer Corale L. Brierley; these papers will be published by the New Mexico Bureau of Mines and Mineral Resources as an informal report.

TABLE OF ORGANIZATION

June 30, 1980

Administration & information
Kottlowski, Director, Sr. Geologist
Austin, Dep. Director, Geologist
Peralta, Executive Secretary
Chavez, J., Admin. Secretary I
Montoya, Clerk Typist
Smith, Lab Technician II
Crespin, Mechanic

Business office & publication sales
Devlin, Director, Bus.-Pub. Office
Meeks, Department Secretary
Baca, Staff Secretary
Oliver, Clerk Typist

Drafting & illustrating
Arnold, Chief Sci. Illustrator
Wooldridge, Sci. Illustrator
House, Sci. Illustrator
Vetterman, Draftsperson

Editing & publishing
Kelley, Editor & Geologist
Pendleton, Associate Editor
Adkins, Assistant Editor
Weber, M., Assistant Editor
Eden, Editorial Clerk

Environmental geology
Hawley, Environmental Geologist
Love, Geomorphologist

Geophysics
Reiter, Senior Geophysicist
Broadwell, Lab Technician I

Hydrogeology & geothermal
Stone, Hydrogeologist
Reiter, Senior Geophysicist (P)
Mizell, Geologist

Industrial minerals & coal
Weber, Senior Geologist
Vacancy, Industrial Minerals Geologist
Vacancy, Coal Geologist
Anderson, Geologist
Campbell, Field Coal Geologist
Osburn, J., Field Coal Geologist
Roybal, Coal Data Geologist
Willis, Driller
Quick, Driller/Driller's Helper
Mauldin, Jr., Driller's Helper

Metallic ores
Chapin, Senior Geologist
Renault, Geologist
Robertson, Mining Geologist
Weber, Senior Geologist (P)
Chamberlin, Uranium Geologist
Osburn, G., Volcanologist

Metallurgy & chemistry
Jennings, Metallurgist
Brandvold, Chemist
Brierley, Chem. Microbiologist
Eveleth, Mining Engineer
Popp, Lab Biotechnologist
Shacklett, Lab Biotechnologist
Archuleta, Lab Technician I

Mineralogy & x-ray
North, Mineralogist
Renault, Geologist (P)

Oil & gas
Bieberman, Senior Petroleum Geologist
Thompson, Petroleum Geologist
Vacancy, Petroleum Geologist
Chavez, R., Assist. Head Petrol. Section
Padilla, Staff Secretary

Paleontology
Hook, Paleontologist
Wolberg, Paleontologist
Flower, Sr. Emeritus Paleontologist

Abandoned mines project
Frost, S., Coal Geologist
Frost, K., Geologist
Baker, K., Field Researcher
Krukowski, Record & Document Manager
Vigil, Dept. Secretary

(P) Secondary assignment

Geology and resource projects

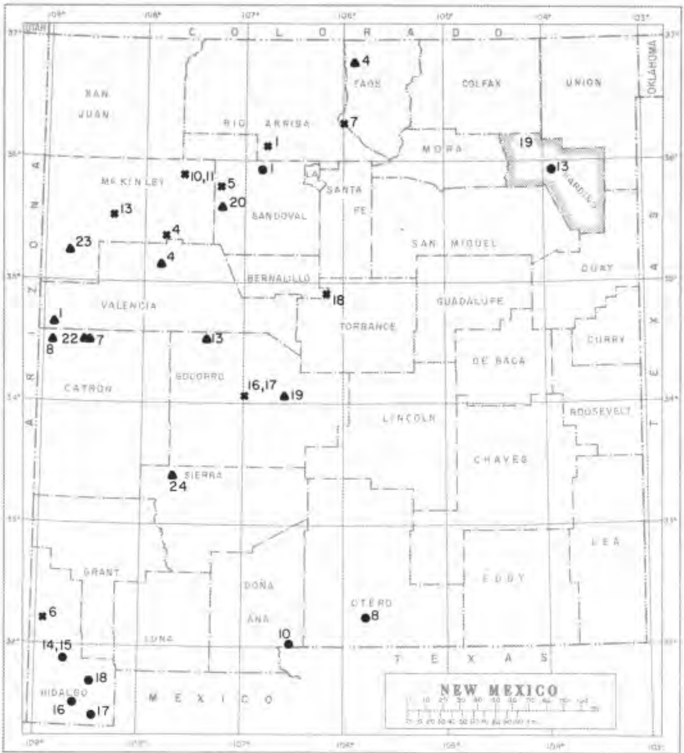
The object of the Bureau's program of investigations is to provide statewide evaluations of mineral resources, to study key areas in detail, and to recommend guidelines for exploration, development, metallurgical extraction, and conservation of New Mexico resources. Completed and continuing projects, wholly or partly funded by the Bureau, are listed in this section. An index map of field projects is shown on pages 10 and 11. A list of part-time research associates on contract to the Bureau appears on page 18. Bureau staff employed during the fiscal year is listed on pages 31–35.

Oil and gas

1. Adams (Anderson)—Petroliferous Pennsylvanian rocks in Nacimiento Mountains
2. Austin, Myers, Bieberman, Reiter, Siemers, and S. Frost—Energy-resources map of New Mexico (in cooperation with U.S. Geological Survey)
3. Bieberman—Oil and gas fields, exploration tests, and major-pipelines map of New Mexico
4. Bieberman—Catalog of samples available in New Mexico Library of Subsurface Data (continuing update)
5. Bieberman—Scout-information file, mechanical-log file, lithologic-log file, driller's-log file, and county petroleum-exploration maps (continuing update)
6. Bieberman, Chavez, J. Osburn, and Bolt—Identification of oil and gas fields in New Mexico (in cooperation with U.S. Department of Energy and University of Oklahoma)
7. Christiansen—History of oil and gas exploration and production in New Mexico
8. King—Petroleum potential of Otero Mesa reigon, south-central New Mexico
9. Osburn, J.—Precambrian structural and lithologic map of New Mexico
10. Potter and S. Thompson—Paleocurrents in the Bliss Formation of southwestern New Mexico and western Texas (article in this report)
11. Renault—Application of carbonate thermoluminescence to petroleum exploration (report available)
12. Renault—Application of crystallite size variation in cherts to petroleum exploration (report available)
13. Scott—Carbon-dioxide fields in northeast New Mexico
14. Thompson, S.—Petroleum geology of southwestern New Mexico
15. Thompson, S.—Analyses of petroleum source and reservoir rocks in southwestern New Mexico (in cooperation with New Mexico Energy Institute)
16. Thompson, S.—Subsurface geology of the Cockrell No. 1 Playas well, Hidalgo County
17. Thompson, S.—Subsurface geology of the Humble No. 1 State BA well, Hidalgo County
18. Thompson, S., and Jacka—Pennsylvanian stratigraphy, petrography, and petroleum geology of the Big Hatchet Peak section, Hidalgo County (Circ. 176)

Industrial minerals and coal

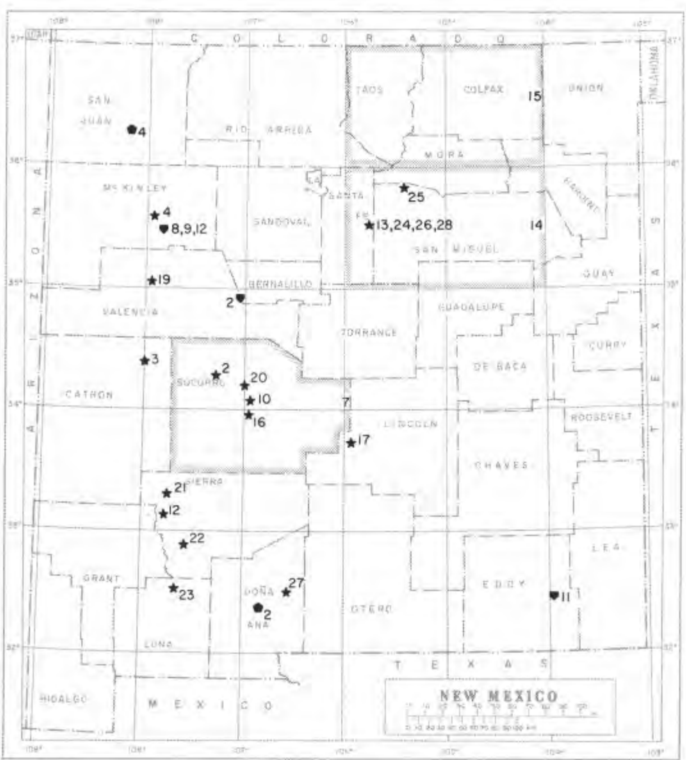
1. Anderson, O.—Geology and coal resources of Cantaralo Spring quadrangle
2. Austin—Shale and clay resources of New Mexico
3. Austin, W. T. Siemers, and Weber—1981 Forum on the geology of industrial minerals
4. Austin and Weber—Perlite deposits of New Mexico
5. Baker, Don, S. Frost, Nickelson, K. Frost, and J. Osburn—Inventory of abandoned coal mines in New Mexico (in cooperation with New Mexico Bureau of Surface Mining and U.S. Office of Surface Mining)
6. Baker, Don, Wolberg, K. Baker, and Urbon—Annotated bibliography of abandoned coal mines in New Mexico
7. Campbell—Coal resources of Cerro Prieto and the Dyke quadrangles
8. Frost, S.—Coal resources of Twentytwo Spring quadrangle
9. Frost, S.—Coal bibliography (continuing update)



Industrial minerals and coal

Oil and gas

Water resources and geothermal

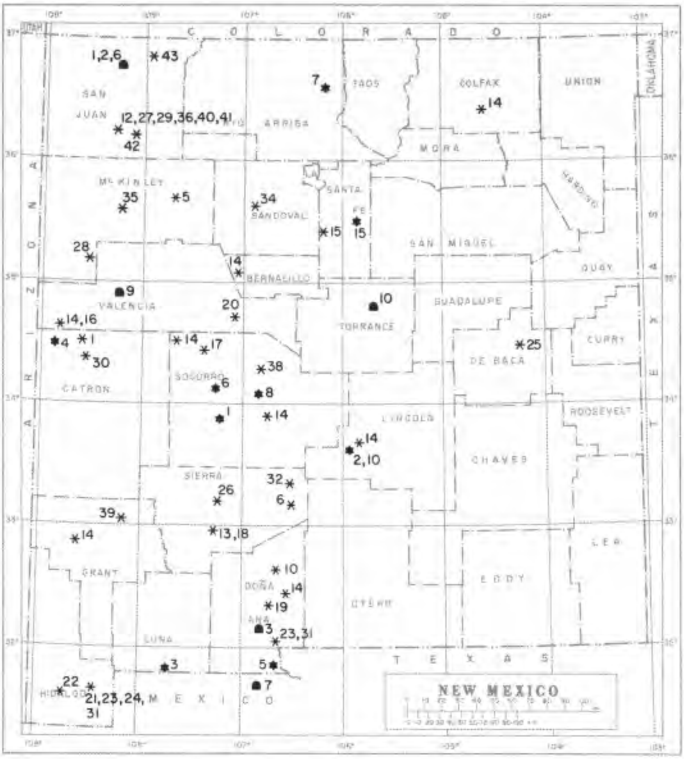


Environmental geology

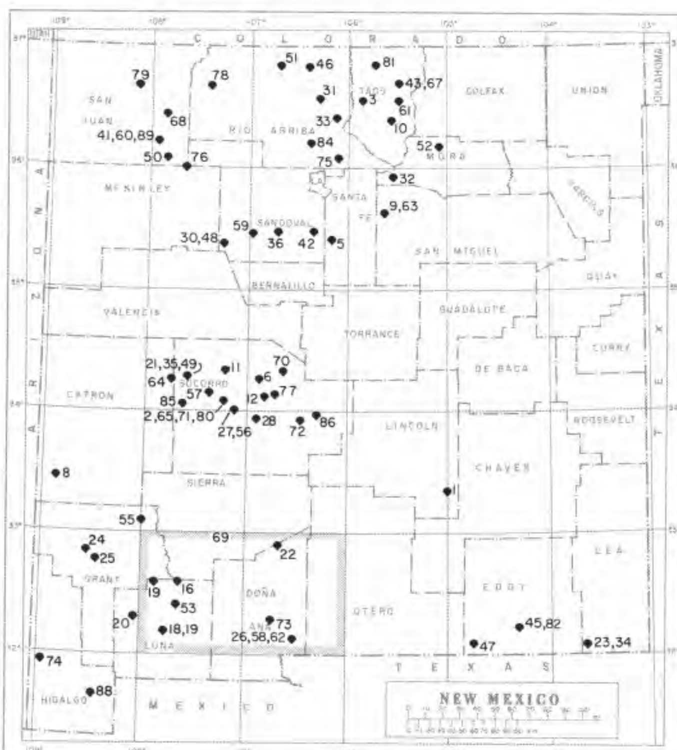
Metallic ores and mining districts

Metallurgy and chemistry

INDEX MAPS OF BUREAU FIELD PROJECTS.



- Mineralogy, Petrology, and Geochemistry
- Geophysics
- Paleontology



- Geology, geologic mapping, stratigraphy, and special projects

INDEX MAPS OF BUREAU FIELD PROJECTS.

10. Frost, S., Roybal, and Campbell—Chemical data on New Mexico coals
11. Kottlowski, Tabet, and S. Frost—New Mexico coal seams (1980 Keystone Coal Industry Manual)
12. Nickelson and S. Frost—History of coal mining in New Mexico
13. Osburn, J.—Geology and coal resources of Pueblo Viejo Mesa quadrangle
14. Roybal and Spence—Computerization of point-source coal data for New Mexico (in cooperation with U.S. Geological Survey)
15. Siemers, W. T.—Evaluation of the economic potential of New Mexico limestones
16. Siemers, W. T., Austin, and Kottlowski—Industrial minerals of New Mexico
17. Smith, T.—Barite of New Mexico, revision of Circ. 76
18. Smith, E. W., and Austin—Sources of adobe bricks in New Mexico (paper in New Mexico Geology, v. 3, no. 2)
19. Tabet—Jornada del Muerto coal field in Socorro County (Circ. 168)
20. Tabet and S. Frost—Reserves of Menefee coals in Torreon Wash area (in cooperation with U.S. Geological Survey; Open-file Rept. 102; GM 49)
21. Tabet and S. Frost—Coal-resources map of New Mexico (Resource Map 10)
22. Tabet, S. Frost, Hook, and Campbell—Coal resources of the Salt Lake and Datil Mountains coal fields (in cooperation with U.S. Geological Survey)
23. Tabet, Massingill, and Campbell—Coal geology of the Pinehaven quadrangle (in cooperation with U.S. Geological Survey)
24. Weber—Zeolites of New Mexico

Water and geothermal resources

1. Anderholm (Stone)—Hydrogeology and water resources of Cuba 15-minute quadrangle (thesis available)
2. Brandvold—Water Quality Control Commission projects (continuing update)
3. Brandvold—Water analyses file (continuing update)
4. Brod and Stone—Hydrogeology and water resources of the Ambrosia Lake–San Mateo area (in press, Hydrogeologic Sheet 2)
5. Craigg (Stone)—Hydrogeology and water resources of the Torreon Wash–Chico Arroyo area (thesis available)
6. Fleischhauer and Stone—Quaternary geology of Lake Animas, Hidalgo County (in review, Circ. 174)
7. May—Neogene geology of the Ojo Caliente–Rio Chama area, Rio Arriba and Taos Counties (thesis available)
8. Mizell—Documentation for computerization of geothermal activity in New Mexico (Open-file Rept. 121)
9. Mizell and Stone—Geothermal leasing and drilling activity computer-data file/display (continuing update)
10. Reiter and Stone—Relations between subsurface temperatures and ground-water movement in southern San Juan Basin
11. Stone—Hydrogeology and water resources of northwestern New Mexico (in cooperation with U.S. Geological Survey and New Mexico State Engineer; Open-file Repts. 90, 91, 105, and 114)
12. Stone—Computerization of New Mexico Bureau of Mines and Mineral Resources well-record data (continuing update)
13. Stone—Hydrogeology of Gallup Sandstone, San Juan Basin
14. Stone, Mizell, and Hawley—Water resources of southwestern alluvial basins (in cooperation with U.S. Geological Survey; Open-file Rept. 109)
15. Stone—Water-resource information available from New Mexico Bureau of Mines and Mineral Resources (free pamphlet)
16. Stone—Hydrogeology of Socorro Peak KGRA
17. Stone—Hydrogeology of Rio Grande valley in Socorro area
18. Titus—Ground-water resources of Sandia and Manzano Mountains (in cooperation with U.S. Geological Survey; HR-5)
19. Trauger—Ground-water resources and geologic map of Harding County (in cooperation with U.S. Geological Survey)

Metallic ores and mining districts

1. Anderson, D. Baker, and Skotte—Survey of abandoned uranium mines and prospects in New Mexico (in cooperation with New Mexico Bureau of Surface Mining and U.S. Office of Surface Mining)
2. Cather (Chapin)—Sedimentary petrology of the Baca Formation in Alamo Reservation area (in cooperation with University of Texas, Austin; thesis available)
3. Chamberlin—Reconnaissance mapping of Red Flats region, Catron County, and evaluation of uranium potential in fluvial sandstones
4. Chamberlin—Monitoring of uranium exploration in New Mexico (continuing update)
5. Chapin—Subsurface stratigraphy and ore controls of the Hansen orebody, Tallahassee Creek uranium district, Colorado (in cooperation with Rampart Exploration Co. and Cyprus Mine Corp.)
6. Chapin—Geology and mineral resources of the southeast Colorado Plateau margin
7. Chapin and G. Osburn—Geology and mineral resources of Socorro-Magdalena area
8. Chapin and G. Osburn—Data bank of radioactive dates, isotopic analyses, and chemical analyses of igneous rocks in New Mexico (continuing update)
9. Eveleth—New Mexico's mining railroads (continuing update)
10. Eveleth—Billing Smelter: its role in the territorial mining industry of New Mexico
11. Eveleth, Mardirosian, Weber, and Siemers—Mineral industry location system (MILS) for New Mexico (in cooperation with U.S. Bureau of Mines; completed)
12. Eveleth and North—Reconnaissance report, Brush Heap mine, Kingston mining district, Sierra County
13. Fulp (Woodward, Robertson)—Precambrian geology and mineralization in Dalton Canyon area
14. Griswold, Austin, Chamberlin, and Reid—Uranium resources of Santa Fe 2° quadrangle (in cooperation with U.S. Dept. of Energy and Bendix Field Engineering)
15. Griswold, Austin, Chamberlin, and Reid—Uranium resources of Raton 2° quadrangle (in cooperation with U.S. Dept. of Energy and Bendix Field Engineering)
16. Jahns—Manganese deposits of Luis Lopez district, Socorro County
17. Jahns—Gold deposits of White Oaks mining district, Lincoln County
18. McLemore—Radioactive occurrences in New Mexico
19. McLemore—Non-sandstone uranium deposits in New Mexico
20. McLemore—Carbonatites in Lemitar Mountains (paper in New Mexico Geology, v. 2, no. 4)
21. McMillan and Jahns—Structure, petrology, and ore deposits of Chise quadrangle in southern Sierra Cuchillo, Sierra County
22. North and Eveleth—Gold mining and occurrences in New Mexico
23. Proctor—Trace base metals in Cooke's Peak stock
24. Robertson—Wall-rock alteration associated with massive sulfide deposits in Pecos greenstone belt
25. Robertson—Evaluation of geology and mineral potential of Pecos Wilderness in north-central New Mexico (in cooperation with U.S. Geological Survey; Open-file Rept. available)
26. Robertson—Precambrian rocks and mineral deposits of Doctor Creek area, Santa Fe County
27. Seager—Geology and mineral deposits of Organ Mountains (Mem. 36, in press)
28. Wyman (Robertson)—Ultramafic rocks of Pecos greenstone belt in Cow Creek area (thesis available)

Metallurgy and chemistry

1. Brandvold—Directory of commercial analytical laboratories in the southwest (updated; new pamphlet June 1980)
2. Brandvold—Heavy-metal and nutrient load of the Rio San Jose–Rio Puerco system (in cooperation with Interstate Stream Commission; report available)
3. Brandvold—A freezing technique for purifying uranium mining-and-milling waste waters
4. Brandvold—Transport mechanisms in sediment-rich streams (in cooperation with Office of Water Research and Technology)
5. Brandvold—Speciation of uranium in organic-rich high-uranium stream sediment from NURE Project

6. Brandvold—Water analyses (continuing update)
7. Brandvold—Rock and ore analyses (continuing)
8. Brierley and Brierley—Biological methods to remove selected pollutants from uranium-mine-waste water (in cooperation with New Mexico Water Resources Research Institute)
9. Brierley and Brierley—Contamination of ground and surface waters by uranium mining and milling (in cooperation with U.S. Bureau of Mines and University of Colorado)
10. Brierley and Brierley—Trace elements in oil shale (in cooperation with U.S. Department of Energy and University of Colorado)
11. Brierley, C., and Lanza—Microbiological flocculation of phosphate and potash slimes (in cooperation with U.S. Bureau of Mines and University of Texas at Dallas)
12. Brierley, Torma, and Brierley—Application of bacterial-leaching technology to deep solution mining of uranium (in cooperation with New Mexico Energy and Minerals Department)
13. Brierley, Torma, and Brierley—Application of bacterial leaching technology to deep-solution-mining conditions (in cooperation with National Science Foundation)
14. Jennings—Pilot study on flotation of discarded slimes fraction before a cyanide dump leach for silver and gold (informal report available)
15. Jennings—Pilot study on use of a new design of Diester Flotaire flotation machine
16. Jennings—Pilot study of gold-ore flotation (informal report available)
17. Jennings—Pilot test of a new design dry riffle (informal report available)
18. Jennings—Study of beneficiation of manganiferous silver ore
19. Jennings—Flotation and cleaning tests of New Mexico coals
20. Jennings—Study of beneficiation of barite ores

Environmental geology

1. Hawley, Love, and Sandor—Quaternary geology of New Mexico (in cooperation with U.S. Geological Survey)
2. Hawley, Gile, and Grossman—Soils and geomorphology in a Basin and Range area of southern New Mexico (Mem. 39, in edit)
3. Hawley, Weber, and Kottlowski—Geologic hazards designations: landslides, earthquakes, volcanic eruptions, flood-prone areas, rock falls, and subsidence (part of National Hazards Information System, in cooperation with Al Lobato, State Planning Office, and Linda Kehoe, Governor's office)
4. Hawley, Love, Weber, Tabet, Stone, Eveleth, Kottlowski, and others—Review and critique of Environmental Impact Statements and mining and reclamation plans (for example, Con Paso mine of Consolidation Coal Co.; EIS of Waste Isolation Pilot Plant)

Mineralogy, petrology, and geochemistry

1. D'Andrea (Chapin)—Geochemistry of potassium-metasomatized volcanic rocks in Socorro area (in cooperation with Florida State University; thesis available)
2. Faris (Renault)—Trace-element geochemistry of Carrizozo basalt (thesis available)
3. Frantes (Hoffer)—Palomas basalt field
4. Frost, S.—Correlation of some Cretaceous bentonites in west-central New Mexico
5. Henell (Hoffer)—Petrography and geochemistry of Cristo Rey pluton
6. Lindley (Chapin)—Chemical changes associated with the propylitic alteration of two ash-flow tuffs, Datil-Mogollon volcanic field (in cooperation with University of North Carolina; thesis available)
7. North—Mineralogy of the Petaca district
8. North—Guide to New Mexico Bureau of Mines and Mineral Resources Mineral Museum (pamphlet available)
9. North and Renault—Preparation of x-ray diffraction standards (continuing)
10. Renault—Geochemistry of New Mexico basalts (continuing)
11. Renault—Resolution of x-ray diffraction lines—a numerical model (report available)
12. Renault—Rapid determination of ash in coal by x-ray fluorescence spectroscopy
13. Renault—Uranium migration and thermoluminescence of quartz (report available)
14. Renault—X-ray diffraction profile analysis of silica (continuing)

15. Robertson—Petrography and geochemistry of Precambrian volcanic rocks from Pecos greenstone belt
16. Robertson and Rose—Major- and minor-element geochemistry of Precambrian volcanic rocks of Portage Lake Volcanics, Michigan

Geophysics

1. Clarkson (Reiter)—Characteristics of thermal anomaly under the San Juan volcanic field
2. Eggleston, R. (Reiter)—Deep-temperature data study in the Colorado Plateau
3. Keller, G. R.—Aeromagnetic mapping of Tortugas Mountain area, Doña Ana County
4. Reiter—Episodic uplift and the thermal state of the lithosphere
5. Reiter—Preliminary consideration of geothermal structure in major volcanic fields
6. Reiter and Mansure—Geothermal characteristics of the San Juan Basin
7. Reiter and Tovar R.—Heat-flow analysis in northern Chihuahua, Mexico
8. Sanford—Continuing survey of earthquakes in New Mexico
9. U.S. Bureau of Land Management—Aeromagnetic mapping of malpais region south of Zuni Mountains (matching funding with New Mexico Bureau of Mines and Mineral Resources)
10. U.S. Geological Survey—Aeromagnetic mapping of central New Mexico, Pedernal area (matching funding with New Mexico Bureau of Mines and Mineral Resources)

Paleontology

1. Campbell—Analyses of pollen in coals of Cerro Prieto quadrangle
2. Cobban and Hook—Upper Cretaceous (Turonian) ammonite family Coilopoceratidae Hyatt in the Western Interior of the United States (U.S. Geological Survey Prof. Paper 1192)
3. Cobban and Hook—Paleontology of the Late Cretaceous "Cephalopod Zone" of Herrick (1900)
4. Cobban and Hook—*Collignoniceras woollgari woollgari* (Mantell) subzone ammonite fauna from Upper Cretaceous of Western Interior (Mem. 37)
5. Cross, Taggart, and Jameossanaie—Paleobotanical study of Menefee Formation in South Hospah area (in cooperation with Chaco Energy Co.)
6. DeKeyser—Conodonts in Lake Valley Formation of San Andres Mountains
7. Flower—Ordovician correlations
8. Flower—Faunas of the New Mexico Devonian
9. Flower—Studies of Endoceratida and Tarphyceratida
10. Flower and LeMone—Faunal and petrographic studies of Bliss Sandstone, El Paso Group and Montoya Group
11. Gutjahr and Hook—A statistical method for analysis of planispiral coiling in shelled invertebrates (Circ. 173)
12. Hartman—Cretaceous-Tertiary fresh-water mollusks in San Juan Basin
13. Hook and Cobban—Stratigraphy and paleontology of Cretaceous rocks of Cooke's Range
14. Hook and Cobban—Stratigraphy and paleontology of Upper Cretaceous of a) Silver City area, b) Fence Lake area, c) southern San Andres Mountains, d) Carthage, e) Carrizozo-Capitan area, f) Rio Puerco area, g) Riley-Puertecito area, h) Springer area, and i) Trans-Pecos Texas
15. Hook and Cobban—Reinterpretation of type section of Juana Lopez Member of the Mancos Shale (New Mexico Geology, v. 2, no. 2)
16. Hook, Cobban, and Landis—Extension of intertongued Dakota Sandstone-Mancos Shale terminology into the southern Zuni Basin (New Mexico Geology, v. 2, no. 3)
17. Hook, Molenaar, and Cobban—Stratigraphy, paleontology, sedimentology, and regional relationships of Upper Cretaceous Tres Hermanos Sandstone
18. Johnson (Hattin)—Sedimentology and trace fossils of Cooke's Peak Greenhorn beds
19. King—Fusulinids of the Hueco Formation in the Las Cruces area
20. Kukalova-Peck—Late Paleozoic fossil insects of Carrizo Arroyo region
21. LeMone—Cretaceous faunas in Big Hatchet Mountains
22. LeMone and Simpson—Upper Paleozoic faunas of Winkler anticline, Hidalgo County
23. LeMone and Simpson—Wolfcampian megafauna and biostratigraphy of Franklin and Big Hatchet Mountains
24. LeMone, Simpson, and Neilsen—Permian megafaunas of Big Hatchet Mountains

25. Leonard and Frye—Stratigraphy and paleontology of Ogallala Formation in New Mexico (includes Circ. 160 and Circ. 161)
26. Lucas and Mateer—Triceratops beds in New Mexico
27. Mateer and Wolberg—Reptiles in the Fruitland and Kirtland Formations
28. Molenaar, Hook, and Cobban—Stratigraphy, paleontology, and regional correlations of the Upper Cenomanian through Lower Coniacian (Upper Cretaceous) strata of western New Mexico
29. Robison—Paleobotany of the Fruitland and Kirtland Formations
30. Schiebout and Schrodt—Biostratigraphy of Baca Formation near Quemado
31. Simpson—Permian brachiopods of southwest New Mexico and west Texas
32. Sorauf—Devonian corals from south-central New Mexico
33. Taylor—Late Cenozoic fresh-water mollusks of New Mexico: an annotated bibliography (Open-file Rept. 124)
34. Tedford, Galusha, and Hawley—Biostratigraphy of north-central New Mexico
35. Tschudy—Normapolles pollen from *Aquilapollenites* province, western United States (Circ. 170)
36. Wolberg—*Goniopholis kirtlandicus* from the Kirtland Formation (New Mexico Geology, v. 2, no. 3)
37. Wolberg—Revision of the eucosmodontid multituberculates
38. Wolberg and B. Baker—Late Cretaceous vertebrates from lower Tres Hermanos Sandstone near La Joya
39. Wolberg and Hawley—*Equus conversidens* from Lake Roberts area (in this report)
40. Wolberg and Holtzman—*Haplaletes diminutirus*, a hyopsodontid condylarth from the Paleocene of North America
41. Wolberg and Hunt—Paleontology and stratigraphy of Late Cretaceous rocks in the Hunter Wash area
42. Wolberg and Rigby—Paleontology and stratigraphy of a Late Cretaceous fossil forest in the San Juan Basin
43. Wolberg and Schiebout—A Torrejonian faunule from Nacimiento Formation in Bohannan Canyon

Geology, geologic mapping, stratigraphy, and special projects

1. Allen, J., Kottlowski, Spence, and Pendleton—Revision of Scenic Trip No. 3, Roswell-Capitan-Ruidoso (in press)
2. Allen, P. (Chapin)—Geology of the Hop Canyon-Mill Canyon area, Magdalena Mountains (thesis available)
3. Anderson (Wells and Hawley)—Cenozoic terrace and pediment deposits in Taos Plateau area
4. Armstrong, Kottlowski, Stewart, Mamet, Baltz, W. T. Siemers, and Thompson—Mississippian and Pennsylvanian Systems of New Mexico (summary chapter for U.S. Geological Survey Prof. Paper; IX-ICC International Carboniferous Congress)
5. Atkinson, Odlund, and Lee—Mineralogy of cores from San Pedro mining district
6. Baker, B. (Hook)—Upper Cretaceous rocks in Sevillata Grant, Socorro County
7. Balk—Stratigraphic nomenclature of New Mexico
8. Bikerman—Age-dating volcanic rocks in Mogollon area
9. Bowring and Robertson—Ages and isotopic geochemistry of Precambrian rocks in northern and central New Mexico
10. Casey and Scott—Basin evolution of Late Paleozoic Taos trough, northern New Mexico
11. Cather (Chapin)—Eocene Baca Formation, Alamo Navajo Reservation and vicinity, Socorro County (thesis available)
12. Chamberlin (Chapin)—Cenozoic stratigraphy and structure of Socorro Peak volcanic center (thesis available)
13. Chapin—Origin and evolution of the Rio Grande rift
14. Chapin—Cenozoic tectonic and magmatic evolution of New Mexico
15. Chapin—mechanics of transport and deposition of ash-flow tuffs and their hydrothermal alteration
16. Clemons—Geology of Good Sight Mountains and Uvas Valley, southwest New Mexico (Circ. 169)
17. Clemons—Geology and mineral resources of Massacre Peak quadrangle (Geol. Map 51)

18. Clemons—Geology of the Florida Mountains region (Geol. Map 52, in edit)
19. Clemons—Geology of Capitol Dome quadrangle
20. Clemons, Thompson, and Stone—Revision of Scenic Trip No. 10, southwestern New Mexico (book available)
21. Coffin (Chapin)—Geology of the east half of the Dog Springs quadrangle, Socorro County (thesis available)
22. Condie—Precambrian rocks of south-central New Mexico (Mem. 35)
23. Crawford (Pray)—Carbonate facies of Goat Seep reef in Guadalupe Mountains
24. Cunningham—Circle Mesa quadrangle
25. Cunningham—Revision of geologic map of Silver City 7½ ′ quadrangle
26. Danko—Canutillo Formation in Franklin Mountains and Bishop Cap
27. Donze (Chapin)—Geology of the Squaw Peak area, western Magdalena Mountains (thesis available)
28. Eggleston, T. (Chapin)—Geology of the central Chupadera Mountains (thesis available)
29. Frost, Kelley, and Pendleton—Topographic base map of New Mexico (RM 11, in edit)
30. Gawne—Zia sand in Sky Village area
31. Gibson (Robertson)—Precambrian geology of Burned Mountain-Hopewell Lake area, Rio Arriba County (thesis available)
32. Grambling—Precambrian geology of Gascon area
33. Griffiths (Ingersoll)—Tertiary rocks of Ojo Caliente-La Madera area (field report available)
34. Harris (Pray)—Geologic study of Cutoff Formation of southern Guadalupe Mountains
35. Harrison (Chapin)—Geology of the west half of the Dog Springs quadrangle, Catron County (thesis available)
36. Hawley, Tedford, Galusha, and Gawne—Upper Cenozoic biostratigraphy of Albuquerque Basin (in cooperation with American Museum of Natural History)
37. Heljeson and Holts—Bibliography of New Mexico geology and mineral technology, 1976 through 1980 (Bull. 110, in edit)
38. Heljeson and Holts—Supplement to bibliography of New Mexico geology and mineral technology through 1975 (Bull. 108)
39. Holts—History of New Mexico Bureau of Mines and Mineral Resources as recorded in legislation, annual reports, and notes (Open-file Rept. 100)
40. Holts—Fayette A. Jones, mining engineer (New Mexico Geology, v. 1, no. 4)
41. Hunt—Stratigraphy of Bisti area
42. Kautz (Ingersoll)—Sedimentary and petrological study of Espinaso Formation in southeast Sandoval County
43. Kelley, R. E.—Precambrian geology of Cabresto Creek area, Taos County
44. Kelley, R. W., and Hawley—Satellite photomap of New Mexico (RM 12)
45. Kelley, R. W., Jacka, and Sorensen—Tepee structures in Guadalupian of Carlsbad area compared to buckles in Meramician of Michigan
46. Kent (Robertson)—Precambrian rocks of the Tusas area (thesis available)
47. Kirkby (Pray)—Study of rocks beneath Cutoff Formation in southern Guadalupe Mountains
48. LaFon—Sedimentology and depositional environments of Upper Cretaceous Semilla Sandstone Member of Mancos Shale (thesis available)
49. LaRoche (Chapin)—Geology of the Gallinas Peak area, Socorro County (thesis available)
50. Love and Hawley—Late Cenozoic geologic map of Rio Chaco Basin in northwest New Mexico
51. Muehlberger—Scenic Trip No. 13 to Española-Chama-Cumbres Pass-Monero-Tres Piedras region (in press)
52. Nielsen—Ocate volcanic field, north-central New Mexico
53. North—Geologic map of Goat Ridge quadrangle
54. North—Small size geologic map of New Mexico
55. O'Brient (Jahns)—Robb Canyon volcanic rocks, Grant County
56. Osburn, G.—Geology of Molino Peak quadrangle
57. Osburn, G.—Geology of Lion Mountain and Gallinas Peaks areas
58. Osleger—La Tuna Formation in Franklin Mountains and Bishop Cap
59. Owen and C. Siemers—Dakota units in southeast San Juan Basin between Laguna and La Ventana

60. Rains—Upper Cretaceous and Paleocene silcrete beds in the San Juan Basin
61. Reed and Robertson—Precambrian geology and mineral potential of the northern Sangre de Cristo Mountains, Taos County (in cooperation with U.S. Geological Survey; Open-file Rept. available)
62. Rinowski—Helms Formation in Franklin Mountains and Bishop Cap
63. Robertson—Geochronology of volcanism and plutonism in Pecos greenstone belt
64. Robinson (Chapin)—Geology of the D-Cross quadrangle, Catron and Socorro Counties (thesis available)
65. Roth (Chapin)—Geology of the Sawmill Canyon area, Magdalena Mountains (thesis available)
66. Schilling—Isochron/West, a periodic journal of isotopic geochronology
67. Schilling, Taggart, and Pendleton—Revision of Scenic Trip No. 2, Taos-Red River-Eagle Nest
68. Schultz (Hawley and Wells)—Geomorphology, sedimentology, and Quaternary history of the eolian deposits in west-central San Juan Basin (thesis available)
69. Seager, Clemons, Hawley, R. E. Kelley, and Alexander—Geology of Las Cruces 1:250,000 quadrangle (northwest quarter is Geol. Map 53, in press)
70. Siemers, T.—Pennsylvanian stratigraphy of west-central New Mexico
71. Siemers, T.—Permian rocks in northern Magdalena Mountains
72. Siemers, T., and Hook—Stratigraphy, petrography and paleoenvironments of the Tres Hermanos Sandstone in Carthage area
73. Seager, Kottlowski, Hawley, and King—Geology of Robledo Mountains
74. Spencer (Ross)—Lower Pennsylvanian rocks of southwesternmost New Mexico
75. Steinpress (Ingersoll and Hawley)—Neogene stratigraphy and structure of the Dixon area, Española Basin (thesis available)
76. Stone—Offshore-beach transition deposits in Pictured Cliffs Sandstone
77. Stone—Quaternary geology and geomorphology of Loma de las Canas quadrangle
78. Stone—Geologic mapping of selected Tertiary deposits in Chaco Canyon (1:100,000) sheet (in cooperation with U.S. Geological Survey)
79. Stone, Baltz, and O'Sullivan—Tertiary-Cretaceous boundary in the Farmington area (in cooperation with U.S. Geological Survey)
80. Sumner (Chapin)—Geology of the Water Canyon-Jordan Canyon area, Magdalena Mountains (thesis available)
81. Thompson, R. A.—Studies of earth-rift-age volcanic rocks, Taos Plateau
82. Thompson, S., and Jacka—Guidebook to depositional and diagenetic features in the Guadalupian of New Mexico and Texas
83. Thompson, S., and Slaczka—A revision of the fluxoturbidite concept based on type examples in the Polish carpathian flysch
84. Vazzana (Ingersoll and Hawley)—Stratigraphy, sedimentary petrology, and basin evolution of the Abiquiu Formation in north-central New Mexico (thesis available)
85. Weber—Geology of Plains of San Agustin
86. Weber—Geology of Mockingbird Gap site
87. Weber—Petrographic and chemical characteristics of seven new meteorites from New Mexico
88. Weise (LeMone)—Carbonate petrology of U-Bar Limestone in Big Hatchet Mountains
89. Wolberg—Geology of Bisti area
90. Wolberg and Kottlowski—Correlation of stratigraphic units in southwest New Mexico and westernmost Texas (COSUNA project)

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Publications

New Mexico Geology, the quarterly journal of science and service published especially for geoscientists in the state and region, is now midway through its second year of publication. Circulation at the close of the fiscal year is 741 paid subscriptions, 190 subscriptions "exchanged" with other agencies or publishers, and 75 free subscriptions to Bureau staff and selected individuals.

Funds allocated to Bureau printing totaled $82,500, which is approximately 5.7 percent of the overall Bureau budget. Most of our printing continued to be handled by the University of New Mexico Printing Plant. About 14 percent of new-page production was printed at the Tech print shop. Reissue of Geologic Map 48 was handled by Williams & Heintz Map Corporation of Washington, D.C., as was compilation and production of the geologic map for Memoir 36 (to be released next fiscal year).

Items released include 19 new publications, 10 reissued publications, 16 open-file reports, and eight publication announcement cards. Included in the new publications were nine large-scale, multicolor map sheets (five were in two book reports, four in three map reports). Also four multicolor map sheets were reworked for reissued publications. At the close of the fiscal year 43 manuscripts were either in review or pending, while 32 were either in edit or in press.

Pages printed in new publications totaled 645 (477 scientific, 32 pricelist, 128 popular, and eight cards). Pages in reissued publications totaled 550 (464 scientific, 32 pricelist, and 54 popular). Page size of most of the scientific reports was $8\frac{1}{2} \times 11$ inches, with text in two columns.

Editing staff at the close of the fiscal year consisted of one editor-geologist, one associate editor, two assistant editors, one editorial clerk (becomes editorial technician next fiscal year), three student proofreaders (part-time), and one student bibliographer (part-time). At midterm, two associates resigned and another took maternity leave. Two assistants (trainees) were hired to fill vacancies. These occurrences reduced productive capacity by about 40 percent. Each new page published this year required about seven hours editor time and one hour student time.

New publications

Memoir 35—GEOLOGY AND GEOCHEMISTRY OF PRECAMBRIAN ROCKS, CENTRAL AND SOUTH-CENTRAL NEW MEXICO, by K. C. Condie and A. J. Budding, 1979, 58 p., 13 tables, 48 figs., 3 geologic maps (scale 1:125,000), 4 appendices (3 on microfiche). $11.00

Summarizes existing field, stratigraphic, petrographic, and geochronologic data from Precambrian terranes; evaluates major- and trace-element data for principal rock types in terms of alteration, models for magma origin, and sediment provenance. Also discusses origin and tectonic setting of Precambrian terrane.

Memoir 37—*COLLIGNONICERAS WOOLLGARI WOOLGARI* (MANTELL) AMMONITE FAUNA FROM UPPER CRETACEOUS OF WESTERN INTERIOR, UNITED STATES, by W. A. Cobban and S. C. Hook, 1979, 53 p., 12 figs., 12 pls. $7.00

Discusses the middle Turonian ammonite range zone of *Collignoniceras woollgari woollgari* (Mantell) in the upper part of the Mancos Shale tongue and the lower part of the Tres Hermanos Sandstone Member of the Mancos Shale in New Mexico and the Western Interior.

Circular 168—GEOLOGY OF JORNADA DEL MUERTO COAL FIELD, SOCORRO COUNTY, NEW MEXICO, by D. E. Tabet, 1979, 19 p., 1 table, 2 figs., geologic map (scale 1:62,500), 2 appendices. $3.50

Describes geology, coal beds, and drill-hole data.

Circular 169—GEOLOGY OF GOOD SIGHT MOUNTAINS AND UVAS VALLEY, SOUTHWEST NEW MEXICO, by R. E. Clemons, 1979, 32 p., 1 table, 23 figs., 2 appendices, geologic map (scale 1:48,000) and cross sections in pocket. $6.00

Describes the 435-sq-mi area of the Good Sight Mountains and the Uvas Valley in Luna, Doña Ana, and Sierra Counties, New Mexico; the geologic map covers the western part of the Good Sight–Cedar Hills volcano-tectonic depression of Oligocene age.

Circular 170—NORMAPOLLES POLLEN FROM *AQUILAPOLLENITES* PROVINCE, WESTERN UNITED STATES, by R. H. Tschudy, 1980, 14 p., 1 table, 3 figs. $2.50

Describes Normapolles pollen usually from northeast United States present in *Aquilapollenites* province of western United States, showing that a few genera crossed the seaway barrier between the two provinces. Presents a record of known occurrences of Normapolles in the western province and shows stratigraphic distribution of these occurrences.

Circular 172—NEW MEXICO'S ENERGY RESOURCES '79—ANNUAL REPORT OF THE BUREAU OF GEOLOGY, compiled by E. C. Arnold and J. M. Hill, 1979, 55 p., 45 tables, 14 figs. $3.00

Annual summary of energy developments in New Mexico; discusses coal, oil, and gas reserves, possible geothermal applications, and production of coal, crude oil, natural gas, and uranium.

Scenic Trip 10—SOUTHWESTERN NEW MEXICO: LAS CRUCES, DEMING, LORDSBURG, SILVER CITY, COLUMBUS, by R. E. Clemons, P. W. Christiansen, and H. L. James, 1980, 120 p., 1 table, 74 figs. $4.00

Includes five road logs that discuss the geology, mining operations, history, and scenic attractions of the area. Completely revised in 1979; incorporates Scenic Trip 5, now out-of-print.

Geologic Map 49—COAL GEOLOGY OF TORREON WASH AREA, SOUTHEAST SAN JUAN BASIN, NEW MEXICO, by D. E. Tabet and S. J. Frost, 1979, 3 sheets, text, scale 1:24,000. $6.00

Maps showing bedrock geology and coal beds of Mesaverde Group rocks in the southeast San Juan Basin. Text describes stratigraphy, structure, and information about coal resources, coal analyses, and coal mines and prospects.

Resource Map 1—HYDROTHERMAL ANOMALIES IN NEW MEXICO, compiled by W. K. Summers, 1979, scale 1:1,000,000. $1.00

Locates sites of known geothermal resource areas and known geothermal resource fields. Includes data on bottom-hole temperatures, temperatures of discharged or sampled water, and depth below surface. Revision of 1972 publication "Geothermal resources of New Mexico," now out-of-print.

Isochron/West–Nos. 25, 26, 27, edited by J. H. Schilling, 30 p., 32 p., and 31 p. Available by subscription (6 issues for $12.00)

A serial journal of isotopic geochronology.

Annual Report—ANNUAL REPORT FOR THE FISCAL YEAR JULY 1, 1978, TO JUNE 30, 1979, by F. E. Kottlowski and staff, 80 p. $1.00

Summarizes Bureau activities and services for the fiscal year. Includes articles on coal data, Upper Cretaceous guide fossils, mineral production, paleontology and coal, energy resources, and scoria deposits.

Pricelist 14—PUBLICATIONS AVAILABLE FROM NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, APRIL 1980. FREE

Comprehensive listing of geologic and mineral reports and maps, with subject and author index and index maps.

Magazine—NEW MEXICO GEOLOGY, VOLUME 1, NUMBER 3, August 1979, 16 p.

Available by subscription (4 issues for $4.00)

Articles: microbiology and mining—practices and problems; Directory of commercial analytical laboratories in New Mexico; Principal mining districts of New Mexico; Turquoise in New Mexico; Ft. Selden State Monument and Leasburg State Park; announcements, new publications, abstracts.

NEW MEXICO GEOLOGY, VOLUME 1, NUMBER 4, November 1979, 16 p.

Articles: Uranium indicator plants of the Colorado Plateau; Fayette A. Jones, mining engineer—a profile in diversity; Feasibility study of gravitational ore separation, Hansonburg mining district, central New Mexico; Summary of mining and mineral-processing operations in New Mexico; Bottomless Lakes State Park; Index of mining and mineral industry periodicals; announcements, new publications, abstracts; index to New Mexico Geology, volume 1.

NEW MEXICO GEOLOGY, VOLUME 2, NUMBER 1, February 1980, 16 p.

Articles: Geology of Cieneguilla Creek drainage basin in southwest Colfax County; Geology and oil characteristics of tar sand near Santa Rosa; Earthquake activity in New Mexico from 1849 through 1961; Potash in New Mexico; Zeller Peak named in Big Hatchet Mountains; City of Rocks State Park; Occurrence of red beryl in the Black Range; announcements, new publications, abstracts.

NEW MEXICO GEOLOGY, VOLUME 2, NUMBER 2, May 1980, 16 p.

Articles: Reinterpretation of type section of Juana Lopez Member of Mancos Shale; Depositional environments and paleocurrents of Chinle Formation (Triassic), eastern San Juan Basin; Proterozoic tectonic setting in New Mexico; Pleistocene horse skull discovered; announcements, new publications, abstracts.

Water-Resource Information Pamphlet, by W. J. Stone, 1980, 7 p., 3 tables, 1 fig. FREE

The purpose of this pamphlet is to identify the water-resource information available so that it may be more readily located and used.

Re-issued publications

Bulletin 11, Part III—THE MINES AND MINERAL RESOURCES OF DOÑA ANA COUNTY, by K. C. Dunham, 1935, 82 p., 5 pls., 11 figs. $6.00

Bulletin 37—GEOLOGY AND MINERAL DEPOSITS OF LAKE VALLEY QUADRANGLE, GRANT, LUNA, AND SIERRA COUNTIES, NEW MEXICO, by H. L. Jicha, Jr., 1954, 93 p. $7.00

Bulletin 48—GEOLOGY OF THE CERRILLOS AREA, SANTA FE COUNTY, NEW MEXICO, by A. E. Disbrow and W. C. Stoll, 1957, 73 p. $9.00

Bulletin 96—GEOLOGY OF THE LITTLE HATCHET MOUNTAINS, HIDALGO AND GRANT COUNTIES, NEW MEXICO, by R. A. Zeller, Jr., 1970, 26 p. $3.50

Circular 76—BARITE DEPOSITS OF NEW MEXICO, by F. E. Williams, P. V. Fillo, and P. A. Bloom, 1964, 46 p. $3.00

Circular 84—COUNTY, TOWNSHIP, AND RANGE LOCATIONS OF NEW MEXICO'S MINING DISTRICTS, by L. File and S. A. Northrop, 1966, 66 p. $4.00

Circular 164—MODEL FOR BEACH SHORELINE IN GALLUP SANDSTONE (UPPER CRETACEOUS) OF NORTHWESTERN NEW MEXICO, by C. V. Campbell, 1979, 32 p. $3.50

Geologic Map 48—GEOLOGY OF ESPAÑOLA BASIN, NEW MEXICO, by V. C. Kelley, 1978, text, scale 1:125,000. $5.00

Pricelist 13—PUBLICATIONS AVAILABLE FROM NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, 1979, 32 p. FREE

Scenic Trip 1—SANTA FE, by B. Baldwin and F. E. Kottlowski, 1968, 51 p. $4.00

Open-file reports

OF-90—DESCRIPTIONS OF SECTIONS MEASURED FOR HYDROGEOLOGIC STUDY OF THE SAN JUAN BASIN, NORTHWEST NEW MEXICO, by W. J. Stone, 1979, reproducible plate, 2 figs., 4 tables, appendix. $27.80

OF-91—BASIC PETROGRAPHIC DATA COMPILED FOR HYDROGEOLOGIC STUDY OF THE SAN JUAN BASIN, NORTHWEST NEW MEXICO, by W. J. Stone. $8.60

OF-96—HYDROCARBON SOURCE-ROCK EVALUATION STUDY, KCM NO. 1 COCHISE STATE A WELL, HIDALGO COUNTY, NEW MEXICO, by P. J. Cernock, 1976, 4 p. (text), 5 tables, 2 figs., 1 appendix. $4.40

OF-97—HYDROCARBON SOURCE-ROCK EVALUATION STUDY, HUMBLE OIL AND REFINING CO. NO. 1 STATE BA WELL, HIDALGO COUNTY, NEW MEXICO, by P. J. Cernock, 1977, 10 p. (text), 8 tables (15 p.), 3 figs. (sep.), 1 appendix; supplement. $8.60

OF-98—RADIOGENIC HEAT CONTRIBUTION TO HEAT FLOW FROM POTASSIUM, URANIUM, THORIUM IN THE PRECAMBRIAN SILICIC ROCKS OF THE FLORIDA MOUNTAINS AND THE ZUNI MOUNTAINS, NEW MEXICO, by D. G. Brookins, 1978, 14 p. $2.80

OF-99—URANIUM AND THORIUM ABUNDANCES, WHOLE-ROCK CHEMISTRY AND TRACE-ELEMENT CHEMISTRY, ZUNI MOUNTAINS, NEW MEXICO, by D. G. Brookins and C. Rautman, 1978, 47 p. $9.40

OF-100—HISTORY OF NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES AS RECORDED IN LEGISLATION, ANNUAL REPORTS, AND NOTES, by C. L. Holts, 1979, 216 p. $43.20

OF-101—URANIUM AND THORIUM ABUNDANCES AND WHOLE-ROCK CHEMISTRY OF THE FLORIDA MOUNTAINS, NEW MEXICO: PRELIMINARY STUDY, by D. G. Brookins, C. Rautman, and L. L. Corbitt, 1978, 23 p., 2 tables, 7 figs. $4.60

OF-102—ENVIRONMENTAL CHARACTERISTICS OF MENEFEE COALS IN THE TORREON WASH AREA, NEW MEXICO, by D. E. Tabet and S. J. Frost, 1979, 134 p., 5 tables, 19 figs., 3 appendices. $10.00

OF-104—REVISION OF TERTIARY VOLCANICS IN GEOLOGIC MAP 30, by J. E. Cunningham. $1.50

OF-105—MAPS SHOWING THE REGIONAL EXTENT OF SANDSTONE BODIES WITHIN THE GALLUP SANDSTONE COMPILED FOR THE SAN JUAN BASIN HYDROGEOLOGIC STUDY, by N. H. Mizell and W. J. Stone, 1979, 20 p., text $4.00, maps (5). $5.00

OF-106—GEOLOGY OF THE SOUTHEASTERN MAGDALENA MOUNTAINS, SOCORRO COUNTY, NEW MEXICO, by D. M. Petty, 1979, 174 p., 2 maps. $36.80

OF-107—GEOLOGY OF RILEY-PUERTECITO AREA, SOUTHEASTERN MARGIN OF COLORADO PLATEAU, SOCORRO COUNTY, NEW MEXICO, by G. L. Massingill, 1979, 316 p., map. $64.20

OF-108—CONSULTING SERVICE AT MINING AND MILLING CORPORATION OF AMERICA, HACHITA, NEW MEXICO (core-drilling program on the Winkler anticline, Hidalgo County, New Mexico), 1979, by W. T. Hamling and J. S. Holland, 17 p. (text), 13 p. (appendix), 2 figs. $6.40

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OF-110—AEROMAGNETIC MAP OF TORTUGAS MOUNTAINS, DOÑA ANA COUNTY, NEW MEXICO, by G. R. Keller, 1979, 2 maps (reproducible), 2 pls. $2.00

OF-111—EXPLORATORY DRILLING IN THE DATIL MOUNTAIN COAL FIELD, by S. J. Frost, D. E. Tabet, and F. Campbell, 53 p., 7 figs. $3.45

OF-112—GEOLOGY OF THE CORKSCREW CANYON-ABBE SPRING AREA, SOCORRO COUNTY, NEW MEXICO, by D. L. Mayerson, 1979, 125 p., 2 tables, 18 figs., 1 pl., 2 appendices. $27.60 plus map

OF-113—GEOLOGY OF THE EASTERN MAGDALENA MOUNTAINS WATER CANYON POUND RANCH, SOCORRO COUNTY, NEW MEXICO, by G. R. Osburn, 1978, 159 p., 35 figs., 1 pl., 3 appendices. $31.80 plus map

OF-114—DESCRIPTION OF CUTTINGS FROM NAVAJO WATER WELLS IN NEW MEXICO 1978 AND 1979, by W. J. Stone and R. Jackson, 26 p., 1 fig. $5.20

OF-115—SUMMARY OF THE GEOLOGY OF THE ENGLE COAL FIELD, by D. E. Tabet, 1980, 9 p. $1.80

OF-116—PRELIMINARY REPORT ON THE LITTLE GRANITE MINE, BLACK RANGE MINING DISTRICT, SIERRA COUNTY, NEW MEXICO, by R. W. Eveleth and W. T. Siemers, 1980, 8 p. $2.20

OF-118—CENOZOIC STRATIGRAPHY AND STRUCTURE OF THE SOCORRO PEAK VOLCANIC CENTER, CENTRAL NEW MEXICO, VOL. I, STRATIGRAPHY (395 p.); VOL. II, STRUCTURE (138 p.), by R. M. Chamberlin, 1980, includes 6 maps. $112.60

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Oral presentations

Austin, G., "Clay minerals," to mineralogy class, New Mexico Institute of Mining and Technology, Socorro, March

Brierley, C., "Microbial extraction of metals from low-grade minerals," to Miles Laboratories, Elkhart, Indiana, November

———, "Microbial extractive processes," to Exxon Research and Engineering Co., Linden, New Jersey, November

———, "Biological methods to remove selected inorganic pollutants from uranium mine wastewater," to the Third International Symposium on Aquatic Pollutants, Jekyll Island, Georgia, October

Chamberlin, R., "Geologic investigation of the uranium-bearing Baca Formation in Catron County, New Mexico—a proposal," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, February

Chapin, C., "Leaky lineaments in the southern Rocky Mountains," to the Annual Exploration Meeting, Conoco Inc., Prescott, Arizona, April

———, "Leaky lineaments," to New Mexico Institute of Mining and Technology Geoscience Seminar, March

———, "Evolution of the Rio Grande rift," to Meeting on possible geothermal development at Sandia Base, Albuquerque, February

Frost, S., "Problems of abandoned mines in New Mexico," to Mine Waste Stabilization Liaison Committee, Santa Fe, July

Hawley, J. W., "Using geological information for water resources development in New Mexico," to the New Mexico Water Well Association, Albuquerque, January

———, "Hydrogeologic criteria used in preliminary site selection for hazardous waste disposal: case history of proposed site in northwest Doña Ana County," to New Mexico Water Conference, Las Cruces, April

Holts, C. L., "Review of AGI geowriting workshop, technical writing for geoscientists," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, January

Kelley, R. W., "Presentation of the 4th Association of Earth Science Editors award to Brian J. Skinner for outstanding editorial and publishing contributions," to the 13th Annual Meeting of the Association of Earth Science Editors, Tulsa, Oklahoma, October

North, R., "Mineralogy of the Petaca District," to the New Mexico Minerals Symposium, Albuquerque, September

———, "Services of the New Mexico Bureau of Mines and Mineral Resources," to the Albuquerque Gem and Mineral Club, Albuquerque, August

Reiter, M., "High quality heat-flow data," to the University of New Mexico, Geology Department Seminar, October

———, "Terrestrial heat-flow studies in the southwestern United States," to the Student Section of the Society of Exploration Geophysicists, New Mexico Institute of Mining and Technology, May

———, "Terrestrial heat-flow studies in the southwestern United States," to New Mexico Institute of Mining and Technology Geoscience Seminar

Renault, J., "Silica crystallite geothermometer," to the Geology Department, University of Texas (El Paso), El Paso, Texas, March

———, "Geological layer cake," to the San Miguel School, Socorro, April

Robertson, J., "Geology and mineralogy of some copper-sulfide deposits near Mt. Bohemia, Keweenaw County, Michigan," to the Department of Geology and Geological Engineering, Michigan Tech., Houghton, Michigan, November

———, "Intermediate and silicic volcanic and subvolcanic rocks of the Portage Lake volcanics, Michigan," to the Department of Geology and Geological Engineering, Michigan Tech., Houghton, Michigan, November

Siemers, W. T., Austin, G. S., and Kottlowski, F. E., "Industrial rocks and minerals of New Mexico," to American Institute of Mining, Metallurgical, and Petroleum Engineers, February

Stone, W., "Water: key to energy-resource development, San Juan Basin, New Mexico," to New Mexico Institute of Mining and Technology Geoscience Seminar, Socorro, September, and CSIRO, Adelaide, Australia, December; University of New South Wales, Sydney, Australia, December; Bureau of Mineral Resources, Canberra, Australia, December

———, "Getting technical help," to the New Mexico Water Well Association, Albuquerque, January

———, "Paleocene and Eocene deposits of the San Juan Basin," to geochemistry class, New Mexico Institute of Mining and Technology, Socorro, February

Thompson, S., "Oil and gas exploration wells in the Pedregosa Basin," to New Mexico Institute of Mining and Technology Geoscience Seminar, April

Weber, R., "Lithic materials for archaeologists," to the Archaeological Society of New Mexico—Museum of New Mexico Field School, Gallup, July

———, "Two 17th-century sites at Socorro, New Mexico," to the Annual Meeting of the Archaeological Society of New Mexico, Santa Fe, April

———, "Geology of the Plains of San Agustin," to New Mexico Institute of Mining and Technology Geoscience Seminar, March

Wolberg, D., and Hook, S., "Fossils, strip mining, and mitigation techniques," to Consol environmental and mining geologists, March

———, "Paleontology and fossils," to Socorro public school second-grade class

Other activities

Participation in scientific and professional conferences

American Association of Petroleum Geologists: Annual meeting, June; Southwest Section, February; Pacific Section, April

American Association of State Geologists, annual meeting, April

American Institute of Mining, Metallurgical and Petroleum Engineers: Annual convention, February; In-situ Uranium Symposium, September

American Chemical Society: New Mexico Section meeting, April

American Geological Institute, Geowriting workshop, November

Archaeological Society of New Mexico: meeting, April

Association of American State Geologists: Annual meeting, April

Association of Earth Science Editors: Annual meeting, October

Clay Mineral Society: Annual meeting, August

Environmental Trace Substances Research Program, Oil Shale Workshop, July

Forum on the Geology of Industrial Minerals: Annual meeting, April

Geological Society of America: Annual meeting, November

Gordon Research Conference: Conference on Microbial Degradation, July

Hawaii Symposium on Intraplate Volcanism and Submarine Volcanism: July

Institute on Lake Superior Geology: May

International Association of Hydrological Sciences: Symposium on Hydrology of Areas of Low Precipitation, December

International Center for Diffraction Data and University of Denver: Annual conference on Applications of X-ray Analysis, August

International Geological Congress: June-July

Mogollon Conference: March

National Cooperative Soil Survey: Arizona Soil Scientist Workshop, April

National Water Well Association: Ground Water Modeling Workshop, parts 1 and 2, April

New Mexico Geological Society: Annual field conference, October

New Mexico Health and Environment Department, EID, Environmental Evaluation Group: Radiological hazard assessment at WIPP, meeting, January; field trip, June

New Mexico Mineral Symposium: meeting, September

New Mexico Mining Association: International Mining Days, October

New Mexico Water Well Association: Annual meeting, January

Rocky Mountain Association of Geologists: Basin and Range field conference, October

Rocky Mountain Coal Symposium: May

Short Course on the Fluvial System: Colorado State University, March

Society for Applied Spectroscopy: Rocky Mountain Section meeting, May

Society for Industrial Microbiology: Annual meeting, August; Fall Board of Directors meeting, November; Spring Board of Directors meeting, April
Society of Historical Archaeology: Annual meeting, January
Society of Vertebrate Paleontology: Annual meeting, November
State Mining and Mineral Resources Research Institute: Rocky Mountain Director's meeting, April
System Development Corporation: Computer-use workshop, September
Tucson Gem and Mineral Society: Annual show, February
United States Geological Survey: Meeting of Geologic Names Committee, January
United States Geological Survey: State Surveys, Central Section meeting, September
Water Resources Research Institute: Water conference, April
Women in Science and Engineering: Spring meeting, May

Participation in committees and commissions

Austin—American Institute of Mining, Metallurgical and Petroleum Engineers-Society of Mining Engineers, Committee on Continuing Education; Forum on the Geology of Industrial Minerals, Executive Committee (ex officio); New Mexico Geological Society, Publications Committee (Chairman)

Bieberman—American Association of Petroleum Geologists, Committee on Preservation of Samples and Cores, Membership Committee, House of Delegates representing New Mexico Geological Society

Brandvold—New Mexico Water Conference Advisory Board; New Mexico Water Quality Control Commission

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Kelley—Association of Earth Science Editors, President and Board member; New Mexico Geological Society, Geologic Roadmap Committee; Sigma Xi, Admissions Committee

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Resignations during the fiscal year were Virginia Baca, Staff Secretary, 6 June 1980; Charles Bolt, Petroleum Geologist, 27 June 1980; Karl Frost, Field Geologist, 18 January 1980; Candace Holts, Associate Editor, 1 February 1980; Stephanie Landregan, Draftsperson, 31 August 1979; Catherine Lucero, Scientific Illustrator, 30 April 1980; Neila MacDonald Pearson, Associate Editor, 8 February 1980; Bruce Reid, Geologist, 29 February 1980; William Terry Siemers, Industrial Minerals Geologist, 30 April 1980; Lars Skotte, Field Geologist, 15 May 1980; Chantravadee Songkran, Staff Secretary, 15 July 1979; Barbara Spence, Coal Geologist, 4 February 1980; David E. Tabet, Geologist, 30 April 1980; John Wright, Paleontological Curator/Preparator, 30 April 1980.

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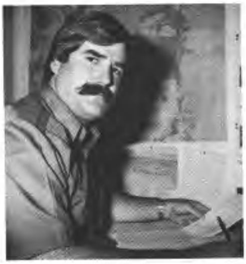

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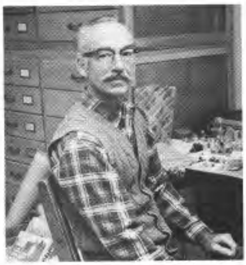

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PALEOCURRENTS OF BLISS SANDSTONE (CAMBRIAN-ORDOVICIAN), SOUTHWESTERN NEW MEXICO AND WESTERN TEXAS

by Sam Thompson III, *Petroleum Geologist*, New Mexico Bureau of Mines and Mineral Resources
and Paul E. Potter, *Professor*, Department of Geology, University of Cincinnati

Abstract

In southwestern New Mexico and western Texas, the Bliss Sandstone nonconformably overlies Precambrian igneous and metamorphic rocks and onlaps northeast-southwest-trending basement ridges along the ancestral continental divide. The Bliss ranges in age from Late Cambrian (Dresbachian-Trempealeauan) to Early Ordovician (Canadian) and is overlain conformably by the El Paso Group of Early Ordovician (Canadian) age. The Bliss is generally less than 300 ft (100 m) thick in the subject area, is thin where it onlaps the basement ridges, and is absent where truncated by Pennsylvanian-Permian erosion across central New Mexico. The Bliss generally is quartzose sandstone. Arkosic constituents are present locally in the basal part, and some thin interbeds of limestone or dolostone are present in the upper part. A preliminary analysis of sedimentary structures and other evidence indicates that the Bliss consists of mostly tidal deposits, some minor beach deposits, and rare fluvial or deltaic deposits.

Composite paleocurrent patterns of the entire Bliss reflect highly variable directions of the tidal and other currents. These patterns were derived from a regional statistical study of measurable inclinations of cross-laminae at 32 localities. Control of the paleocurrents by basement topography is difficult to determine because of the lack of discernible cross-lamination in many of the basal sandstones, especially where bioturbation is pervasive. In the middle and upper Bliss, the abundant cross-laminae appear to be mostly products of deposition in meandering tidal channels and on broad tidal flats. The dominant inclination direction of cross-laminae toward the southwest was probably produced by ebb-tide currents, the opposite direction toward the northeast by flood-tide currents, and the right-angle direction toward the northwest by longshore currents.

Introduction

The purpose of this paper is to show the regional paleocurrent pattern of the Bliss Sandstone (Cambrian-Ordovician) in southwestern New Mexico and western Texas. Paleocurrent analysis provides important information concerning the depositional history of this basal sandstone unit of the Paleozoic section. Specific objectives include the influence of depositional topography on top of Precambrian basement and the role of tidal and other currents in distributing the sand supply over the region during that time. In turn, the understanding of the depositional history is useful in exploration for mineral resources, including oil and gas.

Hayes (1975) provided a regional summary of the Cambrian-Ordovician stratigraphy. He showed (p. 15, fig. 5) the eastward onlap of the Precambrian basement high by progressively younger basal clastic units: 1) Bolsa Quartzite (Middle Cambrian) in southeastern Arizona, 2) Coronado Sandstone (Upper Cambrian—Dresbachian and Franconian) in the Arizona–New Mexico border area, and 3) Bliss Sandstone (Upper Cambrian—Dresbachian to Trempealeauan—and Lower Ordovician—Canadian) in southwestern New Mexico and western Texas. East of the subject area of this paper, the entire Bliss is shown to be in the Lower Ordovician (Canadian). Others who have made significant contributions to the regional stratigraphy of the Bliss include Kottlowski (1963), Flower (1969), and Lochman-Balk (1970, 1971).

Seeland (1968) made the first interregional study of the paleocurrents in the basal clastic units from late Precambrian to Early Ordovician age in the western and northern United States. He showed (p. 141, fig. 4) the axis of the ancestral continental divide trending northeast-southwest through southern New Mexico (about 100 mi west of El Paso), with drainage to the west-northwest and southeast. His vector-mean map (p. 134-135) in this area shows paleocurrents to the southwest at San Lorenzo and Capitol Dome, to the east-southeast at Truth or Consequences (Mud Springs Mountains) and McKelligon Canyon, and to the north-northeast at southern Sacramento Mountains (Agua Chiquita Canyon) and Old Padre mine. We restudied these localities and added more control to see if the position of the divide could be determined more closely using paleocurrent patterns.

Both authors worked on the entire paper, but Thompson was mainly responsible for the section on stratigraphy, and Potter was mainly responsible for the section on paleocurrents. We are grateful to Christina Lochman-Balk for her review of the manuscript and suggestions for improvement.

Stratigraphy

REGIONAL ASPECTS—Fig. 1 shows the thickness distribution of the Bliss Sandstone/Formation (Cambrian-Ordovician) in southwestern New Mexico and adjoining areas. In this region, the Bliss is generally less than 300 ft (100 m) thick, rests nonconformably on Precambrian igneous and metamorphic rocks, and is overlain conformably by the El Paso Group (Lower Ordovician), which is composed mainly of carbonate rocks. This isopach map generally reflects the topography on top of Precambrian basement; however, the Bliss sandstones appear to climb in section a few feet or less per mile toward the northeast intertonguing with the overlying El Paso carbonates.

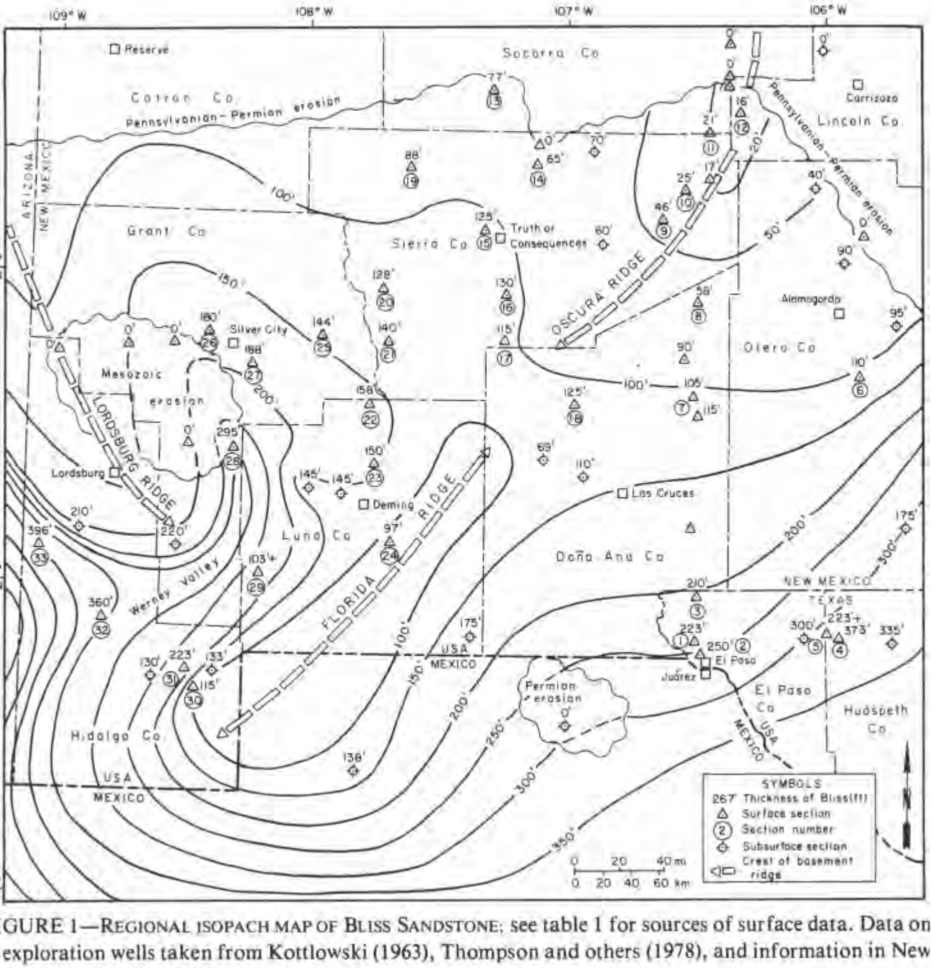

FIGURE 1—REGIONAL ISOPACH MAP OF BLISS SANDSTONE; see table 1 for sources of surface data. Data on exploration wells taken from Kottlowski (1963), Thompson and others (1978), and information in New Mexico Bureau of Mines and Mineral Resources files.

Three prominent ridges are indicated: *Oscura ridge,* most evident in the Oscura Mountains; *Florida ridge,* evident in the Florida Mountains; and *Lordsburg ridge,* the least evident of the three, projected under the city of Lordsburg, New Mexico. The *Werney valley* plunges southward from the thick Bliss section at Werney Hill and then southwestward between the Lordsburg and Florida ridges.

The Oscura and Florida ridges lie along the ancestral continental divide sketched by Seeland (1968). Their coincidence along the northeast-southwest trend indicates a common tectonic origin. Condie and Budding (1979, p. 31-33) stated that the dominant structural trends in the Precambrian are north-south or northeast-southwest in central and southern New Mexico. The anomalous southeastern plunge of the Lordsburg ridge may be on a spur from another northeast-southwest-trending main ridge in southeastern Arizona. Future work may show more clearly the relationship of Precambrian structures and the paleotopography at the base of the Bliss.

The ridges and valleys constituted the main paleoslope controls on the paleocurrents that transported the onlapping basal sandstones of the Bliss. However, the basal sands were not necessarily derived locally from the underlying ridges because they consist mostly of quartz and are well rounded.

The Precambrian surface may have been subjected to widespread subaerial erosion during a lowstand prior to the relative rise of sea level indicated by the Bliss–El Paso sequence deposited during Late Cambrian–Early Ordovician time. In a few places, a paleosol may be present at the top of the Precambrian. At several exposures we studied, no such ancient soil zone is evident, but it may have been removed by subaerial or coastal erosion prior to the deposition of the Bliss.

Local channels are scoured into the basement surface; they exhibit a few feet to several tens of feet of relief. Some of the channel-fill deposits in the basal part of the Bliss are arkosic sandstones that may be fluvial or deltaic in origin. In other areas, more quartzose sandstones are beach deposits that have low-angle inclined laminae of the foreshore type and truncated wave-ripple laminae of the shoreface type (Campbell, 1979).

Most of the Bliss appears to consist of tidal deposits in a classic shoaling-upward succession. Bioturbated sandstones inferred to be subtidal deposits are overlain by sandstones with bipolar cross-laminae indicating intertidal deposition. In this paper, *cross-laminae* refers to strata within beds or laminasets that are inclined to initially horizontal bedding or laminaset surfaces, following Campbell (1967, p. 23). Instead of cross-laminae, many workers use *crossbeds,* following Pettijohn and others (1973, p. 108). Cross-laminae are formed by the migration of ripples or small dunes. Neither thick sets of cross-laminae nor lateral accretion deposits were seen; either would suggest deposition in large tidal channels (Reineck and Singh, 1975, p. 87-91). The upper part of the Bliss tends to have thinner sets of cross-laminae, of the current- or wave-ripple type, that probably were also formed in the intertidal zone but at low-water levels when tidal energy was diminished. No supratidal deposits were recognized in the Bliss.

At some localities, sequences of cross-laminated, intertidal sandstones continue from the uppermost Bliss into the overlying El Paso Group despite the transition from quartz arenites to carbonate grainstones. Beds in the upper Bliss and El Paso are so extensive that nearly all of the relief on the Precambrian basement surface appears to have been buried by the time they were deposited. Thus, the resulting broad, generally smooth, shelf surface that dipped gently to the southwest would not be expected to exert much influence on the paleocurrent patterns.

Knobs of Precambrian basement were onlapped by the El Paso with the Bliss missing; examples are exposed in the Franklin Mountains (Harbour, 1972, p. 19). However, such local features are rare and apparently did not deflect the regional paleocurrent trends. The small bulge of northwesterly thinning near Deming, New Mexico, may reflect a mappable basement knob or a spur from the Florida ridge. More precise measurements of thicknesses in both the surface and subsurface sections would be needed to contour on a thinner interval in order to define such features more accurately. But, even on a larger scale, the present control is so limited that such detailed work could be done only in local areas.

LOCAL SECTIONS—Table 1 lists the 33 surface sections of the Bliss that were visited during this study of 22 field days during 1976-1978. The regional stratigraphic framework is built upon the foundation provided by Hayes (1975). His own extensive work and that by other authors listed in his complete bibliog-

TABLE 1—SURFACE STRATIGRAPHIC SECTIONS OF BLISS SANDSTONE: locations, references, and thicknesses.

	Locations				Hayes (1975)		Thick-nesses
No.	Name of sec.	Mountain range	County, state	Sec.-Twp.-Rge.	Loc.No.	Other references	(ft)
1	McKelligon Can.	Franklin	El Paso, Tex.	–	92	–	223'
2	Scenic Drive	"	"	–	45	Cloud and Barnes (1946)	250'
3	Hitt Can.	"	"	–	44	Harbour (1972)	210'
4	Old Padre Mine	Hueco	Hudspeth, Tex.	–	56	King, King, and Knight (1945)	373'
5	Black Butte	"	"	–	–	" " "	223'+
6	Agua Chiquita Can.	Sacramento	Otero, N.M.	NW¼ 1-19S-10E	1	Pray (1961)	110'
7	Ash Can.	San Andres	Doña Ana, N.M.	NESW 27-19S- 4E	12	Kottlowski et al. (1956)	105'
8	Hembrillo Can.	" "	" "	NENE 11-16S- 4E	11	"	58'
9	Rhodes Can.	" "	Sierra, N.M.	SESE 8-13S- 5E	10	"	46'
10	Salinas Pk.	" "	"	SWSW 7-12S- 5E	–	Bachman and Harbour (1970)	25'±
11	Johnson Park Can.	" "	Socorro, N.M.	NWNW 5-10S- 5E	7	Bachman (1965)	21'
12	So. Oscura	Oscura	Lincoln, N.M.	NENW 16- 9S- 6E	28	Bachman (1968, Sec. "O")	16'
13	Eaton Ranch	San Mateo	Socorro, N.M.	SENE 17- 8S- 4W	35	Kelley and Furlow (1965)	77'
14	Fra Cristobal	Fra Cristobal	Sierra, N.M.	Cen. 11-11S- 3W	36	Kelley and Silver (1952)	65'
15	Cantrell Tank	Mud Springs	"	SWNE 25-13S- 5W	13	" "	125'
16	Burbank Can.	Caballo	"	NWNW 2-16S- 4W	(15)	" "	130'
17	Molinas Can.	"	"	NWNW 26-17S- 4W	16	" "	115'
18	Tonuco	San Diego	Doña Ana, N.M.	NWNW 5-20S- 1W	–	Seager (1975)	125'
19	Winston	Sierra Cuchillo	Sierra, N.M.	SWSW 18-11S- 7W	41	Jahns (1955)	88'
20	Carbonate Ck.	Black Range	"	NWSW 31-15S- 8W	–	Kuellmer (1954)	128'
21	Pierce Can.	" "	"	NWSE 28-17S- 8W	–	Hedlund (1977)	140'–
22	N. Cooke	Cooke's Range	Luna, N.M.	NENW 11-20S- 9W	17	Jicha (1954)	158'
23	Fluorite Ridge	" "	"	NENE 13-22S- 9W	–	Griswold (1961)	150'±
24	Capitol Dome	Florida	"	SENE 10-25S- 8W	39	Lochman-Balk (1958)	97'±
25	San Lorenzo	–	Grant, N.M.	SWNW 25-17S-11W	38	Hedlund (1977)	144'
26	Ash Spr. Can.	Silver City Rge.	"	NWNE 23-17S-15W	–	Lewis(1962), LeMone (unpub.)	180'
27	Lone Mtn.	Lone	"	SENE 29-18S-13W	21	Pratt (1967)	188'
28	Werney Hill	Burro	"	NESW 26-21S-14W	20	Ballman(1960), Hedlund(1978)	295'
29	Sheep Mtn.	Klondike Hills	Luna, N.M.	NESW 22-26S-13W	–	Bromfield and Wrucke (1961)	103'+
30	Mescal Can.	Big Hatchet	Hidalgo, N.M.	NESW 29-30S-15W	24	Zeller (1965)	115'
31	Hatchet Gap	" "	"	SESW 1-30S-16W	–	"	223'+
32	N. Animas	Animas	"	SESE 12-28S-19W	98	Soule (1972)	360'
33	Wood Can.	Peloncillo	"	SENE 22-25S-21W	23	Gillerman (1958)	396'

raphy guided us to most of the key exposures. Other geologists who have mapped or measured sections of the Bliss and who gave us helpful information include D. V. LeMone (localities 1, 2, 4, 5, 26), R. E. Clemons (23), J. W. Hawley (18), D. C. Hedlund (28), W. R. Seager (20, 21), W. T. Siemers (13), and R. G. Warren (14). L. Buescher escorted us to the localities on the White Sands Missile Range (7, 8, 9, 10, 11, 12) that were some of the most important control points in our study. We are indebted to the authorities at White Sands and to the many ranchers who permitted us to work on their land.

Some additional control points shown on the isopach map (fig. 1) are not listed in the table. The few surface localities are the Pasotex (east of 4 and 5) and San Andres Canyon (north of 7) sections of Hayes (1975), the Little San Nicholas Canyon section (south of 7) of Bachman and Myers (1969), the Sheep Mountain section (northeast of 10) of Kottlowski and others (1956), and sections in the Oscura Mountains (north of 12) of Bachman (1968). The subsurface sections are taken from Thompson and others (1978), Kottlowski (1963), and a few scout tickets.

The thicknesses of the Bliss shown on table 1 are taken mostly from Hayes (1975), who measured, described, and sampled many of the sections in detail and checked the others in his list of localities. Some thicknesses are taken from other references. During this study, all the Bliss thicknesses were measured with a Jacob staff and Abney level. The McKelligon Canyon section was measured and described in moderate detail. The other sections were measured in a reconnaissance manner in order to establish the approximate stratigraphic positions of the paleocurrent determinations above the base of the Bliss, to tie to the previously reported thicknesses of Hayes and others, and to add at least approximate thicknesses where no published measurements were available.

Fig. 2 is our stratigraphic column of the type Bliss Sandstone in the McKelligon Canyon section. Hayes (1975, p. 27, 82) designated this locality as the principal reference section of the Bliss; however, his line of section along the crest of ridge on the northwest side of the drainage does not contain the best exposures for sedimentologic analyses. LeMone (1980, p. 16, stop at mile 10.7 in road log) designated this locality as the Bliss stratotype; he showed us the line of good ex-

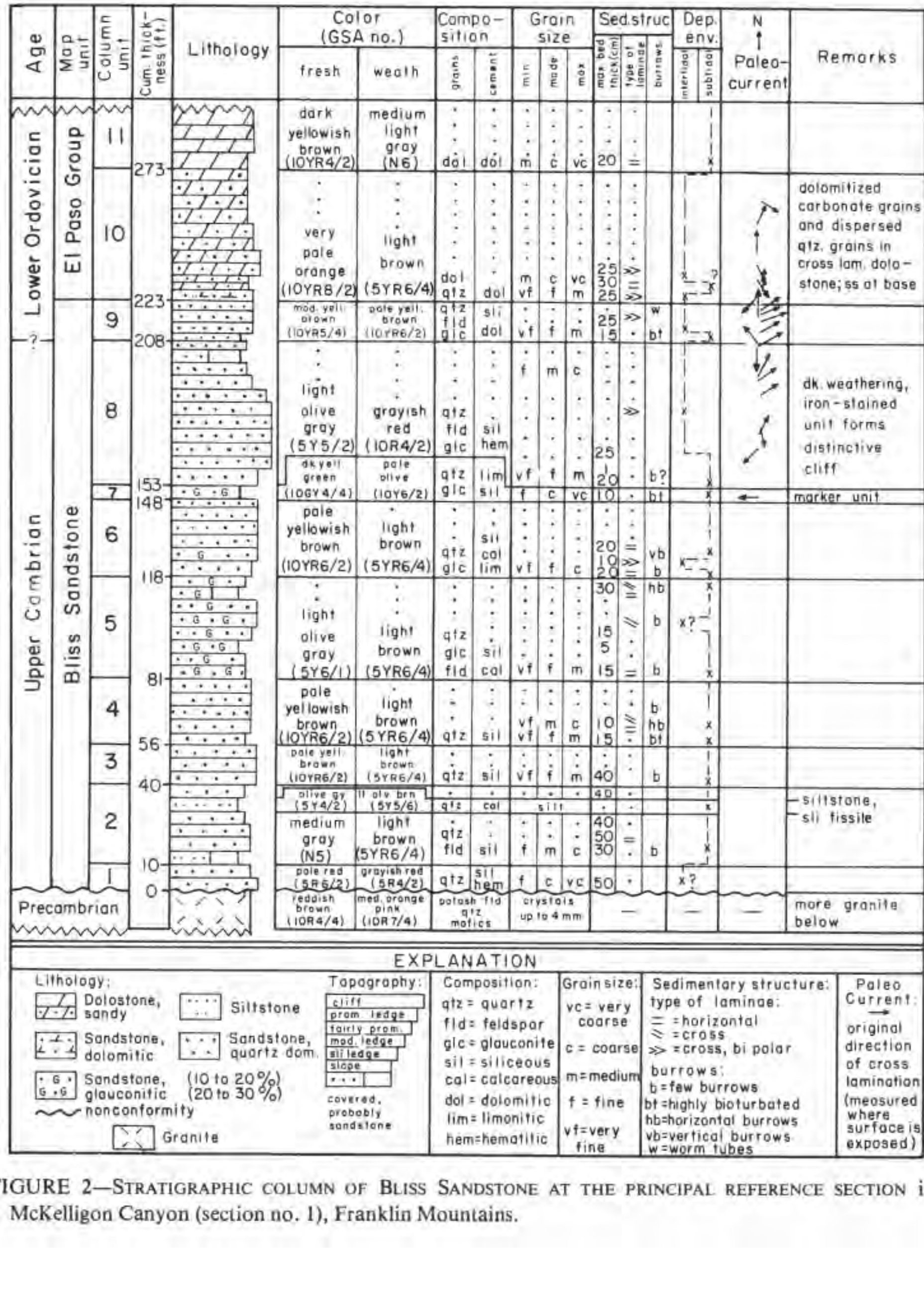

FIGURE 2—Stratigraphic column of Bliss Sandstone at the principal reference section in McKelligon Canyon (section no. 1), Franklin Mountains.

posures along the drainage where we described our section (from stop, walk southwest up short road to drainage).

This columnar plot is a summary of the field description. The bases and the numbers of the column units (1 to 11) were painted in red on the outcrop. At the nonconformity between Precambrian granite and the Bliss, the erosional relief is less than 1 ft. In the lower Bliss (units 1 to 4), the sandstones exhibit rare horizontal lamination, practically no cross-lamination, some hints of burrows, and many thin interbeds (not plotted) whose churned aspect indicates thorough bioturbation. In the middle Bliss (units 5 to 7), many of the sandstones are glauconitic, more beds contain horizontal lamination, some of the cross-laminae appear to be bipolar, tubular burrows (2 mm to 10 mm wide, 20 mm to 45 mm long) are well preserved and are oriented variously from horizontal to vertical, and again some thin interbeds are highly bioturbated. In the upper Bliss (units 8 and 9), the dominant sedimentary structure in the sandstones is bipolar cross-lamination. Depositional environments for these three parts of the Bliss are inferred to have been mainly subtidal, subtidal with minor intertidal, and mainly intertidal, respectively; this succession of environments indicates a shoaling-upward sequence.

LeMone (1969, p. 70) measured 225 ft as the total thickness of the Bliss here; we measured nearly the same, 223 ft. The Bliss–El Paso contact is placed at the subtle change from quartzose sandstones with dolomitic cement (unit 9) to similar sandstones with some dolomitized carbonate grains, which grade upward into sandy dolostones (unit 10). The abundance of bipolar cross-lamination in the sandstones and carbonate grainstones indicates a continuation of intertidal deposition across this transitional boundary. Hayes (1975, p. 82) measured 267 ft as the total thickness along the crest of the ridge about 400 ft horizontally from our line of section along the drainage. Because the lower and upper contacts appear to be at the same stratigraphic positions in both lines of section, the difference in thickness of 44 ft in this short distance may be attributed to local relief on the basement surface, wedging of beds within the Bliss, or differences in measurement.

Fig. 3 shows the outcrop expression of the middle and upper Bliss in the McKelligon Can-

FIGURE 3—MIDDLE AND UPPER BLISS ON NORTHWEST SIDE OF DRAINAGE IN MCKELLIGON CANYON AREA; approximate positions of unit boundaries (5 to 10) are correlated from line of section in drainage (fig. 2). Christina Lochman-Balk places the approximate Cambrian-Ordovician boundary between the dark-weathering sandstones (unit 8) and the overlying light-weathering ones (unit 9). View is northwest; unit 6 is 30 ft thick.

yon area. Christina Lochman-Balk (personal communication, 1976) places the approximate Cambrian-Ordovician boundary at the top of the dark, iron-stained sandstones (unit 8). She infers that the dark ones were reworked to produce the overlying light-colored ones. A precise boundary may be established if a significant erosion surface can be found in the upper Bliss and if the adjacent rocks can be dated. Fig. 4 is a closeup photograph of the bipolar cross-laminae in the upper Bliss.

At other locations, additional sedimentary features were photographed. Fig. 5 shows the sharp, flat nonconformity between Precambrian granite and overlying Bliss Sandstone at Ash Spring Canyon. The lack of a soil zone or other evidence of subaerial exposure at the top of the granite implies planation by surf action. The presence of beach-foreshore deposits in the lower Bliss here support this interpretation. Fig. 6 shows an intraformational (or flat-pebble) conglomerate in sandy dolostone at Lone Mountain that is commonly found as lag material at the bottoms of tidal-channel deposits (see Reineck and Singh, 1975, p. 327, fig. 474).

Fig. 7 shows a bedding surface near Salinas Peak that contains abundant vertical burrowing made by organisms escaping from strong currents; this feature is typical of modern tidal flats (Reineck and Singh, 1975, p. 359). More detailed study of burrows and other trace fossils in the Bliss would add important information on the depositional and diagenetic history. Fig. 8, sandy dolostones also near Salinas Peak, shows horizontal lamination that may represent deposition in a subtidal or low-energy intertidal environment. The erosional scour and fill by slightly inclined laminae indicate deposition in a shallow intertidal channel. Fig. 9, beds in the Mud Springs Mountains, shows thin sets of current- or wave-ripple laminae that are seen above the thicker sets of cross-laminae; this relationship suggests a decline of tidal currents near the end of Bliss deposition.

Paleocurrents

Table 2 is a summary of the paleocurrent data determined at each stratigraphic section of the Bliss Sandstone. In modern intertidal environments, initial inclination of cross-laminae formed by ripples and dunes (not lateral accretion deposits) is observed to be generally the same as the direction of the currents. We infer the same relationship for the paleocurrents in the Bliss sandstones. Each

FIGURE 4—Bipolar ("herringbone") cross-lamination indicating intertidal deposition in upper Bliss at McKelligon Canyon; view is northwest; scale is 15 cm (6 inches) long.

measurement of inclination was made only on an exposed cross-lamination surface where a dip-direction indicator could be superimposed or placed coplanar with the surface in a notch between intersecting outcrop surfaces (Potter and Pettijohn, 1977, p. 97-103). Cross-laminae exposed only as lines of intersection on a single outcrop surface were not measured. The direction and amount of inclination was determined where the set of cross-laminae is thickest and only one measurement per set was made. Structural strike and dip were recorded for each succession of similar attitudes so that corrections could be made for tectonic tilt. At each locality, the entire Bliss was traversed from base to top in search of measurable cross-laminae. The number of reconnaissance measurements per section ranged from none (at no. 18, Tonuco, where no cross-laminae were seen) to 36 (at no. 26, Ash Spring Canyon), averaging 14. In nine sections where the Bliss is thin or exposures are poor, less than 10 measurable sets of cross-laminae per section were found. A total of 473 reconnaissance measurements was made in the 33 outcrop sections.

Where structural dip exceeded 10°, the inclinations of cross-laminae were corrected for tectonic tilt using a stereonet; this work was done by Gregory Hinterlong, a graduate student at the University of Cincinnati. Statistical averages for the entire Bliss at each section were determined by computer. (These procedures are discussed by Potter and Pettijohn, 1977, p. 371-380). Directions of inclination were grouped into classes with a 40° spread of azimuth. The *modal class* (the one with the greatest number of measurements) was determined for each section if one primary mode was evident, and the azimuth of the *mid-point* of the modal class was plotted (4th column of table 2). The *vector mean,* a trigonometric average of all the measurements in a given section, was calculated (5th column). Because of the variable directions of currents in the Bliss intertidal deposits, the midpoint of the modal class is considered a more reliable average than the vector mean. The *variance* (6th column) around the vector mean is a measure of the spread of inclination directions. The *F* ratio (7th column) is the variance of a uniform distribution (10,800) divided by the observed

FIGURE 5—FLAT NONCONFORMITY BETWEEN PRECAMBRIAN GRANITE (p€) AND BLISS SANDSTONE (O€b) at Ash Spring Canyon, Silver City Range (section no. 26). From 4 to 10 ft above the base are sets of gently inclined laminae inferred to be beach-foreshore deposits (f); view is approximately northwest; note pack for scale.

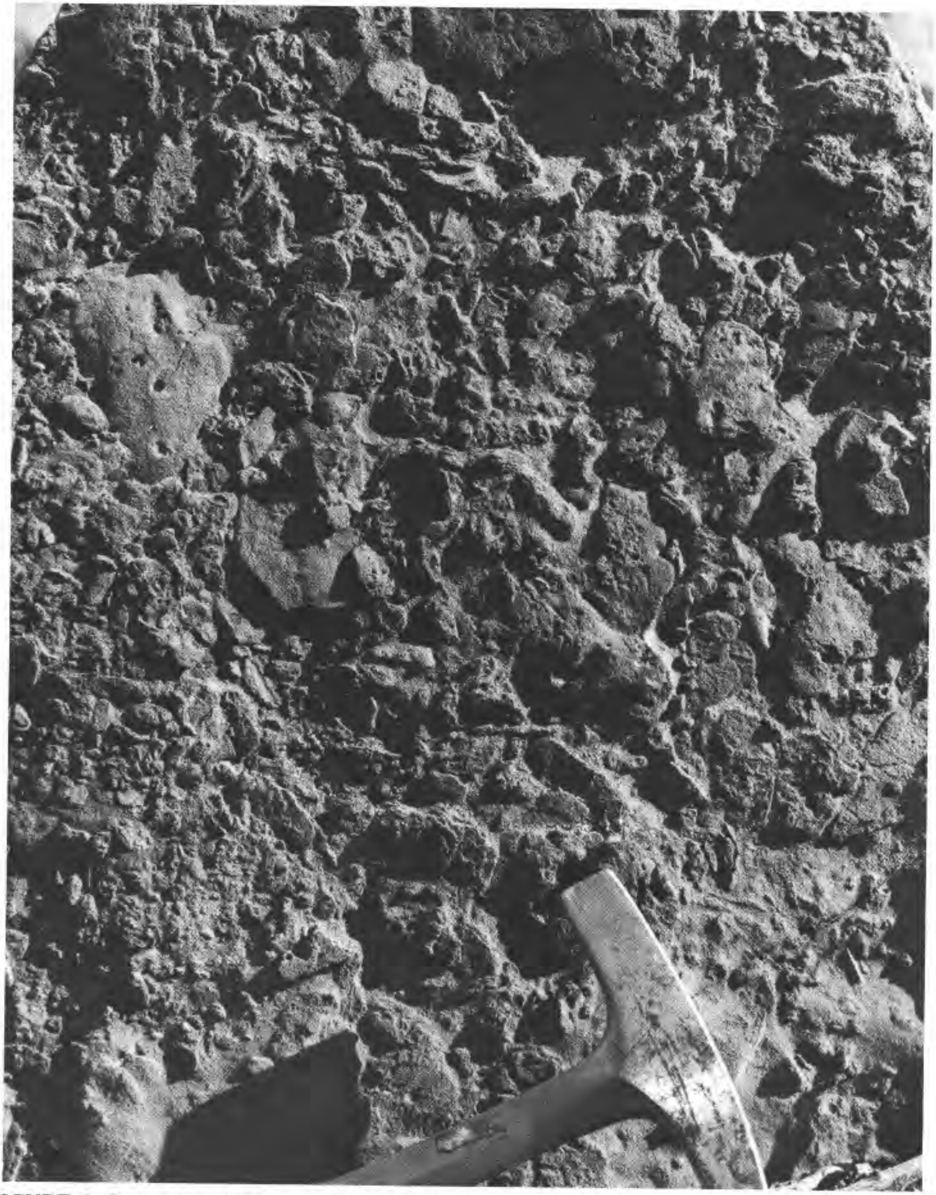

FIGURE 6—BEDDING SURFACE OF INTRAFORMATIONAL CONGLOMERATE IN SANDY DOLOSTONE OF BLISS AT LONE MOUNTAIN (section no. 27). Small pockmarks are solution cavities in the carbonate rock; view of underside of float block.

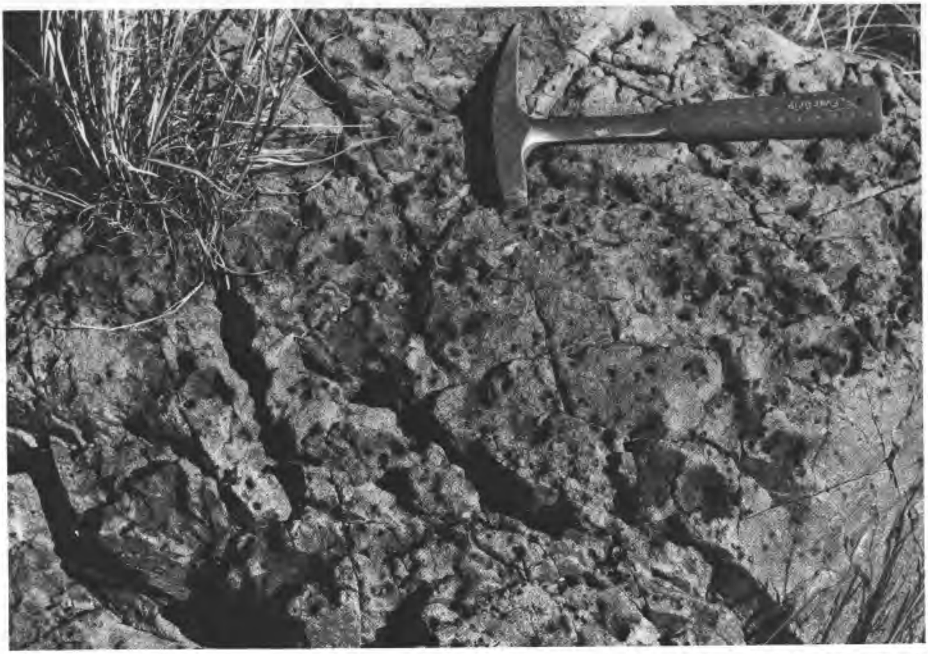

FIGURE 7—ABUNDANT VERTICAL BURROWS, MADE BY ORGANISMS ESCAPING FROM STRONG CURRENTS; view of a bedding surface in Bliss Sandstone near Salinas Peak in the San Andres Mountains (section no. 10).

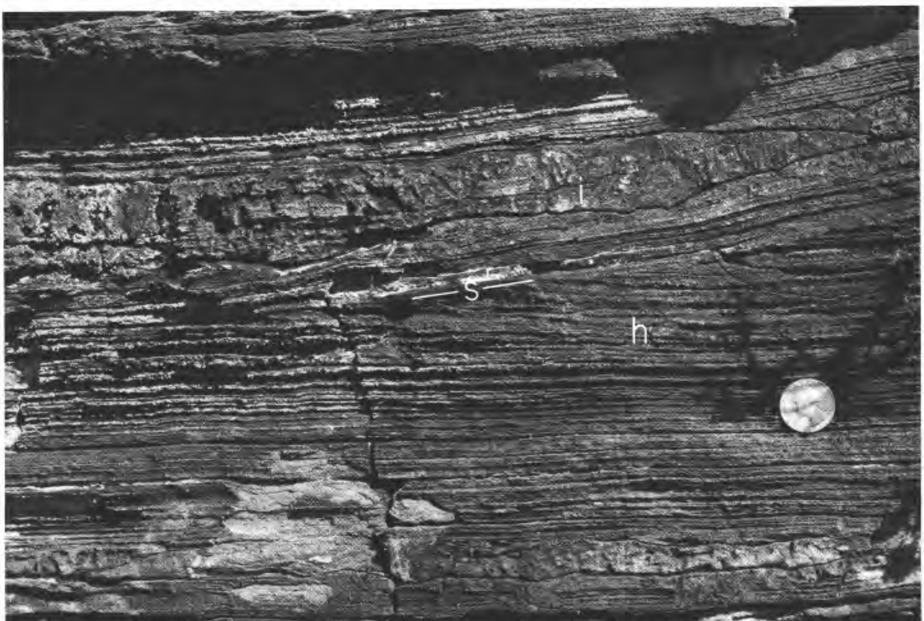

FIGURE 8—SCOUR SURFACE **(s)** TRUNCATES HORIZONTAL LAMINAE **(h)**, AND BROAD CHANNEL IS FILLED WITH SLIGHTLY INCLINED LAMINAE **(i)** in sandy dolostones of the upper Bliss near Salinas Peak.

FIGURE 9—THIN SETS OF RIPPLE LAMINAE IN UPPER BLISS SANDSTONE near Cantrell Tank in the Mud Springs Mountains (section no. 15).

TABLE 2—PALEOCURRENT DATA ON BLISS SANDSTONE MEASURED AT 32 SURFACE SECTIONS; for locations see table 1 and fig. 1. Average paleocurrent directions for the entire Bliss are shown by the modal class or vector mean; statistical measures of variability include the variance, F, and $F_{0.05}$.

No.	Name of sec.	No. of measurements	Azimuth of mid-point of modal class (degrees)	Azimuth of vector mean (degrees)	Variance around vector mean	F (uniform distribution: 10,800/variance)	$F_{0.05}$ (* where $F > F_{0.05}$)
1	McKelligon Canyon	15	60	54	9361	1.15	2.40
2	Scenic Drive	17	180	161	6712	1.61	2.30
3	Hitt Canyon	22	340	271	6330	1.71	2.09
4	Old Padre Mine	12	60	49	3972	2.71	2.83
5	Black Butte	18	40	16	8103	1.33	2.26
6	Agua Chiquita Canyon	11	220	216	610	17.71	2.98 *
7	Ash Canyon	16	260	253	324	33.31	2.40 *
8	Hembrillo Canyon	16	340	303	6458	1.67	2.40
9	Rhodes Canyon	9	180	198	5343	2.02	3.49
10	Salinas Peak	4	-	171	5529	1.95	3.86
11	Johnson Park Canyon	7	-	192	9388	1.15	4.28
12	South Oscura	21	20	353	8325	1.30	2.12
13	Eaton Ranch	14	60	159	8141	1.33	2.50
14	Fra Cristobal	5	-	252	7860	1.37	6.39
15	Cantrell Tank	24	300	249	6662	1.62	1.98
16	Burbank Canyon	12	220	195	3774	2.86	2.84 *
17	Molinas Canyon	24	180	188	7564	1.43	2.01
18	Tonuco	0	-	-	-	-	-
19	Winston	14	320	303	9188	1.18	2.57
20	Carbonate Creek	11	300	263	4065	2.66	2.98
21	Pierce Canyon	12	220	300	7293	1.48	2.83
22	North Cooke	7	260	231	4601	2.35	4.28
23	Fluorite Ridge	8	-	205	5497	1.96	3.79
24	Capitol Dome	13	220	255	3687	2.93	2.69 *
25	San Lorenzo	19	20	331	8684	1.24	2.17
26	Ash Spring Can.	36	220	227	8164	1.32	1.74
27	Lone Mountain	26	180	145	7476	1.44	1.94
28	Werney Hill	25	220	221	8712	1.24	1.98
29	Sheep Mountain	5	100	43	4643	2.33	6.39
30	Mescal Canyon	21	60	26	4629	2.33	5.05
31	Hatchet Gap	6	-	153	529	18.22	5.05 *
32	North Animas	13	260	258	10,376	1.04	2.60
33	Peloncillo Mountains	10	300	248	5227	2.07	3.02

variance. The $F_{0.05}$ (last column) is the critical value of F at a 0.05 significance level. An asterisk is placed where F is greater than $F_{0.05}$ and indicates that the vector mean is statistically significant.

Fig. 10 is a local paleocurrent map of the Werney Hill area (locality no. 28). The line of section for the reconnaissance study was along McDonald Draw in the northern part of the Bliss outcrop. In that study (table 2), 25 measurements were taken in the 295-ft section of Bliss, and the azimuths of the modal class (220°) and the vector mean (221°) were both toward the southwest. To test the local variability of inclination directions in the Bliss, a detailed study was made in this broadly exposed area. A total of 42 measurements (some duplicating the reconnaissance work) was taken for the 11 locations shown on the map. The azimuth of the vector mean is plotted at each location; the azimuth of the modal class differs by less than 45° in most cases. The current rose, which is a circular histogram, shows that the most prevalent (33 percent) of the vector-mean directions is toward the northwest (azimuth 340°), a departure of 120° from the southwest direction (azimuth 220°) determined during the reconnaissance study. The bipolar secondary modes to northeast and southwest may indicate deposition by alternating tidal currents, and the primary mode to the northwest may indicate deposition by longshore currents. These three divergent paleocurrent directions seen here at Werney Hill may be representative of other Bliss sections in this region. Such local variability demonstrates the fallibility of averaging paleocurrent measurements from a single line of section along restricted exposures, as was done for most other localities.

Fig. 11 is a regional paleocurrent map of the Bliss Sandstone in southwestern New Mexico and western Texas. Solid-arrow vectors are plotted at sections that have a single modal class of inclination directions, and the midpoint of that class is shown; dashed-arrow vectors are plotted at sections that have more than one principal modal class, and the vector mean is used (azimuths from table 2). To correlate with data from the other sections, the 25 reconnaissance measurements from the Werney Hill section were used. As seen on this map and the current rose, the dominant inclination directions of cross-laminae are widely dispersed in the southwest, northwest, and northeast quadrants. Only a few directions are in the southeast quadrant. Regional paleocurrent trends are made apparent by the inferred main flowlines that are dashed between the control points on the map.

Because most of the Bliss apparently consists of tidal deposits, the dominant currents to the southwest could have been produced by ebb tides going down the gentle slope of the shallow-marine shelf and the opposite currents to the northeast by flood tides. Right-angle directions to the northwest may have been produced by longshore currents. Because only average directions are plotted on the map, they indicate the dominance of ebb, flood, or longshore currents at each given location during the deposition of the entire Bliss. The vertical and lateral variations at each location may be explained as the results of current fluctuations, with one of the three types leaving the imprint in the cross-lamination record at a given time and place.

The basement ridges apparently exerted little or no influence on the paleocurrent patterns of the Bliss. At least the currents that deposited the basal Bliss were expected to have been controlled by basement topography. However, few cross-laminae were seen in the basal part, and in many cases the record has been obscured by extensive bioturbation. After the basement topography was buried, the middle and upper Bliss were deposited over the broad tidal-flat area; and the paleocurrent patterns developed in response to the tidal and shallow-marine processes operative on the gently dipping shelf.

Recommendations

To improve upon this reconnaissance study that treated the entire Bliss as a single unit, detailed sedimentologic analyses on a bed-by-bed basis in the well-exposed sequences within the Bliss would provide better evidence of the vertical succession of depositional environments to use as a framework for more rigorous interpretation of the evolving paleocurrent fluctuations. Lateral tracing of beds may lead to a better understanding of the paleocurrent systems that deposited these sands. Such work is being done at several sections in south-central New Mexico and western Texas by Donald C. Ottensman for his master's thesis at the University of Texas (Dallas) under the supervision of Kenneth A. Eriksson.

A regional correlation framework of individual units within the Bliss is needed as a

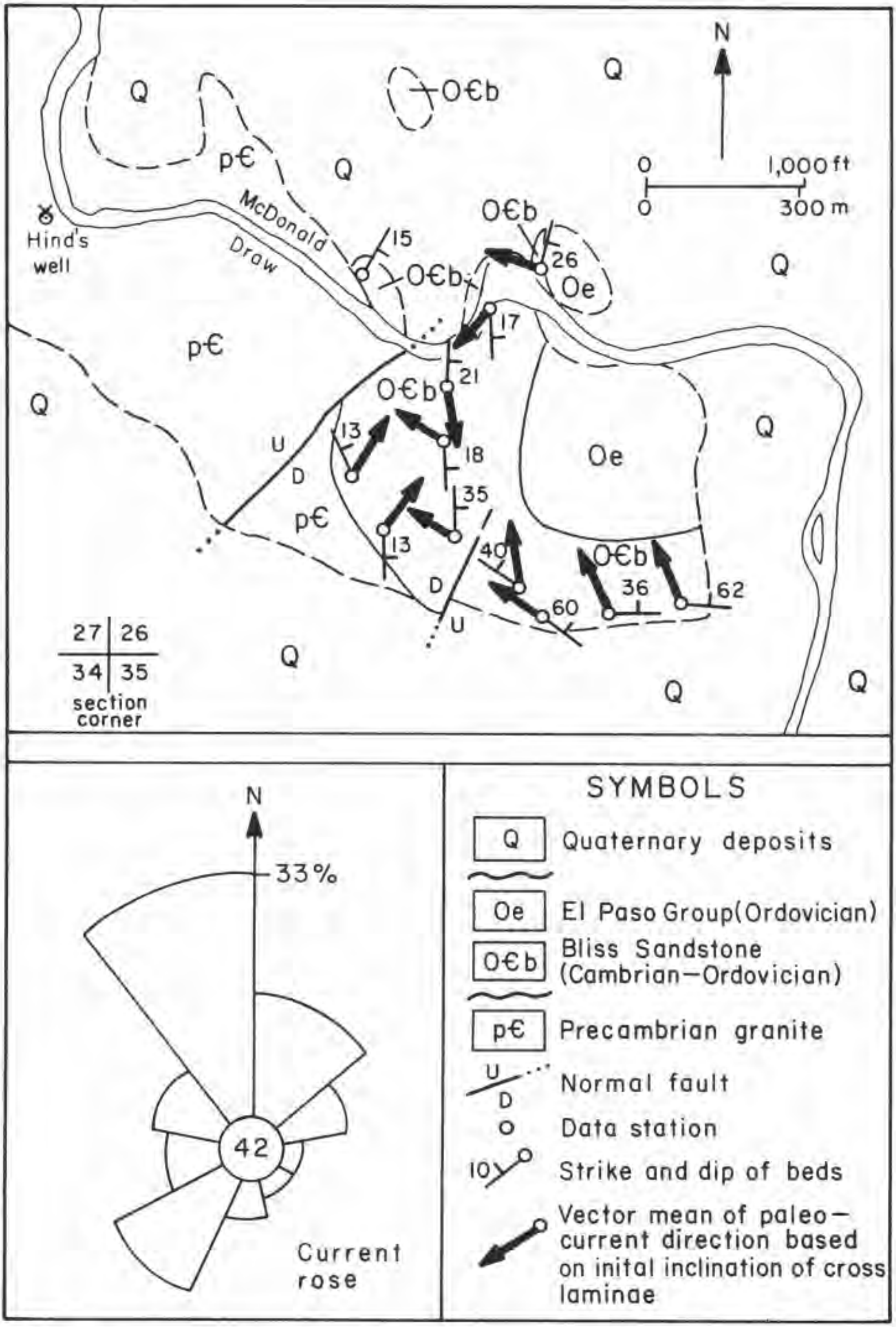

FIGURE 10—PALEOCURRENT MAP OF THE BLISS SANDSTONE IN THE WERNEY HILL AREA in sec. 26, T. 21 S., R. 14 W., Grant County, New Mexico (section no. 28). The vector-mean direction of cross-laminae inclinations is plotted at 11 points to show the local areal variation of paleocurrents in the Bliss; the current rose summarizes the variation and indicates the primary mode is toward the northwest (azimuth 340°); geologic base modified from Hedlund (1978).

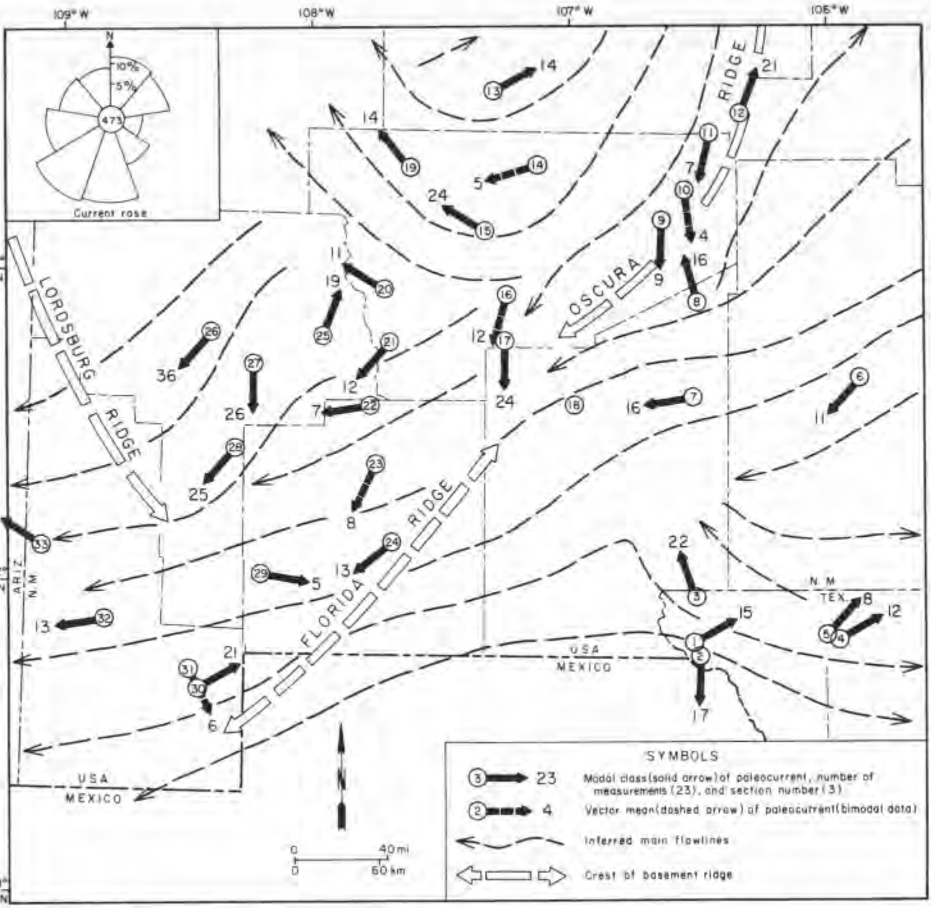

FIGURE 11—REGIONAL PALEOCURRENT MAP OF THE BLISS SANDSTONE IN SOUTHWESTERN NEW MEXICO AND WESTERN TEXAS (same area as fig. 1). Azimuths of modal classes of paleocurrent directions are plotted as solid arrows, and those of vector means are plotted as dashed arrows, according to available data from table 2. Current rose shows summary of 473 measurements; the dominant directions toward the southwest are inferred to be produced by ebb-tide currents, the directions toward the northeast by flood-tide currents, and the directions toward the northwest by longshore currents.

basis for a comprehensive sedimentary analysis. Because lithostratigraphic markers and guide fossils are rare, correlation of the individual units from one locality to another may depend reciprocally upon sedimentologic criteria, including the projection of paleocurrent and other depositional patterns. Such correlations should be checked with independent evidence where possible.

Important control may be added with studies of subsurface data. Logs and cuttings may provide basic data, but cores are needed for definitive analyses. Unfortunately, cores are rarely taken in oil-exploration wells that drill to the Bliss in this region, mainly because of the poor productive history of this formation in the Permian Basin and the poor reservoir quality of the tightly cemented sandstones seen at many surface and subsurface locations. However, in the present study, coarse friable sandstones with excellent porosity and permeability were observed in the bioturbated units of the lower Bliss exposed in the Hueco Mountains. Such a reservoir objective should be cored in future exploration wells drilled in the Hueco Bolson and southern Tularosa Valley.

Tectonic problems may be resolved with evidence based on sedimentary data. Although the averages of cross-lamination inclinations are too variable to use the regional paleocurrent map of the Bliss (fig. 11) to test inferences of major thrusting or strike-slip movement, the regional isopach (fig. 1) has some important implications. Some workers have postulated wrench faults with a northwest-southeast trend in southwestern New Mexico, especially along the Texas lineament. However, the persistent northeast-southwest trend of the Oscura and Florida basement ridges indicates that they have not been subjected to any major lateral offset since Precambrian time. Also the Cordilleran thrust belt of Laramide age, where projected in a northwest-southeast trend across the southwestern corner of New Mexico, does not appear to have displaced the Florida ridge much, except possibly longitudinally during tectonic transport toward the northeast. Closer control on the isopach map and more detailed sedimentologic studies of the Bliss should shed more light on these problems.

A series of regional stratigraphic maps, including isopach-facies-paleocurrent maps for each major unit in the Paleozoic-Mesozoic-Cenozoic and structure-contour maps at key horizons, should be prepared for southwestern New Mexico and adjoining areas. Such a map series would provide a comprehensive basis for understanding the sedimentary and tectonic history of this complex region and would be useful in the exploration for mineral resources.

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LOPHA SANNIONIS (WHITE)—COMMON UPPER CRETACEOUS GUIDE FOSSIL IN NEW MEXICO

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IUGS UNESCO

A contribution to Project Mid-Cretaceous Events

This article is the fourth in a series documenting biostratigraphically important and easily recognizable molluscan fossils that occur in the Upper Cretaceous of New Mexico. Previous papers have described and illustrated the oysters *Pycnodonte newberryi* (Stanton), *P.* aff. *P. kellumi* (Jones), *P.* cf. *P. kellumi* (Jones), and *Lopha lugubris* (Conrad); the ammonites *Scaphites whitfieldi* Cobban, *Prionocyclus macombi* Meek, and *P. novimexicanus* (Marcou); and the bivalve *Inoceramus dimidius* White (Hook and Cobban, 1977, 1979, 1980).

Many Upper Cretaceous oyster species make good guide fossils because they occur in great numbers, are geographically widespread, have restricted stratigraphic ranges, and are easily recognized. *Lopha sannionis* (White) meets all these requirements and, in New Mexico, has proven to be an especially good guide fossil to the Gallup Sandstone (upper Turonian).

Lopha sannionis was described more than a century ago by Charles A. White, M.D. White (1826-1910) was educated as a physician but abandoned medicine to become State Geologist of Iowa in 1869. During his long geological career, White was also Professor of Natural History at Iowa State University and Bowdoin College, Maine; Paleontologist to the Wheeler, Powell, and Hayden Surveys; and Paleontologist and Geologist to the U.S. Geological Survey. He also had an honorary curatorship at the U.S. National Museum (Marcou, 1885; Merrill, 1924).

Lopha sannionis was described by White (1876) in connection with work by the Powell Survey on the Uinta Mountains of Utah, but it was not illustrated until 1879 in a volume by the Hayden Survey on the Cretaceous fossils of the western states and territories (White, 1879). Since that time, *L. sannionis* has appeared in numerous faunal lists (for example, Stanton, 1893; Lee, 1917; and Bachman and Myers, 1969) but has been reillustrated only twice (Veatch, 1907, pl. 19, figs. 1, 1a; Kauffman, 1977, pl. 13, fig. 8). Very little has been published on the stratigraphic range and occurrence and geographic distribution of *L. sannionis*.

Lopha sannionis (White)

Lopha sannionis is an easily identified marine oyster that was originally described as *Ostrea* (*Alectryonia*) *sannionis* White (1876, p. 112; 1879, p. 277, pl. 2, figs. 2a-3). The species is characterized by its prominent radial plicae and by its distinctive shape formed by a posterior auricle that bounds the upper part of a conspicuous posterior concavity. The axis of the shell forms a gentle curve. The anterior margin is straight to slightly convex and bends almost abruptly into the slightly rounded ventral margin, which may be drawn out into a posteroventral extension (fig. 1). A long, curved hingeline further characterizes the species. Fairly sharp-crested to well-rounded radial plicae radiate from the beak and number 7 to 9 along the ventral and anterior margin of the shell. The left valve is slightly convex, and the right valve is nearly flat to slightly concave. Attachment areas on the left valves are very small or absent. The species was, therefore, probably free-living as adults. The configuration of the attachment areas on two specimens from Sandoval County, New Mexico, revealed attachment to turritellid gastropods. Posterior adductor muscle scars on the interior surface of the valves are large, elongate, and comma shaped, with the larger part toward the ventral margin of the shell.

Lopha sannionis is a moderately small species. White's types are 30-40 mm high. The largest specimens in our collections from New Mexico are 43-46 mm high.

The specific name means "one who makes faces, a grimacer," apparently in reference to the gently curved plicae.

Lopha sannionis occurs chiefly in shallow-water or nearshore sandstones in the western part of the Western Interior Late Cretaceous seaway from southern New Mexico to central western Montana (fig. 2).

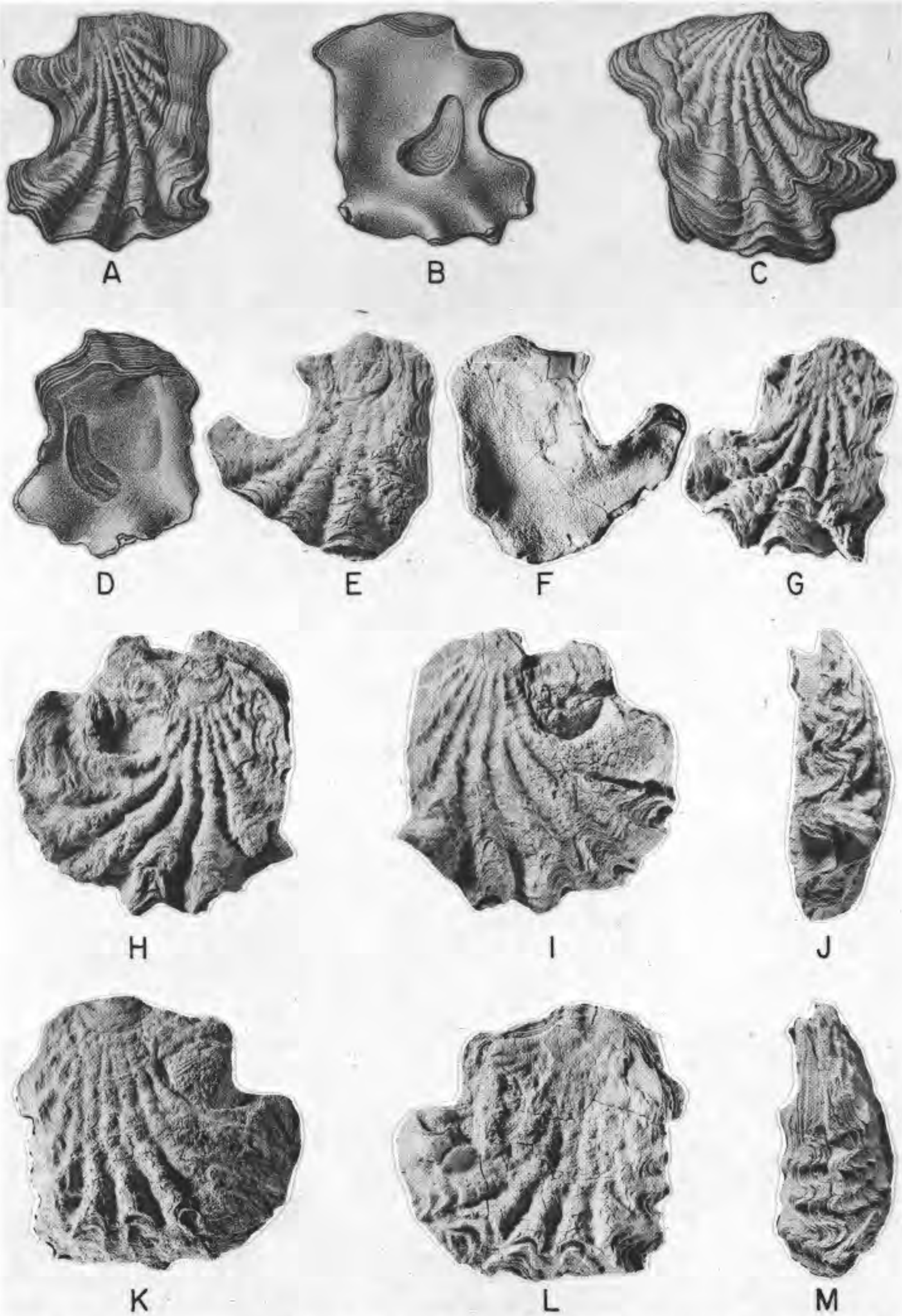

FIGURE 1—*LOPHA SANNIONIS* (WHITE), NATURAL SIZE. **A-D,** exterior and interior views of right (A,B) and left valves (C,D) from White (1879, pl. 2, figs. 2b-e). **E,F,** exterior and interior views of a right valve, hypotype USNM 305422, from the Gallego Sandstone at USGS Mesozoic locality D10595 in SW¼ sec. 20, T. 4 N., R. 7 W., Socorro County, New Mexico. **G,** right valve, hypotype USNM 305423 from the D-Cross Tongue of Mancos Shale at USGS Mesozoic locality D10292 in NE¼ sec. 26, T. 2 N., R. 4 W., Socorro County, New Mexico. **H-J,** hypotype USNM 305424 from the D-Cross Tongue at USGS Mesozoic locality D10351 in NW¼ sec. 35, T. 2 N., R. 4 W., Socorro County, New Mexico. **K-M,** hypotype USNM 305425, from the D-Cross Tongue at USGS Mesozoic locality D10291 in SE¼ sec. 26, T. 2 N., R. 4 W., Socorro County, New Mexico.

FIGURE 2—MAP OF THE WESTERN INTERIOR OF THE UNITED STATES SHOWING LOCALITIES (▲) WHERE *LOPHA SANNIONIS* HAS BEEN COLLECTED and the approximate positions of the Late Cretaceous shoreline during late Turonian time (---) and early Coniacian time (–··–).

Stratigraphic range

Our recent collecting in New Mexico has shown that *Lopha sannionis* first appears low in the late Turonian zone of *Prionocyclus novimexicanus* (Marcou), rather than in the early Coniacian (Kauffman, 1977, p. 245). We (Hook and Cobban, 1979, fig. 5) were in error in showing *L. sannionis* occurring with *P. quadratus* Cobban in the Gallego Member of the Gallup Sandstone. The prionocyclid species in question is *P. novimexicanus,* although *L. sannionis* does occur with *P. quadratus* in southern New Mexico (Bachman and Myers, 1969).

Lopha sannionis ranges up into rocks of Coniacian age as high as the inoceramid zone of *Inoceramus deformis* Meek (fig. 3). White's types came from the upper part of the Frontier Formation near Coalville, Utah, where the Upton Sandstone Member (Hale, 1960) contains *L. sannionis* in association with the early Coniacian inoceramid *I. erectus* Meek.

The few specimens we have collected from the base of the *P. novimexicanus* zone in New Mexico are all small and generally not very abundant. Those from near the top of this zone are larger, more robust, and occur in great abundance.

Geographic distribution in New Mexico

In New Mexico, *Lopha sannionis* has been found at many localities in a broad belt extending southeastward from the Four Corners. Published records include Lee (1917, p. 177, 198), Dane, Bachman, and Reeside (1957, p. 110), Dane, Wanek, and Reeside (1957, p. 193, 194), Bachman and Myers (1969, p. C39), Tabet (1979, p. 14), and Cobban and Hook (1979, fig. 3). In the Four Corners area, *L. sannionis* was found in the Gallup Sandstone. Farther southeast, in the Crownpoint area, the species occurs in the transition beds between the Mancos Shale and Gallup Sandstone. Many localities for the species have been found in the D-Cross Tongue of the Mancos Shale and in the overlying and intertongued Gallup Sandstone in the Acoma Basin, and all seem to be in the late Turonian zone of *Prionocyclus novimexicanus.* In the Rio Puerco area, northeast of the Acoma Basin, *L. sannionis* occurs in and just below the Punta de la Mesa Sandstone of Herrick (1900, p. 338; Lee, 1917, p. 198). The associated inoceramids suggest an early Coniacian age (zone of *Inoceramus erectus*). In the Jornada del Muerto coal field, east of Socorro, *L. sannionis* has been found near the top of the D-Cross Tongue of the Mancos Shale (Tabet, 1979, p. 14). Farther south, in the Carthage coal field, the species occurs in the basal sandstone bed of the Mesaverde Formation (Cobban and Hook, 1979, fig. 3). In the Oscura area, southeast of Carthage, the species occurs in sandstone beds that contain *Inoceramus erectus.* Southwest of Oscura, *L. sannionis* is found in older rocks of late Turonian age. In Mescal Canyon, east of Truth or Consequences, the species occurs sparsely in the D-Cross Tongue of the Mancos Shale associated with *Prionocyclus novimexicanus.* In the Love Ranch area, northeast of Las Cruces, *L. sannionis* is abundant in a sandstone bed in rocks assigned to the Eagle Ford Formation by Kottlowski and others (1956, p. 67). Associated fossils include *Inoceramus incertus* Jimbo and *Prionocyclus quadratus* Cobban.

Stage	Inoceramid and ammonite zones	Range and abundance of *Lopha sannionis* (White)
Coniacian (part)	*Volviceramus involutus, Scaphites ventricosus*	
	Inoceramus deformis, Scaphites preventricosus	
	Inoceramus erectus, Scaphites corvensis	
Turonian (part)	*Inoceramus incertus, Prionocyclus quadratus*	
	Inoceramus perplexus, Prionocyclus novimexicanus	
	Inoceramus dimidius, Scaphites ferronensis	

FIGURE 3—GENERALIZED MOLLUSCAN FOSSIL ZONES OF LATE TURONIAN AND EARLY CONIACIAN AGE IN THE WESTERN INTERIOR and the range and abundance of *Lopha sannionis* (White).

Geographic distribution outside New Mexico

Specimens that are probably *L. sannionis* were recorded by Mudge (1972, p. A68) from the Ferdig Member of the Marias River Shale in the disturbed belt of northwest Montana. The Ferdig Member contains *Prionocyclus* and other mollusks of late Turonian age. *Lopha sannionis* has also been found in the Ferdig Member farther south in the disturbed belt in central western Montana (Schmidt, 1978, p. 25).

Lopha sannionis is widely distributed in the western half of Wyoming. All occurrences are in sandstone beds in the upper part of the Frontier Formation, and most are from the zone of *Inoceramus erectus* of early Coniacian age (Veatch, 1907, p. 67; Fath and Moulton, 1924, p. 21; Love and others, 1951, sheet 1; Cobban and Reeside, 1952, p. 1,923, 1,932, 1,941, 1,951, 1,952).

Sandstone beds of early Coniacian age in Utah contain *L. sannionis* at a few localities. In the Coalville area in north-central Utah, *L. sannionis* occurs in the Upton Sandstone Member at the top of the Frontier Formation (Stanton, 1893, p. 43; Trexler, 1966, p. 34; Cobban and Reeside, 1952, p. 1,937). In the central part of the state, the species is found in the Funk Valley Formation.

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Mineral and mineral-fuel production activities in New Mexico during 1979

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New Mexico mineral and mineral-fuel production for 1979 totaled $4.49 billion, which represents a 43 percent increase over 1978 production (table 1). Large contributors from the nonfuel sector were copper ($337 million), uranium ($310 million), and potash ($229 million). Most metal and nonmetal commodities increased in both production and value; the major exception was uranium, which dropped in both categories.

The greater share of the total, however, was derived from the various mineral fuels, including natural gas, natural-gas liquids, crude oil, and coal.

New Mexico ranked first in the production of perlite, potash, and uranium; second in the

TABLE 1—Mineral and mineral-fuel production in New Mexico. Short tons unless noted; **NA**, not available; **XX**, not applicable; **W**, withheld to avoid disclosing individual company data; *, revised (adjusted from preliminary 1978 figures); †, estimated. Data sources: U.S. Bureau of Mines, unpublished data; U.S. Department of Energy, unpublished data; Oil Conservation Division, New Mexico Department of Energy and Minerals, unpublished data; Oil and Gas Accounting Division, New Mexico Department of Taxation and Revenue, unpublished data; American Gas Association; and Keystone Coal Industry Manual.

Mineral	1978		1979	
	Quantity	Value (thousand dollars)	Quantity	Value (thousand dollars)
Clays, excluding fireclay (thousand tons)	65*	108*	74	124
Coal (thousand tons)	12,863	98,728	14,635	176,466
Copper (tons)	140,906*	187,405*	181,088	336,934
Gem stones	NA	180	NA	180
Gold (troy ounces)	9,879*	1,912*	22,988	7,065
Gypsum (thousand tons)	263*	2,649*	251	3,244
Manganiferous ore, 5-35% Mn (tons)	36,443*	W	33,152	W
Mica (tons)	16,000*	W	17,000	W
Natural gas (million cu ft)	1,159,150	1,117,997	1,162,714	1,616,172
Natural gas liquids (thousand bbls)	44,000†	298,313	38,314	574,710†
Peat (tons)	2,000	60	2,000	40
Perlite (thousand tons)	576*	12,510*	588	14,874
Petroleum, crude (thousand bbls)	83,365	832,550	79,649	1,119,861
Potash (thousand tons)	2,142*	183,554	2,210	228,716
Pumice, including cinder (thousand tons)	631*	2,706*	604	3,550
Salt (tons)	320*	1,617*	W	W
Sand and gravel (thousand tons)	8,239*	17,858*	7,141	18,245
Stone, crushed (thousand tons)	2,438*	6,156*	2,589	6,743
Stone, dimension (thousand tons)	18*	115*	20	117
Uranium, recoverable U_3O_8 (thousand pounds)	15,628*	328,182*	14,118	310,603
Combined barite, carbon dioxide, cement, fireclay, iron ore, lead, lime, molybdenum, silver, sulfur, vanadium, and zinc and W	XX	59,671*	XX	77,521
Totals	XX	3,152,271	XX	4,495,165

manganiferous ores; third in copper and crude mica; fourth in molybdenum; and fifth in pumice and vanadium (American Petroleum Institute, 1979; U.S. Bureau of Mines, 1980).

Commodities are produced from all areas of the state but are concentrated geographically along a wide mountainous belt running from the southwest (Lordsburg–Silver City area) to the north-central portion (Taos-Raton area). Other producing areas are the San Juan Basin in the northwest and the Carlsbad-Hobbs area in the southeast (fig. 1).

Mineral fuels

New Mexico oil production for 1979 decreased by 4.4 percent (3.7 million bbls) from 1978 (table 2). The southeast produced 4.9 percent or 3.8 million bbls less oil than in 1978, while the northwest produced 1.6 percent or 0.1 million bbls more oil than in 1978.

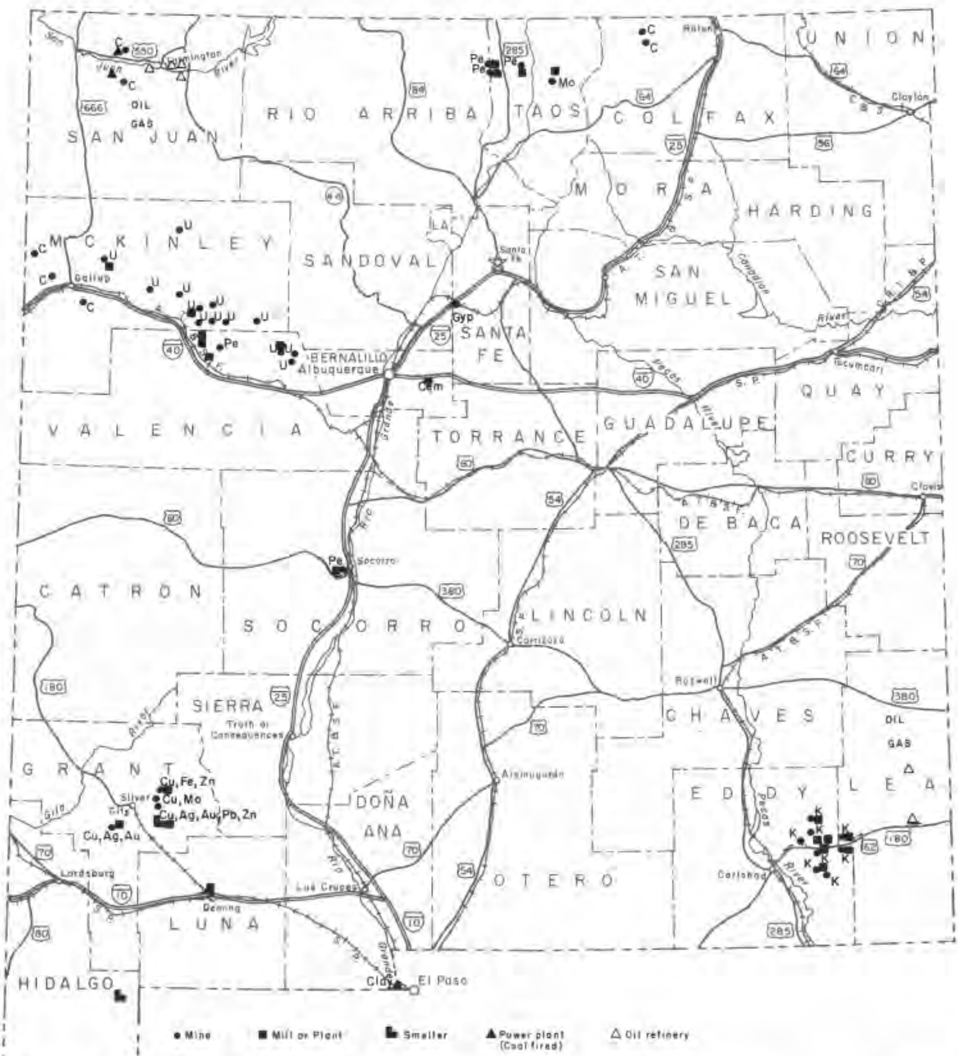

FIGURE 1—GEOGRAPHIC LOCATIONS OF PRINCIPAL MINERAL-PRODUCING AREAS IN NEW MEXICO. **Ag,** silver ore; **Au,** gold ore; **C,** coal; **Cem,** cement plant; **Cu,** copper ore; **Fe,** iron ore; **Gyp,** gypsum; **K,** potash; **Mo,** molybdenum; **Pb,** lead; **Per,** perlite; **U,** uranium ore.

TABLE 2—OIL AND GAS PRODUCTION, 1979 (Source: New Mexico Oil and Gas Engineering Committee, 1978a, b; 1979a, b).

County and area	Crude oil (bbls) Production	Crude oil (bbls) Gain (+) or decline (−) from 1978	Natural gas (thousands cu ft) Production	Natural gas (thousands cu ft) Gain (+) or decline (−) from 1978
Chaves	1,904,543	+454,196	10,209,928	−1,896,688
Eddy	20,032,723	−2,379,037	232,008,448	+118,623
Lea	49,805,509	−2,261,749	352,595,141	−18,679,639
Roosevelt	1,711,670	+401,361	3,680,645	+86,662
Southeast totals	73,454,445	−3,785,229	598,494,162	−20,371,042
McKinley	1,074,328	−84,973	135,111	−163,814
Rio Arriba	2,060,799	+497,540	179,843,113	+17,054,946
San Juan	2,700,866	−286,964	381,759,853	+6,962,274
Sandoval	358,275	−7,998	2,471,042	+87,197
Northwest totals	6,194,268	+117,605	564,209,119	+23,940,603
Mora	0	0	10,404	−4,210
Northeast totals	0	0	10,404	−4,210
State totals	79,648,713	−3,667,624	1,162,713,685	+3,565,351

The state ranked seventh in the nation in crude-oil production. Natural-gas production in New Mexico increased by 0.3 percent or 3.6 billion cu ft. A decline of 3.3 percent or 20.4 billion cu ft in natural-gas production was posted in the southeast, which was offset by a 23.9 billion cu ft or 4.4 percent increase in natural-gas production in the northwest.

In 1979 exploratory drilling and the rates of success in New Mexico increased sharply over 1978 levels (table 3). The 201 wildcats drilled in 1979 with a success rate of 41.3 percent compares with 174 wildcats and a success rate of 28.7 percent in 1978. Higher activity was reported in the southeast and northwest areas of the state for both oil and gas wells.

New-field wildcats, the strongest indicators of the level of exploration activity, also posted increases in the number of wells drilled and the percentage of discoveries of both oil and gas. In 1979, 155 new-field wildcats were drilled with a success rate of 32.3 percent compared to 125 drilled in 1978 with 21.6 percent discoveries. Southeast and northwest New Mexico shared equally in the increased activity and improved results.

Vigorous exploration activity in 1979 can be attributed to increases in the average wellhead price of newly discovered crude oil and natural gas.

Development-well drilling in 1979 continued at levels similar to those of 1978. The total number of development wells drilled in 1979 was 1,358 with 474 producing oil and 759 producing natural gas. In 1978, 1,371 development wells were drilled including 433 oil wells and 782 gas wells. The number of development wells drilled in southeast New Mexico increased slightly from 640 in 1978 to 650 in 1979. A decline from 731 in 1978 to 708 in 1979 in development wells drilled in the northwest area of the state can be attributed to the slowed pace of infill drilling in the natural-gas fields of the San Juan Basin.

The addition to proved oil reserves in New Mexico from all exploratory drilling was about 9.6 million bbls, which is 5.5 million bbls below the 1978 contribution (table 4). New-field discoveries in 1979 added about 0.5 million bbls to proved oil reserves, a significant decrease from the 1978 level.

Contributions to proved natural-gas reserves from all exploratory drilling increased 6.9 percent from the 1978 level to 961 billion cu ft. The additions to proved natural-gas reserves due to new-field discoveries in 1979 was 44.6 billion cu ft, which is 33 percent below the 1978 contribution.

The net effect of crude-oil production exceeding discoveries in 1979 was an approx-

TABLE 3—DRILLING STATISTICS 1978 AND 1979 (Source: American Petroleum Institute, 1979, 1980).

	1978	1979
Wildcats drilled	174	201
Southeast	133	141
Northwest	41	60
Oil	14	22
Southeast	12	17
Northwest	2	5
Gas	36	61
Southeast	33	49
Northwest	3	12
Success rate (percent)	28.7	41.3
Southeast	33.8	46.8
Northwest	12.2	28.3
New-field wildcats drilled	125	155
Southeast	92	113
Northwest	33	42
Oil	9	16
Southeast	7	12
Northwest	2	4
Gas	18	34
Southeast	18	33
Northwest	0	1
Success rate (percent)	21.6	32.3
Southeast	27.2	39.8
Northwest	6.1	11.9
Development wells drilled	1,371	1,358
Southeast	640	650
Northwest	731	708
Oil	433	474
Southeast	363	391
Northwest	70	83
Gas	782	759
Southeast	162	176
Northwest	620	583
Success rate (percent)	88.6	90.8
Southeast	82.0	87.2
Northwest	94.4	94.1

imate 5 percent drop in New Mexico's proved reserves to about 462 million bbls. Field extensions and new reservoirs in old fields continued to offset natural-gas production and helped to boost proved natural-gas reserves by about 1.5 percent over the 1978 figure to approximately 13.5 trillion cu ft. New Mexico ranks fourth in reserves of natural gas and natural-gas liquids and seventh in reserves of crude oil.

Coal production increased nearly 14 percent during 1979 to 14,635,188 tons. Major producers were the McKinley (3.77 million tons), Mentmore (1 million tons), and Amcoal (0.1 million tons) mines in McKinley County; San Juan (2.17 million tons) and Navajo (6.3 million tons) mines in San Juan County; and Kaiser's two mines (1.3 million tons) in Colfax County.

New operations projected to come into production but held up by operational problems or litigation were the Arroyo #1 mine near Cuba and the Con Paso mine near Burnham.

Permits were issued to Chaco Energy's Hospah mine, which is awaiting construction of a Santa Fe Railroad branch line, and to Ideal Basic Industries La Ventana underground mine, which is experiencing difficulties in getting approval of the federal Office of Surface Mining (OSM).

Several other permits have been issued during the last few years but were still inactive during 1979; if these permits are activated during 1980, as many as 14 mines may be in operation.

Metallic minerals

Production of the state's primary metallic commodity—copper—increased 29 percent from 140,906 short tons last year to 181,087 short tons in 1979, reflecting the improved situation in a market that had been severely depressed throughout 1978. The price turnaround occurred in late January, and the price climbed steadily, attaining an all-time United States high of $1.126 per pound on October 2. Copper was still selling above the $1.00 mark at year's end.

All major producers were able to report increased earnings and sales over the previous year. This increase resulted in more exploration activities and prompted plans for improvements in existing plants and facilities.

Kennecott Minerals Corporation, for example, announced plans to construct a new concentrator at Hurley. The plant is expected to cost approximately $300 million. Quintana Minerals disclosed that it would go ahead with plans for an open-pit copper mine at its Copper Flat property near Hillsboro. Quintana has apparently obtained most, if not all, the necessary permits and has made arrangements with the local electric company for construction of a power line to the site.

Exxon Minerals Corporation continued drilling its Pinos Altos prospect, although at a reduced rate. Exploration has revealed the

TABLE 4—CONTRIBUTIONS TO PROVED RESERVES FROM DISCOVERIES, 1978 AND 1979 (American Petroleum Institute, American Gas Association, and Canadian Petroleum Association, 1979, 1980).

	1978	1979
Added wildcat proved oil reserves (million 42-gal bbls)	15.1	9.6
Added new-field wildcat proved oil reserves (million 42-gal bbls)	2.6	.5
Added wildcat proved natural-gas reserves (billion cu ft)	899	961
Added new-field wildcat proved natural-gas reserves (billion cu ft)	67	44.6
Total proved oil reserves (million 42-gal bbls)	486	462
Total proved natural-gas reserves (billion cu ft)	13,300	13,500

existence of a 7-million-ton orebody containing 2 percent copper and 3 percent zinc, plus recoverable amounts of silver and gold. An underground operation is planned for late 1980 or early 1981 to further delineate the orebody and evaluate underground conditions. Initial mining will also provide bulk samples for metallurgical testing.

Elsewhere, Conoco was active in the Pecos area, further delineating a massive sulfide orebody that contains approximately 3 percent copper, 7 percent zinc, and small amounts of silver and gold. No tonnage estimates have been released by Conoco, but the orebody is known to be larger than Exxon's Pinos Altos find.

Few bright spots occurred in the lead and zinc market during the year, and American Smelting and Refining Company's (ASARCO) Groundhog mine at Vanadium remained closed. The only activity was a small-scale diamond-drilling program designed to test ore potential at greater depths.

As a result, production of lead and zinc remained at depressed levels when compared to previous years. In 1975, for example, the latest year for which figures are available, Grant County produced 1,931 short tons of lead and 11,015 short tons of zinc—a large portion of which came from the Groundhog mine. Total lead and zinc production of Grant County for 1979 is less than 10 percent of the 1975 amount. Nevertheless, Grant County is still the major source for these metals with three mines producing: Center and Summit mines at Steeplerock and Continental mine at Fierro. Other producers were the Volcano mine in Hidalgo County and the Silver Monument mine in Sierra County. This lead and zinc was produced only because of its economic association with copper, gold, or silver or because of its fluxing value.

While New Mexico ranks only sixth in the nation in silver production and seventh in gold production, these metals were responsible for much of the exploration activity in the state during the year. Both metals attained all-time-high values: gold reached $515.20 per oz on December 27; silver reached $28.00 per oz the following day. This surge resulted in the reexamination of nearly every precious-metal mining camp in the state by both the individual prospector and corporate geologist alike. Some areas, such as Orogrande, Tres Hermanas, and Gold Hill witnessed various amounts of core-drilling activity.

Two precious-metal operations neared completion during the year. The smaller, Challenge Mining Company at Mogollon, will be reprocessing mine-dump material consisting primarily of low-grade silver ore with small amounts of gold. Annual capacity of the plant, which has been enlarged and improved since originally designed, is approximately 25,000 tons. Goldfields Corporation was nearing completion of its Ortiz mine and recovery plant near Golden southeast of Santa Fe. This large-scale operation will process some 3,000 tons per day of low-grade gold ore. Startup, originally slated for late 1979, was delayed awaiting approval of a water-rights application. Both companies will be utilizing a cyanide heap-leaching technique, developed in part by the U.S. Bureau of Mines, to recover gold and silver.

Nearly all of the present production of these metals is derived from byproduct mining of copper in the Silver City area. Precious metals were also produced at the Center and Summit mines at Steeplerock, the Volcano mine west of Lordsburg, and the Delores placer near Hillsboro.

Molybdenum was produced at three localities: Kennecott's Chino mine at Santa Rita, Kerr-McGee's Ambrosia Lake operation, the Molycorp mine at Questa. The latter is the state's major producer. Molybdenum is recovered as a byproduct at the former two.

Development of Molycorp's underground mine continued during the year. Union Oil, parent of Molycorp, announced the discovery of at least 120 million tons of ore. The mine will be developed through a 7,000-ft decline; two 1,300-ft vertical shafts will provide access and ventilation. The mine is projected to reach full production capacity in 1985 and to have an operating life of 20 yrs. At peak operation the mine will employ 1,000 or more full-time workers. Molycorp has had considerable trouble with tailing spills in the Red River; as a result, a total revamping of the tailings disposal system is planned.

In addition to the activity near Questa, Superior Oil Company drilled for molybdenum in the Nogal area of Lincoln County. Superior was granted permission by the U.S. Forest Service to extend its drilling program into the White Mountain Wilderness. The extent of this activity suggests Superior may have an important discovery.

Iron and manganiferous iron ores were produced at two localites: Luck mines near Silver City and Continental mine near Fierro.

Production and value of uranium dropped 10 percent and 5 percent, respectively, to 14,118,000 lbs recoverable U_3O_8 and $310 million, due in part to the softening market. Likewise, exploration and development drilling dropped to 6 million ft as compared to 10 million ft the previous year, further reflecting future market uncertainties, such as world oversupply and environmental restrictions.

A new development in the industry and perhaps an indicator of things to come was the startup of operations at Mobil's pilot in situ uranium leach plant near Crownpoint. Operations had been held up by environmental lawsuits much of the year.

A major setback to the uranium industry in general occurred on July 16 at United Nuclear's Church Rock mill north of Gallup when a tailings dam failed and allowed an estimated 1,100 tons of solids and 94 million gals of liquids to spill into the Rio Puerco. The mill was ordered closed, and cleanup operations were carried out through much of the remainder of the year. The mill resumed operations with a temporary permit from the New Mexico Environmental Improvement Division late in October.

Uranium exploration activity was concentrated in Socorro and Catron Counties in west-central New Mexico and near Canjilon in Rio Arriba County.

The U.S. Department of Energy credited New Mexico with reserves (at $50/lb) of 482 million tons containing 0.09 percent or 449,000 tons of U_3O_8. That figure amounts to some 40 percent of the nation's known reserves.

Nonmetallic minerals

Most industrial rocks and minerals increased in both volume and value. However, production of gypsum decreased 5 percent to 251,000 tons, and production of pumice decreased 4.3 percent to 604,000 tons. Values of these commodities increased, however, to $3,244,000 and $3,550,000, respectively.

Barite production increased mainly due to startup of operations by Ranger Industries at its small plant north of Socorro.

At Bingham, one of the larger known barite deposits in the state is being developed by Minopco (previously known as the Hansonburg Operating Company) near the Blanchard mine. This company, which plans to produce both fluorspar and lead in addition to barite, was in the construction stage with its crushing and jigging plant. Overburden has been stripped above the ore zone, and a pipeline is being constructed to the site to insure an adequate supply of water.

Barite of America has renovated the old American Peru concentrator north of Deming and is developing mines south of Deming in the Little Florida Mountains and near Rincon.

No fluorspar production was recorded during the year, although many deposits were examined for production potential including the

Lyda K, Greenleaf, Clum, and Red Rock mines.

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EQUUS CONVERSIDENS FROM THE PLEISTOCENE OF NORTHEAST GRANT COUNTY, NEW MEXICO

by Donald L. Wolberg, *Vertebrate Paleontologist*, New Mexico Bureau of Mines and Mineral Resources

An incomplete skull of *Equus conversidens* Owen (1869) was recovered on July 26, 1979, from near Lake Roberts in the Gila National Forest, northeast Grant County, New Mexico. Salvaged under contract, the skull remains the property of the U.S. Forest Service. The specimen, vertebrate paleontology collection number 10001 (VP 10001), is currently housed in the paleontological collections at New Mexico Bureau of Mines and Mineral Resources. VP 10001 occurred in Pleistocene terrace deposits and was found by John Hawley, New Mexico Bureau of Mines and Mineral Resources, and Jon Sandor, University of California, Berkeley, during field investigations in the area. The U.S. Forest Service cooperated with speedy issuance of the salvage contract that insured prompt removal of the specimen.

VP 10001 is the incomplete skull of a relatively young but mature horse referred to *E. conversidens*. The right half of PV 10001 is much better preserved than the left side and retains all or large portions of the right parietal, frontal, squamosal, nasal, and maxillary. Most of the right lacrimal and all of the right premaxillary have been lost except for a premaxillary fragment adhering to the upper incisors. Portions of the left parietal, frontal, nasal, and lacrimal remain as do segments of the left maxillary plate (fig. 1).

The palate is relatively complete but has been laterally compressed and shattered. Some torsional compression has also affected the braincase. The right pterygoid is present and flange-like, but the left is incomplete. The basisphenoid and the anterior of the basioccipital remain. Both the right and left series of cheek teeth, P^2-M^3, are complete and in relatively good condition (fig. 2). All but one of the upper incisors were found with the skull, adhering to soil in approximately their proper position in what would have been the premaxillary. A single incisor, a left I^3, was found isolated approximately 1 m from the skull at the same stratigraphic level.

The left side of the skull is poorly preserved except for the palate and associated cheek teeth. Some of the damage probably occurred before burial. Following separation from the post-cranial portions of the skeleton, the skull must have come to rest with the right side down and probably was partially covered by sediments. Deterioration of the occipital region, left parietal, and maxillary areas as well as nasals and a portion of the premaxillary must have followed. A second episode of exposure must have further damaged the premaxillary areas, more heavily on the left side than the right, and carried one incisor a short distance. Further damage to the left maxillary and indeed the entire left side must also have occurred before the skull was once again covered by sediment. Given the frequent and generally regular inspection of the roadcut in which the specimen was found, no significant additional deterioration probably occurred before the recent discovery of the specimen.

No post-cranial elements or lower jaw fragments were found with the specimen. Careful scrutiny of the exposures in the area failed to yield any additional material. Separation of these elements probably occurred soon after death; therefore, the skull probably could not have been transported any great distance. Sediments removed during placement of the road may have contained elements of the post-cranial skeleton. However, periodic inspections of the site will continue in order to determine whether additional elements remain.

The maxillae of VP 10001 appear to be complete, but there is no evidence of a canine. All of the upper teeth appear to have been recovered; upper canines were lacking in this individual. In recent horses, this condition most frequently is seen in mares. M^3 has erupted and evidences some crown wear. Moreover, the roots of all of the cheek teeth remain open. I^3 is present and evidences some crown wear as well. In recent horses, M^3 erupts at about 3½ yrs, while I^3 does not erupt until approximately 4½ yrs, about the same time as upper and lower canines, if they are present (Schmid, 1972). If present, the upper canines should have been found. VP 10001 must have been approximately 5-5½ yrs old at the time of death.

The anterior border of the internal nares is located at the level of the anterior margin of

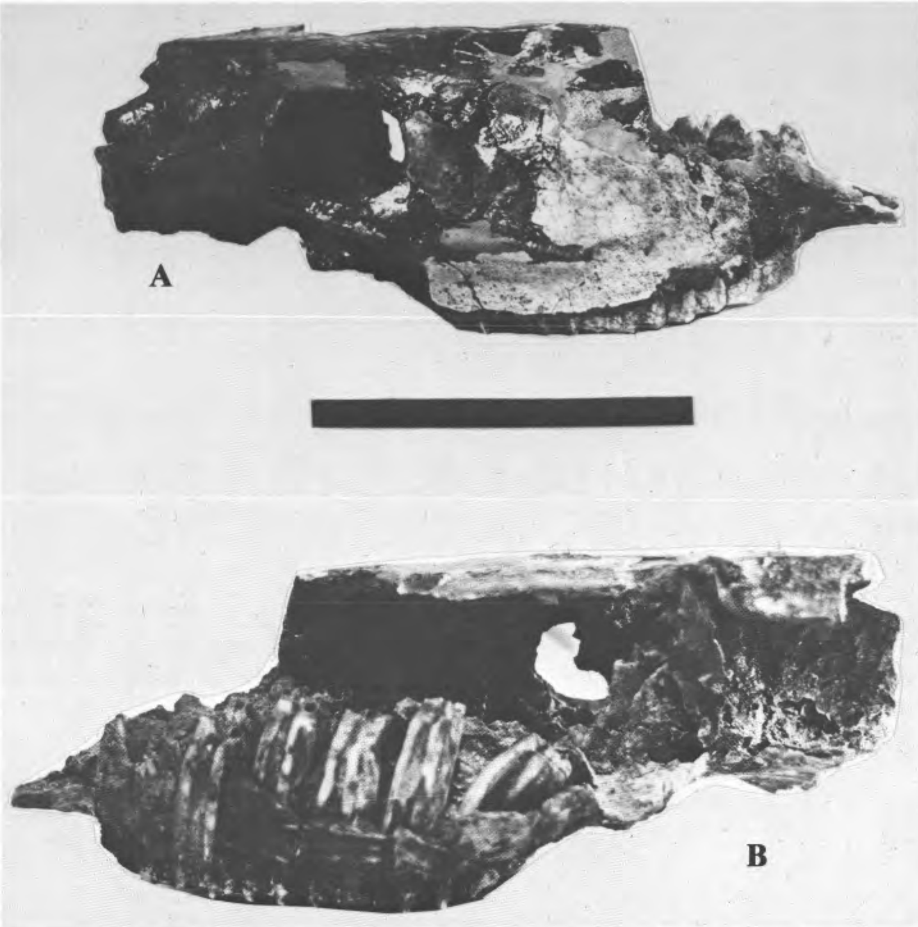

FIGURE 1—VP 10001, *Equus conversidens;* **A,** lateral view; bar is 150 mm in length. **B,** Lateral view; note the extensive damage to this side of the specimen.

the right M^2 but medial to the antero-posterior length of the left M^2. This discrepancy is due to a postero-lateral distortion of the skull. The anterior margin of the internal nares is relatively farther anteriad than is usual in modern horses and confirms the observation of Lundelius (1972) on the Blackwater Draw material.

The anterior edge of the orbit is approximately at the level of the posterior margin of M^3. The antero-posterior length of the orbit is 58.5 mm, and the vertical height is 44.0 mm. This measurement suggests an orbital index of approximately 75 percent. The palatal width at the posterior of M^2 measured about 65 mm in its present and distorted condition, but at least 5 mm of transverse shortening has affected the palate.

The occlusal length of the right P^2-M^3 is 157 mm; the left occlusal length is 158 mm. The length of P^2-P^4 is 86 mm for both left and right. The occlusal length of the molar series is 72 mm for the right and 72.5 mm for the left. These measurements can be compared with measurements of the holotype and referred specimen from Mexico as well as with a referred specimen from Texas (table 1). Measurements of the teeth of VP 10001 are pre-

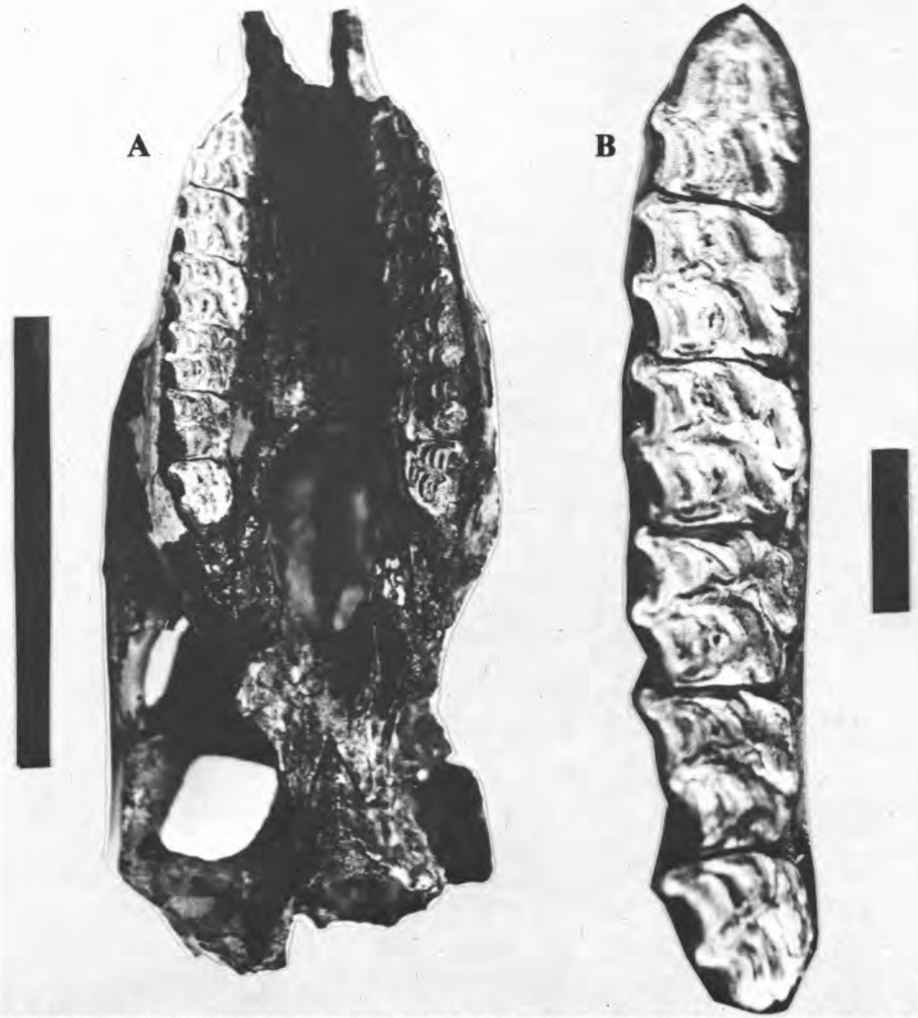

FIGURE 2—VP 10001, *EQUUS CONVERSIDENS;* **A**, palatal view; bar is 150 mm in length. **B**, Right upper dentition; bar is 25 mm in length.

TABLE 1—OCCLUSAL LENGTHS OF *EQUUS CONVERSIDENS* (IN MM).

		P^2-M^3	P^2-P^4	M^1-M^3
VP 10001	(right)	157	86	72
	(left)	158	86	72.5
N. 403*	(right)	148	82.5	67
	(left)	149	83	66
N. 400	(right)	148.5	79.5	69
P 182-1	(left)	147.5	75.5	72

*holotype from Mexico; N. 400 also from Mexico (after Hibbard, 1955)

P 182-1 from Canyon, Texas (after Dalquest and Hughes, 1965)

sented in table 2, together with measurements based on the figures of Hibbard (1955) and Dalquist and Hughes (1965).

Dental morphology

Teeth are very useful anatomical structures for taxonomic studies of mammals. Very resistant to destruction, teeth are composed of calcium-hydroxyl-phosphate (essentially apatite) with a hardness of 5 on the Mohs scale. Mammalian teeth offer a complexity of structure, genetically determined and consistent, that provides excellent opportunities for detailed morphological studies. These studies

TABLE 2—MEASUREMENTS (MM) OF TEETH OF *EQUUS CONVERSIDENS*. Length (L) is after Hibbard (1955) and is taken anteroposteriorly along the midline of the tooth. Width (W) is after Hibbard (1955) and is measured from the enamel of the protocone to the enamel of the mesostyle.

	P^2		P^3		P^4		M^1		M^2		M^3	
	L	W	L	W	L	W	L	W	L	W	L	W
VP 10001	32.5	24.0	27.0	27.0	26.0	26.5	24.5	25.0	24.0	22.0	24.0	18.0
	33.0	25.0	27.0	27.0	26.0	26.0	24.5	26.0	24.0	23.5	23.5	17.5
N. 403*	(33.0)	23.0	26.0	23.0	24.5	22.5	22.5	(23.0)	22.0	21.0	21.5	16.5
	(34.0)	(22.0)	26.0	23.5	24.5	(22.0)	23.0	22.5	(22.0)	(21.0)	21.0	16.0
N. 400	32.0	23.5	24.5	25.0	23.5	24.0	21.5	24.0	22.5	20.5	25.0	18.0
N. 406			26.5	23.5	24.0	22.0	23.0	21.0	23.5	19.5	21.0	17.0
P 182-1	31.5	21.5	26.0	26.0	24.5	26.0	22.0	24.0	23.0	23.0	27.0	22.0
TMM 937-504							22.5	22.0	22.0	18.0	27.0	20.0
											26.5	20.0

*N. 403 is the holotype of *Equus conversidens*. Measurements based on figures in Hibbard (1955). N. 400 and N. 406 are also from the Valley of Mexico. Measurements based on figures in Hibbard (1955). P 182-1 is from Clayton, Texas. Measurements based on a figure in Dalquest and Hughes (1965). TMM 937-504 is a specimen from Blackwater Draw, New Mexico. Measurements based on a figure in Lundelius (1972).

provide insights into the evolution of various taxa through time, as well as into the relationships between the components of various taxa. A useful nomenclature for different dental structures and landmarks has developed with special terms applied to various animal groups. Fig. 3 is a generalized upper right horse tooth; certain features of the tooth crown are labeled.

The first tooth present in the upper jaw of VP 10001 is the second upper premolar (P^2). In occlusal view, P^2 is triangular in outline with the apex directed anteriorly. M^3, the last tooth of the series and the last (or third) upper molar, is also roughly triangular in outline but with the apex of the triangle directed posteriorly. In P^2 the protocone is conspicuous but is directed only posteriorly, although an incipient preprotoconal groove is present.

The pli caballin fold is present in P^2-P^4 but is best developed in P^2 and progressively less so in P^3 and P^4. This fold is absent in the molars. The preprotoconal groove is clearly distinct in P^3-M^3 and forms deep indentations in these teeth. In VP 10001 the preprotoconal groove appears to be antero-posteriorly straight rather than internally convex labially as seen in the type specimen of *E. conversidens*. However, this trait is consistent with TMM 937-504 from Blackwater Draw, as figured by Lundelius (1972). The teeth between P^2 and M^3 are basically square in outline.

The postprotoconal valley in VP 10001 is narrower in the molars than in the premolars. Hibbard (1955) notes the opposite: the postprotoconal valley is narrower in the premolars than in the molars. However, this fig. 3 and plate 3 clearly indicate that the postprotoconal valleys of M^1-M^3 are narrower than those of P^2-P^4. Similarly, fig. 1 of Dalquist and Hughes (1965), an upper dentition of *E. conversidens* from Canyon, Texas, allows concurrence with this view. In fact, the postprotoconal valley of M^2 is so constricted posteriorly in VP 10001 that the enamel of the hypocone and protocone are almost in contact.

The pre- and postfossettes are, in agreement with Hibbard (1955), more complexly plicated in the premolar series than in the molar series. In P^2-P^4 the metaloph sends a series of intrusions into the posterior region of the prefossettes and a major lingual and minor labial intrusion into the anterior region of the postfossettes. In M^1 and M^2 the plications are more simplified and undular in form.

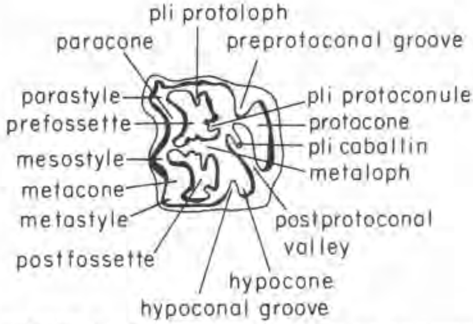

FIGURE 3—GENERALIZED FEATURES OF AN UPPER RIGHT TOOTH.

The metaloph is broader in P^2-P^4 than in M^1-M^3. In M^3 the metaloph is very constricted. Labially, the posterior margin of the prefossette and the anterior margin of the postfossette do appear to be closer to each other than in other examples of *E. conversidens* reported to date. The plications are not as well developed as those figured by Hibbard (1955) or Dalquist and Hughes (1965) but do approach the condition figured in Quinn (1957) and Lundelius (1972).

The pli protoloph is present in P^2-P^4 but absent in the molars. The pli protoconule is present in all the teeth but is narrow in P^2, P^4, and M^2 and M^3. It is broader and almost rectangular in P^3 and M^1. The pli hypostyle is barely present in P^2, better developed in P^3-M^1, and hardly or just noticeable in M^2 and M^3.

The para-, meso-, and metastyles of P^3-M^2 are well developed, although the para- and mesostyles are better developed than the metastyles. The parastyle of P^2 is present but poorly developed; the metastyle of M^3 is just barely present. The metastyles of the type specimen appear to be slightly better developed than those in VP 10001. The external labial grooves between the para- and mesostyles of P^3-M^3 are very strongly developed. In occlusal view, they are deepest just anterior to the mesostyles. The groove between the mesostyle and the metastyle is well developed but less prominent than the above. In this respect, VP 10001 differs from the type specimen of *E. conversidens* in which the posterior groove is better developed.

The roots of M^3 are strongly curved posteriorly. In occlusal view, the crown is reduced in size. No evidence of a hypoconal fossette was noted on VP 10001. The hypoconal groove is present and well developed on all the teeth except M^3, where it is reduced.

Discussion

Equus conversidens was originally described by Owen in 1869, apparently from photographs sent to him of a specimen from the Upper Becerra Formation, Valley of Tequixquiac, Mexico. The holotype, consisting of both maxillaries, right and left P^2-M^3, and part of the palate, was rediscovered and redescribed by Hibbard (1955). Quinn (1957) included *E. conversidens* in *Asinus* (where the species surely does not belong). Dalquest and Hughes (1965) referred material from Canyon and Slaton, Texas, to *E. conversidens* and reviewed the species, placing several nominal species in synonomy. They demonstrated that *E. conversidens* is known from Mexico, Arizona, New Mexico, Texas, Oklahoma, Kansas and Florida. The species ranges in age from Yarmouthian to Wisconsinan. Lundelius (1972) described a partial skull from the Blackwater Draw Locality No. 1 in eastern New Mexico. VP 10001 probably represents the best intact upper dentition of *E. conversidens* yet reported from New Mexico.

Since the publication of Dalquest and Hughes (1965), the known or reported occurrences of *E. conversidens* have expanded greatly. Churcher (1968) described a broken M^3, a P^3, and five upper incisors from Cochrane, Alberta. He referred these to *E. conversidens* along with other skeletal material. Corner (1977) assigned but did not describe lower teeth and incomplete skeletal material to *E. conversidens,* largely on the basis of size, from Red Willow County, Nebraska.

Mooser and Dalquest (1975) once again discussed the type material from Mexico in addition to other material now referred to *E. conversidens.* They removed *E. tau* from synonomy with *E. conversidens,* resulting in the prospect of sympatric species, presumably doing the same things in similar environments and competing with one another. Lundelius (1972) presents an argument against this hypothesis.

If the referrals of Churcher (1968) and Corner (1977) are valid, the range of *E. conversidens* would be very great. A more southern distribution might be considered more appealing for the form, at least in terms of Pleistocene biogeographic analyses.

The remains of small Pleistocene horses are not uncommon in the southern Great Plains (Dalquest and Hughes, 1965). Whether all of the recovered material can be reasonably included within a relatively broad concept of *Equus conversidens* remains to be determined. At present, VP 10001 is best referred to this species on the basis of morphologic features and comparative measurements. Dental distinctions of VP 10001 have been noted, but at present these are best considered as normal variations to be expected of a species with a relatively broad geographic range and a relatively long temporal range. A larger sample as well as a concerted comparative study emphasizing geographic locality and temporal relationships might well separate distinct populations and lead to the recognition of new (and valid) species or even subgenera.

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Financial statement

New Mexico Bureau of Mines and Mineral Resources
July 1, 1979, to June 30, 1980

Funds available			
Beginning balance July 1, 1979		$ 9,254*	
State appropriation		1,384,800	
Publication receipts		49,409	$1,443,463
Expenditures			
Salaries:			
Full-time staff	$772,911		
Part-time staff (students)	105,846	$ 878,757	
Employee benefits		106,898	
Project contracts		74,828	
Travel & vehicles		56,496	
Scientific laboratories:			
Maintenance	$ 15,306		
Materials & supplies	34,767	$ 50,073	
Office supplies		8,418	
Postage & freight		10,255	
Printing		84,408	
Equipment		37,935	
General expenses:			
Telephone	$ 15,993		
Subscriptions & dues	3,697		
Computer service	3,945		
Overhead & audit (to Tech)	61,195		
Heat, water, electricity	27,620	$ 112,450	$1,420,518
Balance June 30, 1980			$ 22,945

*changed by NMT from $10,774.