Annual Report

July 1, 1978 to June 30, 1979

Contributed articles

Kritosaurus navajovius
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see page 3

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

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

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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November 15, 1979

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, 1978 through June 30, 1979, as required by law (Section 3, Chapter 115, Eighth New Mexico Legislature, approved March 14, 1927).

In this, our 52nd year of service and applied research, the Bureau provided information concerning exploration, development, and conservation of New Mexico's geology and mineral resources. This information was dispersed in 8,300 letters, 5,190 telephone inquiries, 7,390 visitations in our offices and the 21,200 copies of our technical reports distributed during the year. Nineteen new mineral resource documents were published. More than 3,800 analytical reports were prepared on mineral, ore, metallurgical, and water samples. About 8,900 copies of our publications were distributed without charge to state officials, libraries, and scientific agencies worldwide.

The Bureau's service to New Mexico is based on the expertise and dedication of our staff. Early in the fiscal year we lost 14 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 was a significant problem.

Ongoing programs were continued; investigations in applied research in coal, uranium, and petroleum were increased. The Bureau cosponsored both the international symposium on the Rio Grande rift and the symposium on the Grants uranium region. Charles E. Chapin chaired the program for the rift symposium; Christopher Rautman, the uranium symposium. John W. Hawley headed field trips for the rift symposium. During the year, James M. Robertson served as president of the New Mexico Geological Society and Robert W. Kelley served as president of the Association of Earth Science Editors. Many other staff members also assisted programs of other professional and scientific organizations.

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, 1978 to June 30, 1979

by

Frank E. Kottlowski
and staff

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Purpose and functions

INTRODUCTION

For 52 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, 35 memoirs, 167 circulars, 10 ground-water reports, 4 hydrologic reports, 1 hydrogeologic sheet, 48 geologic maps, 12 scenic-trip guidebooks, 10 progress reports, 10 resource maps, and 103 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 1978, the value of minerals extracted in New Mexico totaled more than $3.1 billion. Payments from the U.S. Bureau of Land Management and compensatory reimbursement in lieu of taxes totaled $70.4 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 1978 plus bonuses and royalties totaled $291 million. Thus, New Mexico's mineral industry contributes substantially to the state's economy.

Most of the talents 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 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 several billion dollars, are freely accessible at the Bureau; the value of these files increases with the passing of time.

COVER SKETCH—Skull and reconstructed head of *Kritosaurus*. This genus commonly occurs in Late Cretaceous deposits in the San Juan Basin, New Mexico. The upper figure actually represents a Canadian specimen. Similar, if not identical, specimens can be found in New Mexico; however, the type specimen of *Kritosaurus navajovius* from the Kirtland Formation, San Juan Basin, New Mexico, was improperly reconstructed.

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 $56,800 this fiscal year; about 8,900 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 comprises "ground truth" investigations, as demonstrated by the more than 265,000 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 8,300 letters and 5,190 telephone inquiries were answered, and 7,390 office visitors were counseled. Many adults and school children toured the Bureau's mineral museum. More than 3,800 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 71,000 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

Analytical and x-ray

The Bureau's laboratories are equipped to perform extensive chemical, mineralogical, and petrological tests. Chemical analyses, both qualitative and quantitative, are performed by classic wet-chemical and optical-spectrographic procedures as well as by atomic absorption, x-ray, and electron-microprobe spectrometry. Capabilities include analyzing water, ores, concentrates, geological samples, and leach liquids for the common elements and parameters. This year a total of 2,145 analytic reports on 721 samples was prepared, in addition to partial analyses of 1,620 samples by x-ray methods.

New Mexico Library of Subsurface Data

Industry, graduate students, and staff geologists continued to make heavy use of our data files. Data was supplied to 825 office visitors and, in addition, to 434 persons who made telephone inquiries.

During the year, 1,003 boxes (representing 484 wells) of well cuttings were added, bringing the total number of represented wells on hand to more than 10,500. Also, electric and other types of mechanical logs for 1,267 wells and 1,706 well records were acquired from drilling operations. The Oil Conservation Division of the Energy and Minerals Department continued to make duplicate mechanical logs available to the library, and Continental Oil Company contributed approximately 3,000 logs to our library.

The library continues to be an important source of data for coal, uranium, and carbon-dioxide exploration as well for petroleum exploration.

METALLURGY

The Bureau metallurgy group performed routine metallurgical tests and provided technical assistance in both metallurgy and biology as applied to mining. Research conducted through federal and state-supported grants contributed to the development of techniques for extraction of metals from ores occurring in the Southwest. The staff published research data and presented talks at professional meetings, industrial establishments, educational institutions, and civic organizations.

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, nine 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 38 new specimens valued at approximately $1,000.00. The museum staff also prepared 4 special exhibits that were shown at mineral and gem club shows around the state.

An international symposium, Tectonics and Magmatism of the Rio Grande Rift, was held in Santa Fe, October 8-17, 1978. The meeting was sponsored by Working Group 4 of the Inter-Union Commission on Geodynamics and by nine other organizations, including the New Mexico Bureau of Mines and Mineral Resources.

About 190 geoscientists attended the symposium, which included representation from 13 foreign countries. Eighty-seven papers were presented. Field trips were held before, during, and after the technical sessions. Road logs and descriptive articles of routes from El Paso to Santa Fe to Denver and back to El Paso were published in *Guidebook to the Rio Grande rift in New Mexico and Colorado,* our Circular 163, compiled by John W. Hawley. Selected reports from the symposium were published in American Geophysical Union special publication *Tectonics and magmatism of the Rio Grande rift,* edited by R. E. Riecker. Program chairman for the symposium was Charles E. Chapin.

A symposium on the geology and uranium resources of the Grants uranium region was held in Albuquerque, May 13-16, 1979. Sponsored jointly by the New Mexico Bureau of Mines and Mineral Resources, the Energy Minerals Division of the American Association of Petroleum Geologists (AAPG), and the Central New Mexico Section of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME), the symposium was attended by more than 850 persons, including geologists from Canada, England, France, Japan, Mexico, South Africa, and West Germany. A field trip to the active uranium-mining areas prior to the technical sessions was led by A. Eugene Saucier and William L. Chenoweth.

More than 40 papers were presented at the symposium; these are being edited by the program chairman, Christopher Rautman, and are scheduled to be published as our Memoir 38.

February 8-9, 1979, the U.S. Geological Survey and New Mexico Bureau of Mines and Mineral Resources sponsored a meeting on the Silver City (New Mexico and Arizona) 1:250,000 quadrangle CUSMAP project. The USGS's Conterminous United States Mineral Appraisal Program is designed to provide information for national minerals policy and for federal, industry, and state decisions concerning the resources. The purpose of the meeting, which was attended by more than 70 geologists and engineers, was to describe the Silver City CUSMAP project, its plans and goals, review work being accomplished, and to seek advice and comment so that the project could be structured to fit the needs of land-management and resources agencies, industry, and the general public.

ACKNOWLEDGMENTS—Preparation of the annual report is the product of input by the entire staff. Particular acknowledgment is made to Candace Holts, Joan Pendleton, and Robert Kelley for editing and compilation, William Arnold for drafting, Judy Peralta for compilation and typing, and Arleen Montoya, Virginia Baca, and Kathy Eden for typing of the various manuscripts and lists.

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

TABLE OF ORGANIZATION

as of January 1979

Administration & information
- Director
- Deputy Director
- Executive Secretary
- Buildings Technician
- Vehicle Technician
- Driller
- Receptionist/Secretary
- Assistant Driller
- Librarian/Typist

Business office & publication sales
- Office Manager
- Secretary I
- Staff Secretary

Drafting & illustrating
- Chief Scientific Illustrator
- 3 Scientific Illustrators

Editing & publishing
- Editor-Geologist
- Associate Editor
- 2 Assistant Editors
- Editorial Clerk

Environmental geology
- Environmental Geologist
- Field Geologist

Geophysics
- Geophysicist (part-time)
- Geophysical Engineer
- Assistant Geoscientist

Hydrogeology & geothermal
- Hydrogeologist
- Geophysicist (part-time)
- Geologist
- Field Geologist (part-time)

Industrial minerals & coal
- Senior Geologist
- 3 Coal Geologists
- Industrial Minerals Geologist
- Field Geologist

Metallic ores
- Senior Geologist
- Mining Geologist
- Petrologist (part-time)
- Economic Geologist
- Volcanologist

Metallurgy & chemistry
- Research Metallurgist
- Mining Engineer
- Chemist
- Chemical Microbiologist
- Laboratory Biotechnologist

Mineralogy & x-ray
- Mineralogist
- Petrologist (part-time)
- Geological Technician

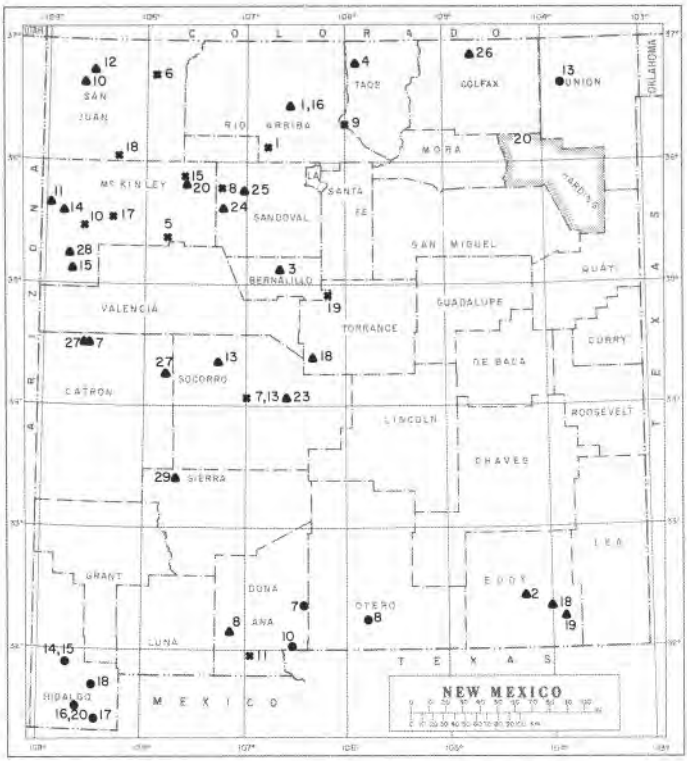
Oil & gas
- Senior Petroleum Geologist
- 2 Petroleum Geologists
- Laboratory Technician
- Secretary

Paleontology
- Paleontologist
- Vertebrate Paleontologist (part-time)
- Emeritus Paleontologist
- Paleontological Preparator-Curator

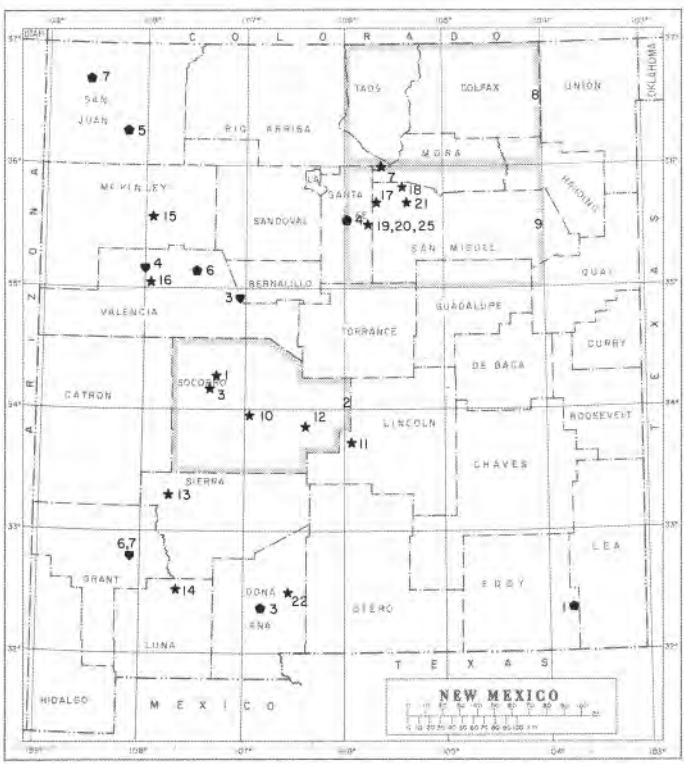
partly funded by the Bureau, are listed in this section. An index map of field projects is shown on pages 8 and 9. A list of part-time research associates on contract to the Bureau appears on page 16. Current Bureau staff is listed on pages 29-33, and staff employed during the fiscal year is given on page 29.

Industrial minerals and coal

1. Austin—Shale and clay resources of New Mexico
2. Austin—Geology and mineral deposits of Ochoan rocks in Delaware Basin and adjacent areas (in cooperation with New Mexico Geological Society; Circ. 159)
3. Austin and Siemers—1981 Industrial Minerals Forum
4. Austin and Weber—Perlite deposits of New Mexico
5. Baker, Anderson, Nickelson, K. Frost, Wolberg, J. Osburn, and Skotte—Inventory of abandoned surface mines in New Mexico (in cooperation with New Mexico Bureau of Surface Mining and U.S. Office of Surface Mining)
6. Brierley—Leaching of pyritic sulfur from coal (in cooperation with Texas Industries; informal report available)
7. Campbell—Coal resources of Cerro Prieto quadrangle
8. Cima (Austin)—Scoria deposits in New Mexico (thesis available; article in this report by J. Cima Osburn)
9. Frost—Chemical data on New Mexico coals

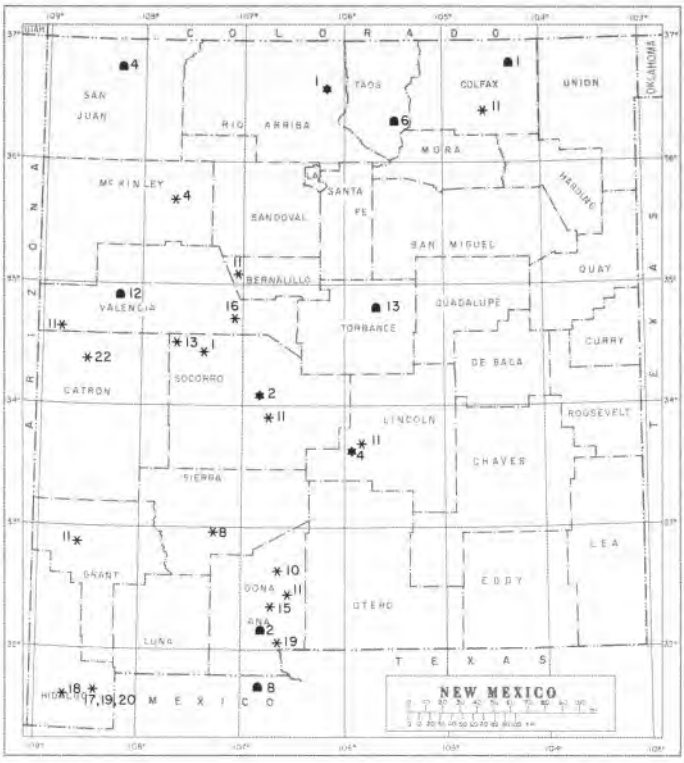


- ▲ Industrial minerals and coal
- ● Oil and gas
- ■ Water resources and geothermal

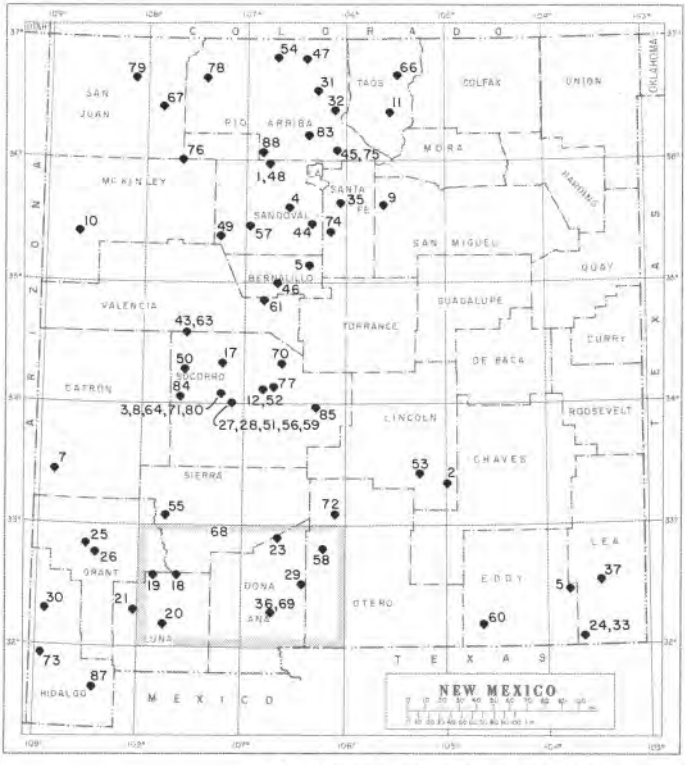


- ● Environmental geology
- ★ Metallic ores and mining districts
- ♥ Metallurgy and chemistry

INDEX MAPS OF BUREAU FIELD PROJECTS.



- Mineralogy and x-ray
- Geophysics
- Paleontology



- Geology, geologic mapping, stratigraphy, and special projects

INDEX MAPS OF BUREAU FIELD PROJECTS.

10. Frost—Coal bibliography (continuing update)
11. Frost—Coal-mine file (continuing update)
12. Kottlowski, Tabet, and Frost—New Mexico coal seams (1979 Keystone Coal Industry Manual)
13. Massingill (Chapin)—Cretaceous coals and Tertiary uranium in Riley-Puertecito area (thesis available; Open-file Rept. 107)
14. Nickelson and Frost—History of coal mining in New Mexico
15. Owen and Levinson—Analyses of coals and shales in Dakota Sandstone of southern and western San Juan Basin (thesis available)
16. Russell (Austin)—Refractory clays of Dakota Formation of eastern San Juan Basin (thesis available)
17. Siemers—Evaluation of the economic potential of New Mexico limestones
18. Siemers, Austin, and Kottlowski—Industrial minerals of New Mexico
19. Siemers, Hawley, Rautman, and Austin—Evaluation of mineral potential (excluding hydrocarbons, potash, and water) of the WIPP site (in cooperation with Sandia Corp.; Open-file Rept. 87)
20. Speer, Beaumont, and Shomaker—Coal resources of the San Juan Basin (in cooperation with New Mexico Bureau of Geology; Open-file Rept. 84)
21. Spence—Computerization of active and abandoned coal-mines data
22. Spence and Tabet—Computerization of point-source coal data for New Mexico (in cooperation with U.S. Geological Survey)
23. Tabet—Jornada del Muerto coal field in Socorro County (Circ. 168 in press)
24. Tabet and Frost—Reserves of Menefee coals in Torreon Wash area (in cooperation with U.S. Geological Survey; Open-file Rept. 102; GM 49)
25. Tabet and Frost—Coal resources of New Mexico (continuing update)
26. Tabet and Frost—Coal-resources map of New Mexico (Resource Map 10)
27. Tabet, Frost, Hook, and Campbell—Coal resources of the Salt Lake and Datil Mountains coal fields (in cooperation with U.S. Geological Survey)
28. Tabet and Massingill—Coal geology of the Pinehaven 7½′ quadrangle (in cooperation with U.S. Geological Survey)
29. Weber—Zeolites of New Mexico

Oil and gas

1. Austin, Myers, Bieberman, Reiter, Siemers, and Frost—Energy-resources map of New Mexico (in cooperation with U.S. Geological Survey)
2. Bieberman—Oil and gas fields, exploration tests, and major-pipelines map of New Mexico
3. Bieberman—Catalog of samples available in New Mexico Library of Subsurface Data (continuing update)
4. Bieberman—Scout-information file, mechanical-log file, lithologic-log file, driller's-log file, and county petroleum-exploration maps (continuing update)
5. Bieberman, Bolt, Robertson, and J. Osburn—Precambrian structural and lithologic map of New Mexico
6. Christiansen—History of oil and gas exploration and production in New Mexico
7. Foster, Hawley, and Austin—Evaluation of oil, gas, and other mineral resources on state lands in White Sands Missile Range (Open-file Rept. 92)
8. King—Petroleum potential of Otero Mesa region, south-central New Mexico
9. Kottlowski and Thompson—Estimates of energy resources of New Mexico 1979 (in this report)
10. Potter and Thompson—Paleocurrents in the Bliss Formation of southwestern New Mexico and western Texas
11. Renault—Application of carbonate thermoluminescence to petroleum exploration
12. Renault—Application of crystallite size variation in cherts to petroleum exploration
13. Scott—Carbon-dioxide fields in northeast New Mexico
14. Thompson—Petroleum geology of southwestern New Mexico
15. Thompson—Analyses of petroleum source and reservoir rocks in southwestern New Mexico (in cooperation with New Mexico Energy Institute)
16. Thompson—Subsurface geology of the Cockrell No. 1 Playas well, Hidalgo County
17. Thompson—Subsurface geology of the Humble No. 1 State BA well, Hidalgo County
18. Thompson and Jacka—Pennsylvanian stratigraphy, petrography, and petroleum geology of the Big Hatchet Peak section, Hidalgo County
19. Thompson and Kottlowski—Recursos energeticos de Nuevo Mexico
20. Thompson, Tovar, and Conley—Oil and gas exploration wells in the Pedregosa Basin (New Mexico Geological Society guidebook no. 29)

Water resources and geothermal

1. Anderholm (Stone)—Hydrogeology and water resources of Cuba 15-minute quadrangle
2. Brandvold—Mercury in New Mexico surface waters (Circ. 162)
3. Brandvold—Water Quality Control Commission projects (continuing update)
4. Brandvold—Water analyses file (continuing update)
5. Brod (Stone)—Hydrogeology and water resources of the Ambrosia Lake-San Mateo area
6. Brown and Stone—Hydrogeology of Aztec quadrangle (Hydrogeologic Sheet 1)
7. Chapin, Chamberlin, and G. Osburn—Geology and geothermal potential of Socorro area (supported by Energy Resources Board; Open-file Rept. 88)
8. Craigg (Stone)—Hydrogeology and water resources of the Torreon Wash-Chico Arroyo area
9. May—Geology and geothermal potential of Ojo Caliente-Rio Chama area, Rio Arriba and Taos Counties
10. Mizell and Stone—Regional extent of sandstone bodies within Gallup Sandstone (Open-file Rept. 88)
11. Mizell and Stone—Geothermal leasing and exploration activity computer-data file/display (continuing update)
12. Reiter—Geothermal analysis of uplift-and-basin formation
13. Reiter and Mansure—Subsurface temperature data in the Socorro Peak KGRA
14. Reiter and Stone—Relations between subsurface temperatures and ground-water movement in southern San Juan Basin
15. Stone—Hydrogeology and water resources of northwestern New Mexico (in cooperation with U.S. Geological Survey and New Mexico State Engineer; Open-file Repts. 89, 90, 91, and 105)
16. Stone—Computerization of New Mexico Bureau of Mines and Mineral Resources water-resource data (continuing update)
17. Stone—Hydrogeology of Gallup Sandstone, San Juan Basin (in review for *Ground Water*)
18. Stone, Brod, and Anderholm—Description of cuttings from Navajo water wells drilled in New Mexico—1977 (Open-file Rept. 82)
19. Titus—Ground-water resources of Sandia and Manzano Mountains (in cooperation with U.S. Geological Survey)
20. Trauger—Ground-water resources and geologic map of Harding County (in cooperation with U.S. Geological Survey)

Environmental geology

1. Foster—Evaluation of proposed site for disposal of nuclear waste, WIPP; I. mineral resources and II. historical review (informal report available)
2. Hawley—Quaternary geology of New Mexico
3. Hawley—Geology and geomorphology of Desert Project area in Doña Ana County
4. 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)
5. Hawley, 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)
6. Hunt—Physiographic map and description of New Mexico
7. Tabet, Sheffer, and Inglis—Landsat imagery as a tool for monitoring coal surface mining and reclamation (Technical Applications Center TR 78007)

Metallurgy and chemistry

1. Brandvold—Directory of commercial analytical laboratories in the southwest (New Mexico Geology, v. 1, no. 3)
2. Brandvold—Reliability of commercial laboratories for gold and silver analyses (New Mexico Geology, v. 1, no. 1)
3. Brandvold—Heavy metal and nutrient load of the Rio San Jose-Rio Puerco system
4. Brandvold—Round-robin selenium analyses (in cooperation with Environmental Improvement Division, Kerr-McGee Corp., United Nuclear-Homestake Partners, and Controls for Environmental Pollution)
5. Brandvold—A freezing technique for purifying uranium mining-and-milling waste waters
6. Brierley—Review of bacterial-leaching processes in extraction of copper and uranium (published by Chemical Rubber Co. in Critical Reviews in Microbiology)
7. Brierley—Column leaching of low-grade chalcopyrite ores using thermophilic bacteria (in cooperation with U.S. Bureau of Mines)

8. Brierley—Electrochemistry of bacterial attack of copper-sulfide minerals (in cooperation with Metallurgy Dept., University of Utah)
9. Brierley—Biological methods to remove selected pollutants from uranium-mine waste water (in cooperation with New Mexico Water Resources Research Institute)
10. Brierley—Application of bacterial-leaching technology to deep solution mining of uranium (in cooperation with New Mexico Energy and Minerals Department)
11. Brierley—Leaching of pyritic sulfur from coal (in cooperation with Texas Industries)
12. Brierley—Microbial fouling of ion-exchange resins and lixiviant restoration apparatus (in cooperation with Rocky Mountain Energy Co.)
13. Brierley—Microbial plugging of in-situ uranium operations (in cooperation with Nuclear Dynamics)
14. Kelly, Norris, and Brierley—Microbiological methods for extraction and recovery of metals (published in Symposium of Society for General Microbiology)

Metallic ores and mining districts

1. Cather (Chapin)—Sedimentary petrology of the Baca Formation in Alamo Reservation area (in cooperation with University of Texas, Austin)
2. Chapin and G. Osburn—Geology and mineral resources of Socorro County
3. Chapin and G. Osburn—Geology and mineral resources of Magdalena area
4. Chapin and G. Osburn—Data bank of radioactive dates, isotopic analyses, and chemical analyses of igneous rocks in New Mexico (continuing update)
5. Eveleth, Mardirosian, Weber, and Siemers—Mineral industry location system (MILS) for New Mexico (in cooperation with U.S. Bureau of Mines)
6. Eveleth—The 1872 mining law—is it really obsolete?
7. Grambling (Robertson)—Precambrian rocks and mineral deposits in Truchas Peaks area (thesis available)
8. Griswold, Austin, Rautman, and Reid—Uranium resources of Santa Fe 2° quadrangle (in cooperation with U.S. Dept. of Energy and Bendix Field Engineering)
9. Griswold, Austin, Rautman, and Reid—Uranium resource of Raton 2° quadrangle (in cooperation with U.S. Dept. of Energy and Bendix Field Engineering)
10. Jahns—Manganese deposits of Luis Lopez district, Lincoln County
11. Jahns—Gold deposits of White Oaks mining district, Lincoln County
12. Kottlowski and Steensma—Barite-fluorite-lead mines of Hansonburg mining district (New Mexico Geology, v. 1, no. 2)
13. McMillan and Jahns—Structure, petrology, and ore deposits of Chise quadrangle in southern Sierra Cuchillo, Sierra County
14. Proctor—Trace base metals in Cooke's Peak stock
15. Rautman—Uranium resources of New Mexico (continuing status file of uranium industry in New Mexico)
16. Rautman—Non-sandstone uranium deposits in New Mexico
17. Riesmeyer and Robertson—Precambrian geology and ore deposits of the Pecos mining district
18. Robertson—Evaluation of geology and mineral potential of Pecos Wilderness in north-central New Mexico (in cooperation with U.S. Geological Survey)
19. Robertson—Precambrian rocks and mineral deposits of Doctor Creek area, Santa Fe County
20. Robertson—Geochemical data on Pecos greenstone belt in southern Sangre de Cristo Mountains
21. Robertson and Budding—Geology and ore deposits of Rociada-Elk Mountain area
22. Seager—Geology and mineral deposits of Organ Mountains (Mem. 36, in editing)
23. Sheffer and Eveleth—Minerals in the economy of New Mexico (published by U.S. Bureau of Mines, SMP-5)
24. Siemers and Austin with Bieberman, Robertson, Rautman, Shantz, Tabet, and Weber—Mines, processing plants, and power plants in New Mexico (Resource Map 9)
25. Wyman (Robertson)—Ultramafic rocks of Pecos greenstone belt in Cow Creek area

Mineralogy and x-ray

1. North—Mineralogy of the Petaca district
2. North—Guide to New Mexico Bureau of Mines and Mineral Resources Mineral Museum
3. North and Renault—Preparation of x-ray diffraction standards
4. Renault—Geochemistry of Carrizozo basalt flow
5. Renault—Resolution of x-ray diffraction lines-a numerical model
6. Renault—Rapid determination of ash in coal by x-ray fluorescence spectroscopy

Geophysics

1. Edwards, Reiter, Shearer, and Young—Terrestrial heat flow and crustal radioactivity in northeast New Mexico and southeast Colorado (Geological Society of America, Bull. 89)
2. Keller, G. R.—Aeromagnetic mapping of Tortugas Mountain area, Doña Ana County
3. Reiter—Isothermal (100°C) map of New Mexico
4. Reiter—Geothermal characteristics of the San Juan Basin
5. Reiter—High-precision high-temperature logging techniques
6. Reiter, Shearer, and Mansure—Geothermal characteristics of the southern Rocky Mountain complex (American Geophysical Union)
7. Reiter, Mansure, and Shearer—Geothermal characteristics of the Colorado Plateau (Tectonophysics, v. 61)
8. Reiter and Tovar—Heat-flow analysis in northern Mexico
9. Sanford—Continuing survey of earthquakes in New Mexico
10. Shearer and Reiter—Regional heat-flow studies in western New Mexico and Arizona (in cooperation with U.S. Dept. of Energy)
11. Shearer and Reiter—Compilation of basic heat-flow data in New Mexico (Open-file Rept. 93)
12. 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)
13. 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. Chaiffetz (Chapin)—Palynology of Cretaceous and Eocene rocks in the Riley-Puertecito area, Socorro County (in cooperation with University of Texas, El Paso)
2. Cobban and Hook—Paleontology of the Late Cretaceous "Cephalopod Zone" of Herrick (1900)
3. Cobban and Hook—*Collignoniceras woollgari woollgari* (Mantell) subzone ammonite fauna from Upper Cretaceous of Western Interior (Mem. 37)
4. Cross, Taggart, and Jameossanaie—Paleobotanical study of Menefee Formation in South Hospah area (in cooperation with Chaco Energy Co.)
5. Flower—Ordovician correlations (in preparation)
6. Flower—Faunas of the New Mexico Devonian
7. Flower—Studies of Endoceratida and Tarphyceratida
8. Flower and LeMone—Faunal and petrographic studies of Bliss Sandstone, El Paso Group and Montoya Group
9. Gutjahr and Hook—A statistical method for analysis of planispiral coiling (Circ. 173)
10. Hook and Cobban—Stratigraphy and paleontology of Cretaceous rocks of Cooke's Range
11. 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, and h) Springer area
12. Hook and Cobban—Type Juana Lopez Member of the Mancos Shale
13. Hook, Cobban, and Siemers—Stratigraphy, paleontology, sedimentology, and regional relationships of Upper Cretaceous Tres Hermanos Sandstone
14. Johnson (Hattin)—Sedimentology and trace fossils of Cooke's Peak Greenhorn beds
15. King—Fusulinids of the Hueco Formation in the Las Cruces area
16. Kukalova-Peck—Late Paleozoic fossil insects of Carrizo Arroyo region
17. LeMone—Cretaceous faunas in Big Hatchet Mountains
18. LeMone and Simpson—Upper Paleozoic faunas of Winkler anticline, Hidalgo County
19. LeMone and Simpson—Wolfcampian megafauna and biostratigraphy of Franklin and Big Hatchet Mountains
20. LeMone, Simpson, and Neilsen—Permian megafaunas of Big Hatchet Mountains
21. Leonard and Frye—Stratigraphy and paleontology of Ogallala Formation in New Mexico (includes Circ. 160 and Circ. 161)
22. Schiebout and Schrodt—Biostratigraphy of Baca Formation near Quemado
23. Sorauf—Devonian corals from south-central New Mexico
24. Taylor—Freshwater mollusks of New Mexico
25. Tschudy—Normapolles pollen from *Aquilapollenites* province, western United States (Circ. 170, in press)

Geology, geologic mapping, stratigraphy, and special projects

1. Adams (Anderson)—Petroliferous Pennsylvanian rocks in Nacimiento Mountains
2. Allen, J., Kottlowski, Spence, and Pendleton—Revision of Scenic Trip No. 3, Roswell-Capitan-Ruidoso

3. Allen, P. (Chapin)—Geology of the Hop Canyon-Mill Canyon area, Magdalena Mountains
4. Anderson (Wells and Hawley)—Cenozoic terrace and pediment deposits in Taos Plateau area
5. Armstrong, Kottlowski, Stewart, Mamet, Baltz, Siemers, and Thompson—Mississippian and Pennsylvanian Systems of New Mexico (summary chapter for U.S. Geological Survey Prof. Paper; IX-ICC International Carboniferous Congress, in press)
6. Balk—Stratigraphic nomenclature of New Mexico
7. Bikerman—Age-dating volcanic rocks in Mogollon area
8. Bowring (Chapin)—Geology of the central Magdalena Mountains (thesis available)
9. Bowring (Robertson)—Ages and isotopic geochemistry of Precambrian rocks in northern and central New Mexico
10. Campbell, C. V.—Model for beach shoreline in Gallup Sandstone (Upper Cretaceous) of northwestern New Mexico (Circ. 164)
11. Casey and Scott—Basin evolution of Late Paleozoic Taos Trough, northern New Mexico
12. Chamberlin (Chapin)—Geology of Socorro Peak and the Lemitar Mountains
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
16. 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.)
17. Chapin, G. Osburn, Frost, and Hook—Geology and energy potential of the Colorado Plateau margin in the Riley-Alamo Reservation region (supported by Energy Resources Board; Open-file Rept. 103)
18. Clemons—Geology of Good Sight Mountains and Uvas Valley, southwest New Mexico (Circ. 169)
19. Clemons—Geology and mineral resources of Massacre Peak 7½′ quadrangle (Geologic Map 51)
20. Clemons—Geology of the Florida Mountains region
21. Clemons, Thompson, and Stone—Revision of Scenic Trip No. 10, southwestern New Mexico
22. Coffin (Chapin)—Geology of the east half of the Dog Springs quadrangle, Socorro County
23. Condie—Precambrian rocks of south-central New Mexico (Mem. 35)
24. Crawford and Pray—Carbonate facies of Goat Seep reef in Guadalupe Mountains
25. Cunningham—Circle Mesa quadrangle
26. Cunningham—Revision of geologic map of Silver City 7½′ quadrangle
27. D'Andrea (Chapin)—Geochemistry of potassium-metasomatized volcanic rocks in the Socorro area (in cooperation with Florida State University)
28. Donze (Chapin)—Geology of the Squaw Peak area, western Magdalena Mountains
29. Dunning (Wilson)—Channel deposits in Holder Formation (Pennsylvanian) of Sacramento Mountains (thesis available)
30. Fleischhauer and Stone—Quaternary geology of Lake Animas, Hidalgo County
31. Gibson (Robertson)—Precambrian geology of Burned Mountain-Hopewell Lake area, Rio Arriba County
32. Griffiths (Ingersoll)—Tertiary rocks of Ojo Caliente-La Madera area (field report available)
33. Harris (Pray)—Geologic study of Cutoff Formation of southern Guadalupe Mountains
34. Harrison (Chapin)—Geology of the west half of the Dog Springs quadrangle, Catron County
35. Hawley—Guidebook to the Rio Grande rift (Circ. 163)
36. Hawley, Gile, and Grossman—Quaternary geology and soil-geomorphic relations in Las Cruces region
37. Hawley and Sandor—Quaternary map of New Mexico—southeast sector
38. Heljeson and Holts—Bibliography of New Mexico geology and mineral technology, 1976 through 1980
39. Heljeson and Holts—Supplement to bibliography of New Mexico geology and mineral technology through 1975 (Bull. 108, in edit)
40. Holts—History of New Mexico Bureau of Mines and Mineral Resources as recorded in legislation, annual reports, and notes (Open-file Rept. 100)
41. Holts—Fayette A. Jones, mining engineer (New Mexico Geology, v. 1, no. 4)
42. Hurley (Pray)—Facies of Seven Rivers and Yates Formations, North McKittrick Canyon, Guadalupe Mountains (thesis available)
43. Jackson (Chapin)—Geology of the Abbey Springs-Puertecito area
44. Kautz (Ingersoll)—Sedimentary and petrological study of Espiñaso Formation in southeast Sandoval County
45. Kelley, V.—Geology of Española Basin (Geologic Map 48)

46. Kelley, V., and Kudo—Volcanoes and related basalts of Albuquerque Basin (Circ. 156)
47. Kent (Robertson)—Precambrian rocks of the Tusas area
48. Kurtz (Anderson)—Poleo Sandstone member of Chinle Formation in Nacimiento Mountains (thesis available)
49. LaFon—Sedimentology and depositional environments of Upper Cretaceous Semilla Sandstone Member of Mancos Shale
50. LaRoche (Chapin)—Geology of the Gallinas Peak area, Socorro County
51. Lindley (Chapin)—Geochemistry of propylitically altered ash-flow tuffs in the Socorro area (in cooperation with University of North Carolina; thesis available)
52. Mayerson (Chapin)—Geology of the Corkscrew Canyon-Abbey Springs area, Socorro County (thesis available)
53. Milner—Genesis, provenance, and petrography of Glorieta Sandstone of eastern New Mexico (Circ. 165)
54. Muehlberger—Scenic Trip No. 13 to Española-Chama-Cumbres Pass-Monero-Tres Piedras region
55. O'Brient (Jahns)—Robb Canyon volcanic rocks, Grant County
56. G. Osburn—Geology of the Water Canyon Mesa-Sixmile Canyon area, Magdalena Mountains (thesis available)
57. Owen and Siemers, C.—Dakota units in southeast San Juan Basin between Laguna and La Ventana
58. Pendleton—White Sands National Monument
59. Petty (Chapin)—Geology of the southeastern Magdalena Mountains (thesis available)
60. Pray, Neese, and Schwartz—Lithofacies of Yates-Tansill Formations in Walnut and Rattlesnake Canyons, Guadalupe Mountains (thesis available)
61. Renault—Petrology and geochemistry of volcanic rocks of Cerro de Los Lunas, Cat Hills and Wind Mesa, Socorro and Bernalillo Counties
62. Renault—Thermoluminescence dating of ancient land surfaces
63. Robinson (Chapin)—Geology of the D-Cross 7½ ' quadrangle, Catron and Socorro Counties
64. Roth (Chapin)—Geology of the Sawmill Canyon area, Magdalena Mountains
65. Schilling—Isochron/West, a periodic journal of isotopic geochronology
66. Schilling, Taggart, and Pendleton—Revision of Scenic Trip no. 2, Taos-Red River-Eagle Nest
67. Schultz (Hawley and Wells)—Eolian geomorphology of west-central San Juan Basin
68. Seager, Clemons, Hawley, R. E. Kelley, and Alexander—Geology of Las Cruces 1:250,000 quadrangle
69. Seager, Kottlowski, Hawley, and King—Geology of Robledo Mountains
70. Siemers, T.—Pennsylvanian stratigraphy of west-central New Mexico
71. Siemers, T.—Permian rocks in northern Magdalena Mountains
72. Spence and Decker—Bibliography of Tularosa Basin region
73. Spencer (Ross)—Lower Pennsylvanian rocks of southwesternmost New Mexico
74. Stearns—Ortiz surface in north-central New Mexico
75. Steinpress (Ingersoll)—Late Cenozoic stratigraphy and structure of the Dixon area, Española Basin
76. Stone—Nature of Lewis Shale-Pictured Cliffs Sandstone contact
77. Stone—Quaternary geology and geomorphology of Loma de las Cañas quadrangle
78. Stone—Geology of west half of Aztec 1:250,000 quadrangle (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 North Fork Canyon-Jordan Canyon area, Magdalena Mountains (thesis available)
81. Thompson and Jacka—Guidebook to depositional and diagenetic features in the Guadalupian of New Mexico and Texas
82. Thompson and Slaczka—Concepts and type examples of fluxoturbidites
83. Vazzana (Ingersoll)—Abiquiu Formation near Abiquiu
84. Weber—Geology of Plains of San Agustin
85. Weber—Geology of Mockingbird Gap site
86. Weber—Petrographic and chemical characteristics of seven new meteorites from New Mexico
87. Weise (LeMone)—Carbonate petrology of U-Bar Limestone in Big Hatchet Mountains
88. Woodward—Geology and mineral resources of Jarosa quadrangle (Geologic Map 47)
87. Wright and Kottlowski—Correlation of stratigraphic units in southwest New Mexico and westernmost Texas (COSUNA project)

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Publications

In February the Bureau inaugurated a new quarterly journal of science and service entitled *New Mexico Geology*. This periodical features short, mostly technical articles providing insight into state geology and mineral resources. It also publishes information on new publications, sources, conferences, and what is going on around the state. The editor of *NMG*, Neila M. Pearson, transferred to editing from the drafting section on the first of September. Distribution of *NMG* increased to about 900 copies by the time the second issue was released in May. Subscriptions are on an annual basis, with paid subscriptions composing about 80 percent of the total distribution.

The Bureau released 19 new publications (including a pricelist and two leaflets), 5 reissued publications, and 10 open-file reports. Nine new large-scale, full-color map sheets were issued (4 in 2 book reports, 5 in 4 map reports); 9 large-scale, full-color map sheets were reworked and reissued (6 in 2 book reports, 3 in 1 map report).

Pages printed in new publications totaled 734 (679 scientific, 32 pricelist, 16 leaflets, 7 announcement cards). Pages in reissued publications totaled 546 (473 scientific, 73 popular).

Funds allocated to printing totaled $82,541, or about 6.1 percent of the Bureau's overall budget. Approximately 3 percent of the new-publication pages were composed in the Bureau; also, approximately 13 percent of the new-publication pages were printed in the New Mexico Tech printshop. Geologic Map 48 was compiled and printed by Williams & Heintz Map Corporation in Washington, D.C. All other printing continued to be handled by the Printing Plant at the University of New Mexico in Albuquerque. At the close of the fiscal year, 40 manuscripts were in review or pending, while 23 were in edit or in press.

The editing section was staffed with an editor-geologist, one associate editor, two assistant editors, one editorial clerk, two student proofreaders (part time),

and one student bibliographer (part time). In addition to handling the preparation of Bureau publications, the editors also assisted staff in editing their outside papers.

The drafting and illustrating section was staffed with a chief scientific illustrator and three scientific illustrators. Two members attended a workshop in Denver for preparing the illustrations and film materials for color slides. A camera and lettering device were purchased for making slides. Two members also attended a workshop on photographic papers.

About 150 hours of drafting were performed for other offices at Tech. About 770 hours were spent on open-file reports; 120 hours were spent on staff-members' slides and outside publications. The Technology Application Center (University of New Mexico) was assisted with a soils erosion map in exchange for map-making materials. All other drafting time was devoted to primary function of producing maps and illustrations for Bureau publications.

New publications

Circular 156—VOLCANOES AND RELATED BASALTS OF ALBUQUERQUE BASIN, NEW MEXICO, by V. C. Kelley and A. M. Kudo, 1978, 30 p. 16 tables, 32 figs., 2 geologic maps in pocket. $5.00

Discusses petrology, geochemistry, and field relationships of basalts and volcanoes of the Albuquerque Basin; includes color geologic maps.

Circular 159—GEOLOGY AND MINERAL DEPOSITS OF OCHOAN ROCKS IN DELAWARE BASIN AND ADJACENT AREAS, compiled by George S. Austin, 1978, 88 p., 16 tables, 73 figs. $6.50

Contains papers and abstracts of papers presented at the Symposium on the Ochoan Rocks of Southeastern New Mexico and West Texas, at Carlsbad, New Mexico, May 4, 1977.

Circular 162—MERCURY IN NEW MEXICO SURFACE WATERS, by Lynn A. Brandvold, 1978, 16 p., 1 map. $3.50

Discusses analyses of mercury content in selected surface waters and well samples taken over a 4½-year period in New Mexico. A total of 151 samples were analyzed by flameless atomic absorption.

Circular 163—GUIDEBOOK TO RIO GRANDE RIFT IN NEW MEXICO AND COLORADO, compiled by J. W. Hawley, 1978, 241 p., 4 tables, 156 figs., 2 tectonic maps in pocket. $18.00

Discusses the details of geologic features along the rift zone. Included are short papers on topics relative to the overall region. These papers and the road logs are of interest to anyone studying the rift; includes color tectonic maps.

Circular 164—MODEL FOR BEACH SHORELINE IN GALLUP SANDSTONE (UPPER CRETACEOUS) OF NORTHWESTERN NEW MEXICO, by C. V. Campbell, 1979, 32 p., 1 table, 32 figs. $3.50

A model stratigraphic cross section for beach deposits in the Gallup Sandstone (Upper Cretaceous) in the Ship Rock area, northwestern New Mexico, was constructed for comparison with ancient deposits and modern beaches. This model provides a basis for predicting the location of petroleum reservoirs, evaluating source and seal relationships, determining volumes of both the reservoir and the aquifer providing the water drive, and predicting flow patterns within the reservoir.

Circular 165—GENESIS, PROVENANCE, AND PETROGRAPHY OF THE GLORIETA SANDSTONE OF EASTERN NEW MEXICO, by Sam Milner, 1978, 25 p., 3 tables, 23 figs. $3.00

Discusses the upper Yeso and lower San Andres Formations in Lincoln County; includes the Glorietta Sandstone and middle Permian stratigraphy outside of Lincoln County.

Geologic Map 47—GEOLOGY OF JAROSA QUADRANGLE, NEW MEXICO, by L. A. Woodward and R. S. Timmer, 1979, text, 2 cross sections, scale 1:24,000. $2.50

Includes rock units, structure, and tectonic features of Jarosa quadrangle; Nacimiento uplift, Chama Basin, and Jemez volcanic field.

Geologic Map 48—GEOLOGY OF ESPAÑOLA BASIN, NEW MEXICO, by Vincent C. Kelley, 1978, text, 4 cross sections, scale 1:125,000. $5.00

Along with the geologic map of the Albuquerque Basin published in Memoir 33 (Kelley, 1977), covers most of the middle Rio Grande depression; an extensive study of stratigraphic, geomorphic, and structural relationships.

Resource Map 9—MINES, PROCESSING PLANTS, AND POWER PLANTS IN NEW MEXICO, by W. T. Siemers and G. S. Austin, 1979, text in 28-p. pamphlet, scale 1:1,000,000. $4.00

Locates metallic and nonmetallic mines, mineral-processing plants, oil refineries, gas-processing plants, and power plants; includes addresses and production figures.

Isochron/West—Nos. 22, 23, 24, edited by J. H. Schilling, 32 p., 31 p., and 29 p. Available by subscription (6 issues for $12.00)

A serial journal of isotopic geochronology.

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

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

Annual Report—NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, July 1, 1977 to June 30, 1978, by F. E. Kottlowski and staff, 1978, 64 p. $1.00

Summarizes Bureau activities and services for the fiscal year. Also includes mineral production table and articles on mining law, coal industry, Upper Cretaceous guide fossil, and industrial rocks and minerals.

Hydrogeologic Sheet 1—HYDROGEOLOGY OF AZTEC QUADRANGLE, SAN JUAN COUNTY, NEW MEXICO, by D. R. Brown and W. J. Stone, 1979, 5 tables, 12 figs.; includes geologic map (scale 1:62,500) and hydrochemical diagrams, text. $3.00

The Aztec 15-minute quadrangle covers a semiarid to arid area near the center of the San Juan structural basin. This area has relied heavily on surface-water supplies, but population growth has intensified the competition. Water for future municipal and industrial use must be ground water or negotiated surface water.

Leaflet—SCENIC TRIPS TO THE GEOLOGIC PAST—Lists a series of 12 publications. Most of these handbooks take you on guided tours of selected areas of New Mexico via road logs, maps, and color photos. FREE

Leaflet—SILVER CITY, NEW MEXICO-ARIZONA 1°×2° SHEET CUSMAP PROJECT, by New Mexico Bureau of Mines and Mineral Resources and the U.S. Geological Survey. FREE

Magazine—NEW MEXICO GEOLOGY, VOLUME 1, NUMBER 1, edited by Neila Pearson, February 1979, 16 p. Available by subscription (4 issues for $3.00)

The Bureau inaugurated a new quarterly journal of science and service, *New Mexico Geology*, featuring short, mostly technical articles on state geology and mineral resources. Articles: Tertiary geology of Hidalgo County; New methods of working an old mine; Reliability of gold and silver analyses; meetings, publications, abstracts.

NEW MEXICO GEOLOGY, VOLUME 1, NUMBER 2, May 1979, 16 p.

Articles: Barite-fluorite-lead mines of Hansonburg mining district, central New Mexico; Montezuma Hot Springs; Mining, milling, and smelting; Valley of Fires State Park; announcements, new publications, abstracts, reviews.

Re-issued publications

Memoir 15—GEOLOGY AND TECHNOLOGY OF THE GRANTS URANIUM REGION, prepared by The Society of Economic Geologists; V. C. Kelley, general chairman Uranium Field Conference, 1963, 277 p. $8.00

Memoir 24—GEOLOGY OF THE PECOS COUNTRY, SOUTHEASTERN NEW MEXICO, by V. C. Kelley, 1971, 75 p. $7.00

Bulletin 67—MINERAL DEPOSITS OF LINCOLN COUNTY, NEW MEXICO, by G. B. Griswold, 1959, 117 p. $7.00

Geologic Map 31—GRANTS URANIUM REGION, VALENCIA, BERNALILLO, SANDOVAL, AND MCKINLEY COUNTIES, by Chapman, Wood and Griswold, Inc., 1974, text, 3 sheets, scale 1:126,720, revised 1979. $6.00

Scenic Trip 11—CUMBRES AND TOLTEC SCENIC RAILROAD, by H. L. James, 1972, 73 p. $2.50

Open-file reports

OF-82—DESCRIPTIONS OF CUTTINGS FROM NAVAJO WATER WELLS IN NEW MEXICO—1977, by W. J. Stone, R. C. Brod, and S. K. Anderholm, 1978, 81 p., 1 table, 1 fig. $17.60

OF-84—COAL RESOURCES OF THE SAN JUAN BASIN, NEW MEXICO, by W. R. Speer, E. C. Beaumont, and J. W. Shomaker, 1977, 103 p., 4 tables, 3 figs., lease map. $20.60

OF-87—EVALUATION OF THE MINERAL POTENTIAL (EXCLUDING HYDROCARBONS, POTASH, AND WATER) OF THE WASTE ISOLATION PILOT PLANT SITE, EDDY COUNTY, NEW MEXICO, by W. T. Siemers, J. W. Hawley, C. Rautman, and G. Austin, 1978, 48 p., 5 tables, 2 figs., 1 appendix. $9.60

OF-88—EXPLORATION FRAMEWORK OF THE SOCORRO GEOTHERMAL AREA, NEW MEXICO, by C. E. Chapin, R. M. Chamberlin, G. R. Osburn, A. R. Sanford, and D. W. White, 1978, 68 p., 1 table, 3 figs., 5 appendices. $21.70

This report supercedes OF-46 and OF-47.

OF-89—BASIC SUBSURFACE DATA COMPILED FOR HYDROGEOLOGIC STUDY OF THE SAN JUAN BASIN, NORTHWEST NEW MEXICO, by W. J. Stone and N. H. Mizell, 1979, 41 p., 28 plates. $39.20

OF-92—OIL AND GAS EVALUATION OF THE WHITE SANDS MISSILE RANGE AND FORT BLISS MILITARY RESERVATION, SOUTH-CENTRAL NEW MEXICO, by R. W. Foster, July 1978, 82 p., 10 tables, 22 figs., 2 appendices. $30.00

OF-93—BASIC HEAT-FLOW DATA IN NEW MEXICO, compiled by C. Shearer and M. Reiter, September 1978. Available for inspection in Bureau office.

OF-94—BACA FORMATION, by G. L. Massingill, 17 p., 7 figs. Map $1.00; text $3.40

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Austin, G., "Potash deposits of New Mexico," to Horseshoe Bend Rotary Club, Horseshoe Bend, Arkansas, July

———, "New Mexico mineral resources," to Association of New Mexico Bankers, Socorro, May

Brandvold, L., "Women and chemistry," to conference on Science and Engineering, Socorro, December

———, "Careers in chemistry," to conference on Women in Science and Engineering, Socorro, March

———, "Reliability of commercial laboratories for gold and silver analyses," to Pacific Conference on Chemistry and Spectroscopy, San Francisco, California, September

———, "Real-world selenium analyses," to National Conference on Environmental Measurements, Denver, Colorado, November

Brierley, C., "Minerals and microbes," to University of Colorado, Boulder, November

———, "The effect of hydrogen peroxide on Thiobacilli," to Society for Industrial Microbiology, Houston, Texas, August

———, "Energy, minerals, and microbes," to Atlantic Richfield Corp. seminar, Dallas, Texas, October

———, "Basics of bacterial leaching," to metallurgy class, New Mexico Institute of Mining and Technology, Socorro, October

———, "Mining of New Mexico coal and reclamation of strip-mined lands," to Beta Sigma Phi, Socorro, October

———, "Mining of New Mexico coal and reclamation of the land," to Zimmerly School, Socorro, November

———, "Microbiology of mining," to Sandia Laboratory seminar, Albuquerque, February

———, "Microbiological methods for the extraction and recovery of metals," to Society for General Microbiology, at University of Cambridge, Cambridge, England, April

———, "Bacterial oxidation of inorganic sulfur," to Ciba Foundation, London, England, April

———, "Principles and applications of geomicrobiology," to Concordia University, Montreal, Canada, May

———, "Minerals and microbes: practices and problems," to Shell Research Laboratory, Sittingbourne, Kent, England, May

Chamberlin, R., "Structural development of the Lemitar Mountain, an intrarift tilted fault-block uplift, central New Mexico," to International Symposium on the Rio Grande Rift, Santa Fe, New Mexico, October

———, "The Cenozoic geology of the Socorro area," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, Socorro, April

———, "The Cenozoic geology of the Socorro area," to Geology Department seminar, Colorado School of Mines, Golden, May

Chapin, C., "Evolution of the Rio Grande rift," to Rocky Mountain Association of Geologists, Denver, Colorado, May

Eveleth, R., "A review of the location-patent system of the American mining law of 1872," to mining class, New Mexico Institute of Mining and Technology, Socorro, November

———, "New methods of working an old mine: case history of the Eberle Group, Mogollon, New Mexico," to First Small-Scale Mining of the World Congress, Queretaro, Mexico, November

Foster, R., "Natural occurrences of CO_2 in the western United States," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, Socorro, October

———, "Economics of CO_2 flooding," to Waterflood Operators, Artesia, New Mexico, November

———, "Natural occurrences of CO_2 in the western United States," to Bravo Dome Study Commission, Tucumcari, New Mexico, December

Hawley, J., "Geology and geomorphology of Desert Project area, Doña Ana County," at New Mexico Soil Scientist Workshop, Las Cruces, October

———, "Approaches to environmental geology in New Mexico," to Soil Conservation Society of America, Albuquerque, New Mexico, January

———, "Geology and geomorphology of Desert Project area," to Department of Geology, University of California at Berkeley, June

———, "Soil-geomorphic relationships, northern San Juan Basin," to USGS Office of Surface Mining workshop on geomorphic concerns in mined-land reclamation, Denver, Colorado, March

Holts, C., "Fayette A. Jones: A profile in diversity," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, Socorro, February

Hook, S., "Stratigraphy, paleontology, regional relationships, and correlation of Cenomanian-Turonian rocks in Acoma, Zuni, and southern San Juan Basin," to U.S. Geological Names Committee, Denver, Colorado, January

Kelley, R., "The editor as a manager," to Association of Earth Science Editors, Butte, Montana, September

Kottlowski, F., "More wilderness or more minerals," at RARE II Forum-New Mexico State University, Las Cruces, December

———, "Mineral museum of New Mexico Bureau of Mines and Mineral Resources," to Socorro Rotary, July

———, "Projects of New Mexico Bureau of Mines and Mineral Resources," to Albuquerque Geological Society, July

———, "Total energy picture in New Mexico in 1979," to Petroleum in the energy environment seminar by New Mexico Oil and Gas Association, Albuquerque, June

Kottlowski and Thompson, "Recursos energéticos de Nuevo México (Energy Resources of New Mexico)," to Sociedad Geologica Mexicana (Mexican Geological Society) in Chihuahua City, Mexico, February

North, R., "Mineral collecting in New Mexico," to Chaparral Rockhounds, Roswell, October

Reiter, M., "Methods in deep, high-precision temperature logging," at USGS-Southern Methodist University Geothermal Conference, Taos, New Mexico, May

———, "Geothermal characteristics of the southern Rocky Mountain complex, including the Colorado Plateau," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, Socorro, October

———, "Geothermal characteristics of the Colorado Plateau," to Lunar and Planetary Institute and Working Group 7 of the U.S. Geodynamics Commission Conference on Plateau Uplift, Mode and Mechanism at Lunar Planetary Institute, Flagstaff, Arizona, August

———, "Geothermal characteristics of the Rio Grande rift within the southern Rocky Mountain complex," to International Symposium of the Rio Grande Rift, Santa Fe, New Mexico, October

Renault, J., "Crystallization," to Thoreau High School, Thoreau, New Mexico, March

———, "Volcanism," to Bernalillo High School, Bernalillo, New Mexico, February

Robertson, J., "The Pecos Greenstone Belt: A Proterozoic volcano-sedimentary sequence in the southern Sangre de Cristo Mountains, New Mexico," to Geological Society of America, Toronto, Canada, October

———, "Geology and mineralogy of some copper-sulfide deposits near Mt. Bohemia, Keweenaw County, Michigan," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, Socorro, November

———, "Intermediate and silicic volcanic and subvolcanic rocks of the Portage Lake volcanics, Michigan," to North-Central section, Geologic Society of America and Institute on Lake Superior Geology, Duluth, Minnesota, May

Siemers, T., "Industrial minerals," to mineral deposits class, New Mexico Institute of Mining and Technology, Socorro, October

———, "Paleozoic stratigraphy of west-central New Mexico," to Bernalillo High School, Bernalillo, New Mexico, January

Stone, W., "Water: key to energy development, northwest New Mexico," to III World Congress on Water Resources, Mexico City, April

Tabet, D., "Depositional environments for Menefee Formation low-sulfur coals in southeastern San Juan Basin of New Mexico," to Ninth International Congress of Carboniferous Stratigraphy and Geology, Urbana, Illinois, May

Thompson, S., "The Fra Cristobal Range from Mitchell Point Exit (Stop S8)," to Rio Grande Rift Symposium Field Conference, Mitchell Point Exit, New Mexico, October

———, "Modern and ancient carbonate buildups, Western Australia," to New Mexico Bureau of Mines and Mineral Resources Geoscience Seminar, Socorro, January

———, "Review of oil and gas research projects," to New Mexico Energy Research and Development Review Board, Socorro, October

Weber, R., "Lithic typology," to Archaeological Society of New Mexico, at Ghost Ranch Seminar, Abiquiu, New Mexico, September

Other activities

Participation in scientific and professional conferences

Administration of Federal Grants Workshop: National Graduate University, October

American Association of Petroleum Geologists: Annual meeting, April; Rocky Mountain Section, May

American Association of Petroleum Geologists, American Institute of Mining Engineers, and New Mexico Bureau of Mines and Mineral Resources: Grants Uranium Symposium, May

American Chemical Society: Annual meeting, October

American Institute of Mining Engineers: National meeting, February; In-situ Uranium Seminar, September; Central New Mexico Section, October

American Institute of Professional Geologists: Annual meeting, December

Archaeological Society of New Mexico: Ghost Ranch Seminar, September; meeting, April

Association of American State Geologists: Annual meeting, June; Federal Liaison Committee meetings, November, March

Association of American State Geologists-U.S. Geological Survey: Central Region meeting, September

Association of Earth Science Editors: Annual meeting, September

Clay Mineral Society: Annual meeting, October

Conference on Chemistry and Spectroscopy: September

Conference on Women in Science and Engineering: March

Forum on Geology of Industrial Minerals: Annual meeting, June

Friends of the Pleistocene: Annual conference, November

Geological Society of America: Annual meeting, October; North-Central Section, May

Geomorphic Concerns in Mineral Land Reclamation by Office of Surface Mining and U.S. Geological Survey: March
Governor's Conference on Inflation: May
Institute on Lake Superior Geology: May
International Symposium on Rio Grande Rift: October
International Water Resources Association: III World Congress, April
Mine Waste Stabilization Committee: June
National Bureau of Standards: Symposium on Accuracy in Powder Diffraction, June
National Cooperative Soil Survey Workshop: October
New Mexico Geological Society: Fall field conference, November
New Mexico Mapping Advisory Committee: October
New Mexico Mining Association: Annual meeting, October
New Mexico Oil and Gas Association: Annual meeting, October
New Mexico Water Well Association: April
Ninth International Congress of Carboniferous Stratigraphy and Geology: May
Sigma Xi: Annual meeting, October
Society of Economic Paleontologists and Mineralogists: National meeting, April; Rocky Mountain Section, December
Society for General Microbiology: April
Society for Industrial Microbiology: August
Soil Conservation Society of America: January
United States Geodynamics Committee: Conference on Colorado Plateau Uplift, October
United States Geological Survey: Geologic Names Committee meeting on Gallup Sandstone, January
United States Office of Surface Mining: Abandoned Mine Lands meetings, February, May
Water Resources Research Institute: Water conference, August

Participation in committees and commissions

Austin—American Institute of Mining, Metallurgical, and Petroleum Engineers-Society of Mining Engineers, Committee on Short Courses; Forum on Geology of Industrial Minerals, Steering Committee; New Mexico Geological Society, Publications Committee

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

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

Brierley—New Mexico branch of American Society for Microbiology (President); New Mexico Tech representative to American Association of University Women; Society for Industrial Microbiology, Membership Committee

Chapin—International Symposium on the Rio Grande Rift (Program Chairman)

Hawley—Geological Society of America/Correlations of Stratigraphic Units of North America Committee; Geological Society of America/Soil Science Society of America, Interdisciplinary Committee; International Symposium of Rio Grande Rift (field trip coordinator); New Mexico Energy and Minerals Dept. of Coal Surface Mining, Regulations Task Force; Group leader on Alluvial Valley Floors & Prime Farmlands

Holts—Association of Earth Science Editors (Associate Editor of newsletter)

Hook—New Mexico Paleontological Task Force

Kelley—Association of Earth Science Editors (Board of Directors and President); Sigma Xi, New Mexico Tech Chapter, Admissions Committee

Kottlowski—American Association of Petroleum Geologists, Stratigraphic Correlations Committee, Publications Committee (Associate Editor), Energy Minerals Division (Publications Councilor); American Commission on Stratigraphic Nomenclature; Association of American State Geologists, Federal Liaison Committee; Geological Society of America, Panel on Access to Federal Lands for Scientific and Educational Purposes; Geological Society of America, Publications Committee (Chairman), Coal Geology Division, Publications Committee; New Mexico Coal Surface Mining Commission; New Mexico Energy Research and Development Review Board; New Mexico Mines Safety Advisory Board (Chairman); New Mexico Mining Association, Board of Directors, and Information and Education Committee; New Mexico Paleontologic Task Force; Potential Gas Committee; Regional Coordinator for COSUNA (Correlations of Stratigraphic Units of North America)

Renault—New Mexico Energy Institute, Advisory Committee; Sigma Xi, New Mexico Tech Chapter (President)

Robertson—International Union of Geological Sciences, Commission on Precambrian Stratigraphy; New Mexico Geological Society (President), Publications Committee; Sigma Xi, New Mexico Tech Chapter, Admissions Committee

Stone—New Mexico Water Conference, Advisory Committee; New Mexico Water Well Association, Technical Support Group (Chairman)

Tabet—New Mexico Coal Surface Mining Commisssion, Task force on regulations

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New employees joining the Bureau were: Ruben Archuleta, Technician I, 16 April 1979; Virginia Baca, Staff Secretary, 1 March 1979; Kevin Baker, Technician, 4 June 1979; Frank Campbell, Coal Geologist, 1 April 1979; Kathy Eden, Editorial Clerk, 25 January 1979; Don Jordan, Technician I, 5 June 1978; Walter Kubilius, Technician I, 1 January 1979; Stephanie Landregan, Scientific Illustrator, 1 October 1978; Wes Mauldin, Jr., Driller's Helper, 11 June 1979; Susan McCue, Lab. Technician I, 16 November 1978; Hurald Miller, Geologist, 12 February 1979; Robert North, Mineralogist, 1 September 1978; Connie Oliver, Receptionist, 25 June 1979; Linda Padilla, Staff Secretary, 16 November 1978; Barbara Popp, Lab. Biotechnologist, 17 July 1978; Bruce Reid, Geologist, 1 January 1979; Chantravadee Songkran, Staff Secretary, 1 September 1978; Barbara Spence, Coal Geologist, 5 September 1978; Donald Wolberg, Field Geologist/Vertebrate Paleontologist, 15 December 1978; John Wright, Paleontologic Preparator/Curator, 12 October 1978.

Resignations during the fiscal year were: Kathy Bradley, Department Secretary, 15 August 1978; Jim Dodson, Technician I, 6 November 1978; Roy Foster, Petroleum Geologist, 31 December 1978; Don Jordan, Technician I, 1 September 1978; Walter Kubilius, Technician I, 15 May 1979; Gary L. Massingill, Coal Geologist, 31 May 1979; Robert Mattis, Technician I, 5 September 1978; Susan McCue, Lab. Technician I, 15 June 1979; Terrence McMahon, Geophysical Field Engineer, 31 May 1979; Hurald Miller, Geologist, 31 May 1979; Karen Patterson, Editorial Clerk, 1 January 1979; Christopher Rautman, Economic Geologist, 8 September 1978; Robert Shantz, Metallurgist, 31 July 1978; and Julie Zepeda, Receptionist, 8 August 1978.

Promotions (all 1 July 1978) were: Ruben Crespin to Technician II; Stephen Frost to Research Associate-Coal Geologist; Candace Holts to Associate Editor; Neila Pearson to Assistant Editor; and Joan Pendleton to Assistant Editor.

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NATIONAL COAL RESOURCES DATA SYSTEM IN NEW MEXICO

by Barbara J. Spence, *Geologist*

As our nation's need for energy resources increases, commercial companies and state and federal agencies are looking at other suitable fuels to fulfill these needs. In the past several years, this has led to renewed interest in coal exploration and production. Abundant information exists and is currently being generated as these organizations work to delineate coal reserves.

The USGS has initiated a project to compile this information into a computerized data bank to provide easy access, manipulation, and retrieval of the diverse data available on coal. The project, the National Coal Resources Data System (NCRDS), is under the supervision of M. Devereau Carter, USGS, Geology Division, Reston, Virginia.

Under federal grant 14-08-0001-G582, the New Mexico Bureau of Mines and Mineral Resources is working with the USGS to compile available coal data from New Mexico for use in the NCRDS. The grant will span five years and is renewed annually. The search for data will be by basin, with the San Juan Basin examined the first and second years and data from other basins gathered in successive years. The information is derived from state and federal organizations, companies and consulting firms when possible, publications, and from ongoing projects at the New Mexico Bureau of Mines and Mineral Resources and other organizations. Eventually an adequate data base will be developed for New Mexico, at which time the Bureau will maintain direct access to the coal files.

The National Coal Resources Data System has been discussed in Carter and Medlin (1976), Stanton and Carter (1979), and in the NCRDS Newsletter (first published July 1979). A summary of those articles is presented below.

The NCRDS consists of two parts: Phase I is now operational and contains areally recorded resource and chemical data derived from the published reports of state geologic surveys and the U.S. Bureau of Mines. Included in Phase I are data concerning original and remaining coal resources by coal seam and overburden thickness and by coal rank, age, and chemical composition. The information is retrievable in tabular or graphic form by state, county, and—where available—by quadrangle, township, or bed. Graphic displays include two- and three-dimensional statistical graphs (fig. 1), sample plot locations, trend surfaces, and isoline maps (fig. 2).

Phase II is presently undergoing testing and revision (as of July 1979). Data are entered into the Phase II system by point source, and they are derived from field observations and drill-hole logs. Information includes:

1) physical data: seam thickness, location, identification, elevation, extent, and type of mining
2) geologic and borehole data: overburden character and thickness, coal-bed description, outcrop-line location, surface-slope angle, and cleat orientation
3) topographic: drainage, cultural features, and political boundaries (in the form of digitized land terrain)
4) geochemical: proximate and ultimate analyses; major, minor, and trace elements (the USGS has an ongoing project to sample and analyze major coal beds in the United States; most analyses in the NCRDS were generated through this program)

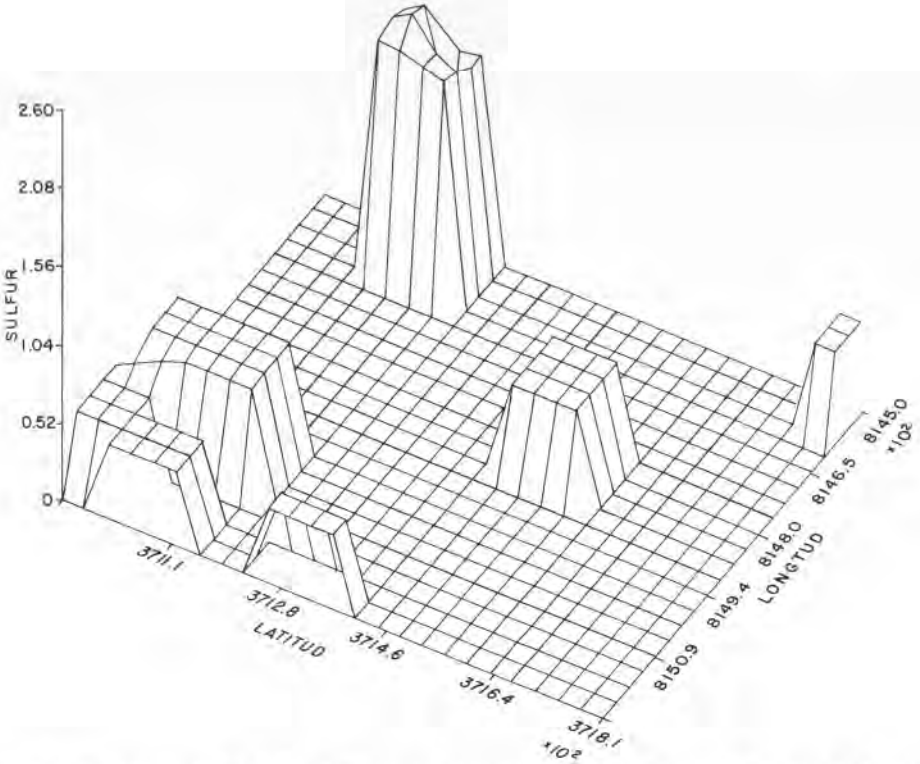

FIGURE 1—SAMPLE OF THE TYPE OF THREE-DIMENSIONAL PLOT THAT IS POSSIBLE WITH THE NCRDS; axes are longitude (LONGTUD), latitude (LATITUD), and percent sulfur (modified from NCRDS Newsletter, 1979).

5) geophysical
6) petrographic

Retrieval of Phase II data will be in several forms:

1) Resource estimates by coal quantity and quality of an area or bed, or by sulfur, ash, trace elements, petrography, lateral extent and/or overburden
2) cross sections and maps, including structure contours, isopach maps of coal beds or overburden, and isoline maps
3) tables and graphs for data summary and statistical display
4) modeling to project location of coals that meet specific requirements

The NCRDS was originally designed as an open-ended system to facilitate expansion and change. Also, because of the sensitivity of many coal-bearing areas due to leasing options, etc., information entered into the NCRDS can be kept confidential by a security code that prevents access to the data by unauthorized parties. With this code, all or part of the data can be withheld from general use. Otherwise, the data base is accessible to all interested persons either by direct interactive remote terminal or by oral or written request to the USGS. Direct access is through a commercial computer time-sharing company, the Computer Sciences Corporation, where the data are stored. For information concerning this company contact:

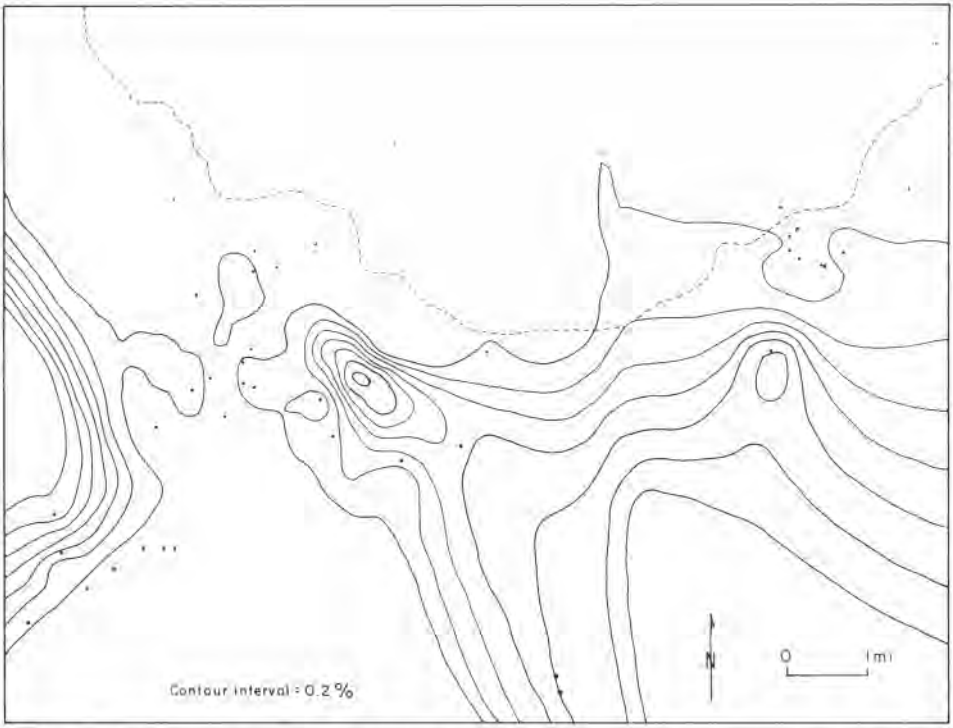

FIGURE 2—EXAMPLE OF AN ISOLINE MAP FOR SULFUR; contour interval = 0.2 percent (modified from NCRDS Information Manual, 1977).

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Information on the user operation of the NCRDS is available from the USGS in the following publications:

Bowen, R. W., and Botbol, J. M., 1975, The Geologic Retrieval and Synopsis Program (GRASP): U.S. Geological Survey, Prof. Paper 966, 87 p.

Cargill, S. M., Olson, A. C., Medlin, A. L., and Carter, M. D., 1976, PACER—Data entry, retrieval, and update for the National Coal Resources Data System (Phase I): U.S. Geological Survey, Prof. Paper 978, 107 p.

GRASP was designed specifically for interactive access to earth-science data banks and was expanded to facilitate the NCRDS data bank through the PACER programs.

At the Bureau, we are primarily interested in acquiring data from drill-hole logs, measured sections of coal-bearing areas, mine-out information when this is applicable, and geochemical analyses. Any help that might be offered in gathering coal data will greatly assist this program.

By concentrating a great amount of diverse information into a single data base, we hope to provide a useful, easily accessible tool for the exploration of coal in

New Mexico. Questions concerning the NCRDS in New Mexico should be directed to: David Tabet, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801, (505) 835-5640.

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SOME GUIDE FOSSILS IN UPPER CRETACEOUS JUANA LOPEZ MEMBER OF MANCOS AND CARLILE SHALES, NEW MEXICO

by Stephen C. Hook, *Paleontologist,* New Mexico Bureau of Mines and Mineral Resources, and William A. Cobban, *Paleontologist,* U.S. Geological Survey, Denver, Colorado

Introduction

This report is the third in a series on stratigraphically important Cretaceous fossils found in New Mexico and, often, throughout the Western Interior. These reports have 3 purposes: 1) to illustrate and describe some of the more common and easily recognized Cretaceous guide fossils found in New Mexico; 2) to precisely relocate or, if necessary, redesignate the type localities of fossils described before the advent of modern topographic maps; and 3) to recount some of the history surrounding the collection of these fossils. Some of these fossils have not been reillustrated since their original publication in the middle to late 1800's. The three fossils profiled here were described in the reports of the U.S. Army's exploration of the West and are closely associated with the Territorial history of New Mexico.

The first article in this series discussed the oyster *Pycnodonte newberryi,* described by Stanton in 1893 (Hook and Cobban, 1977); the second article discussed the ammonite *Prionocyclus novimexicanus,* described by Marcou in 1858 and one of the first fossil species to be named from New Mexico (Hook and Cobban, 1979). The present paper includes descriptions of the oyster *Lopha lugubris* (Conrad), the bivalve *Inoceramus dimidius* White, and the ammonite *Prionocyclus macombi* Meek. In New Mexico, these three fossils are commonly found in the lower and middle parts of the Juana Lopez Member of the Mancos and Carlile Shales, as well as in the D-Cross and Pescado Tongues and the Tres Hermanos Sandstone Member of the Mancos Shale.

ACKNOWLEDGMENTS—We thank Mr. and Mrs. Gene Sauble, Buddy Scott, Gus Lopez, and Zeke Trujillo for access to private land in the Taylor Springs, New Mexico area; Clifford Nelson, U.S. Geological Survey, Reston, Virginia, supplied a copy of the Ives Report. Robert Burkholder, U.S. Geological Survey, Denver, Colorado, prepared and photographed the fossils; G. R. Osburn, New Mexico Bureau of Mines and Mineral Resources, printed the outcrop photographs. Robert Bieberman, also of the New Mexico Bureau, provided a copy of Van Valkenburg's unpublished work that was instrumental in locating the type locality of *Inoceramus dimidius.* Funding for Hook was provided in part by U.S. Geological Survey Grant 14-08-0001-G525 to the New Mexico Bureau of Mines and Mineral Resources.

JUANA LOPEZ MEMBER—The Juana Lopez Member of the Mancos Shale (Dane and others, 1966), one of the most distinctive and persistent lithologic units in the Upper Cretaceous of New Mexico, contains a characteristic late Turonian fauna. Originally called the Juana Lopez sandstone member of the Carlile Shale (Rankin, 1944), this lithostratigraphic unit consists of thin beds of rusty-brown-weathering calcarenite interbedded with dark-gray, generally noncalcareous shale. Although shale is the dominant lithology, the hard, platy weathering calcarenites are more conspicuous, commonly littering the outcrop and standing in topographic relief above the softer shales.

The Juana Lopez Member was originally thought to be less than 4 ft (1.2 m) thick at its type locality northwest of Cerrillos on the Mesita de Juana Lopez Grant (Kauffman in Dane and others, 1966, p. H13, H14); consequently, Dane and others (1966) established a reference section for the Juana Lopez near La

Ventana, New Mexico, where the unit is 107 ft (32.6 m) thick and contains an abundant late Turonian fauna. Recent field work by us in the type area of the Juana Lopez Member (SE¼ sec. 33, T. 15 N., R. 7 E.) has shown that the Juana Lopez as measured by Kauffman is incomplete rather than abnormally thin. The beds of calcarenite in the basal Juana Lopez are thin and generally inconspicuous, but they are well exposed in a 1965 railroad cut at the type locality and can be traced laterally in outcrop. These basal beds also contain the *Prionocyclus macombi-Lopha lugubris* fauna characteristic of the lower part of the Juana Lopez at the reference section. A redescription of the type section of the Juana Lopez Member is now in preparation by us as part of our regional work on the mid-Cretaceous of New Mexico and will be published in 1980 in *New Mexico Geology*.

Individual calcarenite beds of the Juana Lopez Member range in thickness from a fraction of an inch to 2 ft (0.6 m), are fine to coarse grained, and are composed primarily of bioclastic debris—predominantly the fragmented, prismatic layer of *Inoceramus* shells. Some beds contain abundant disarticulated fish teeth, bone, and scales. This feature led early workers to describe these beds as "fish-tooth conglomerates," "fish-bone beds," "fish-tooth beds," etc. Appreciable percentages of silt- to very fine sand-size grains of silica are also present in the calcarenites, particularly those in the lower part of the member (Dane and others, 1966).

The macroinvertebrate fauna of the Juana Lopez is dominated by 12 species of mollusks: the ammonites *Prionocyclus macombi* Meek, *P. wyomingensis* Meek, *P. novimexicanus* (Marcou) (listed as *P. wyomingensis elegans* Haas), *Scaphites warreni* Meek and Hayden, *S. ferronensis* Cobban, *S. whitfieldi* Cobban, *Baculites yokoyamai* Tokunaga and Shimizu (listed as *B.* cf. *B. besairei* Collignon), and *Coilopoceras* n. sp. (listed as *C. colleti* Hyatt); and the bivalves *Lopha lugubris* (Conrad), *Inoceramus dimidius* White, *I. perplexus* Whitfield, and *Lucina* sp. cf. *L. mattiformis* Stephenson (Dane and others, 1966). The three species profiled in this article—*Lopha lugubris, Inoceramus dimidius* and *Prionocyclus macombi*—are guides to the lower and middle Juana Lopez; *P. novimexicanus,* a guide to the uppermost Juana Lopez, is discussed in Hook and Cobban (1979). Most of the mollusks in the Juana Lopez have restricted vertical ranges and are widely distributed in the Western Interior. Fig. 1 shows the known area of the *L. lugubris-I. dimidius* fauna in the Western Interior.

The distinctive nature of the Juana Lopez Member has been known since the Colorado Exploring Expedition of Lieutenant Joseph Christmas Ives in 1857-58. In the geological report of this expedition, John Strong Newberry, M.D., briefly described the geology along the Santa Fe Trail. Some 10 mi (16 km) west of Las Vegas, New Mexico, Newberry (1861, p. 106) first noted that the shales in the Upper Cretaceous ". . . include thin arenaceous bands, containing fragments of shells of *Inoceramus,* which at first sight resemble fish scales. . . . We found these strata much better displayed further eastward, but even here they exhibit characters sufficient to distinguish them from any rocks we had before met with."

In 1859 Newberry accompanied Captain J. N. Macomb on an "exploring expedition from Santa Fe, New Mexico, to the junction of the Grand and Green Rivers of the great Colorado of the west." In the geological report of this "San Juan" expedition, Newberry (1876, p. 33) described in more detail a section of Upper Cretaceous rocks exposed along the Santa Fe Trail at the "Breaks of the Red River" (Canadian River), southeast of Springer, New Mexico. From these

FIGURE 1—REGIONAL DISTRIBUTION OF *LOPHA LUGUBRIS* (CONRAD) AND/OR *INOCERAMUS DIMIDIUS* WHITE IN THE WESTERN INTERIOR OF THE UNITED STATES.

outcrops the distinctive fauna of the Juana Lopez Member was first reported as follows (updated faunal and formational names in brackets):

> The section from the summit of the hills at the "Breaks of Red River," down to the bed of the stream, is as follows:
>
> 1. Rolled gravel, composed of fragments of porphyry, trap, Paleozoic limestone, & c., drift from the Rocky Mountains.
> 2. Light-blue compact limestone, on exposure cracking into flattish chips or "spalls" containing *Inoceramus problematicus*, [*I. waltersdorfensis*], *Gryphaea Pitcheri* [only unidentifiable fragments], & c. [Fort Hays Limestone Member of the Niobrara Formation]
> 3. Ferruginous, laminated, sandy limestone, with rounded concretions, one to five feet in diameter, of compact blue limestone, much cracked, and fissures filled with crystallized carbonate of lime. This rock is a great store-house of fossils, of which, perhaps, the most abundant is a remarkably neat little *Ostrea*, hitherto undescribed, which I have called *Ostrea elegantula* [*Lopha lugubris*]; one of the most common and widely distributed Middle Cretaceous fossils of New Mexico. With this are *Inoceramus fragilis*, H.& M. [*I. dimidius*], *I. Crispii*? [*I. perplexus*?], Shark's teeth (*Lamna* and *Oxyrhina*) & c. The surfaces of the layers of this stratum are covered with small *Ostreas* (*O. congeata* [sic]) [*Lopha lugubris*] and fragments of *Inoceramus*, which resemble fish scales; thickness 80 ft [Juana Lopez and Blue Hill Members of the Carlile Shale; fig. 2]
> 4. Light-blue compact limestone in thin beds, weathering white, similar to No. 2; about 30 ft exposed. From this point to the bed of the river, some 700 to 800 ft, the cliffs are composed of blue compact limestone in thin beds, alternating with dark-blue and brownish bituminous calcareous shales, which underlie the preceding members of the section, and rest upon Lower Cretaceous sandstone. In every part of these lower limestones *In-*

oceramus problematicus [*Mytiloides mytiloides*] is exceeding abundant. They also contain large numbers of *Gryphaea Pitcheri* [*Ostrea beloiti*], of which remarkably large and fine specimens were collected a short distance east of the crossing. [Greenhorn Formation, Graneros Shale, and Dakota Sandstone; fig. 3]

In attempting to relocate the type localities for *Lopha lugubris* and *Prionocyclus macombi,* we placed a great emphasis on recovering Newberry's measured section and in duplicating his faunal collections because Macomb's map, which shows their route, does not extend far enough eastward to include the Canadian River. Fortunately, the main route of the Santa Fe Trail where it crossed the Canadian River is mapped on the Taylor Springs 7.5 minute quadrangle, Colfax County, New Mexico. Using the Taylor Springs quadrangle and Newberry's description, we determined that Newberry's section had to have been measured in two parts: the lower part, Newberry's unit 4, along the banks of the Canadian River in the N½NW¼ sec. 22, T. 24 N., R. 23 E.; and the upper part, units 1-3 approximately 2.5 mi (4 km) farther northeast in the N½SW¼ sec. 12, T. 24 N., R. 23 E. Fig. 4 shows the composite outcrop section of the Upper Cretaceous rocks along the Santa Fe Trail east of the Canadian River, Colfax County, New Mexico.

Duplication of the fauna from this measured section proved to be more difficult than expected because of Newberry's confusion concerning the identity of the abundant, "remarkably neat little *Ostrea*" in the Juana Lopez Member. Newberry (1876, p. 33) first referred to it as a new species, *Ostrea elegantula* (first illustrated by White, 1883), then in the same paragraph as *O. congesta* Conrad,

FIGURE 2—OUTCROP OF CARLILE SHALE AND NIOBRARA FORMATION EXPOSED IN SE¼NE¼ SEC. 13, T. 26 N., R. 24 E., COLFAX COUNTY, NEW MEXICO. Large concretions in upper Blue Hill Member, Carlile Shale, are approximately 3 ft (1 m) in diameter (see graphic section, fig. 4).

FIGURE 3—OUTCROP OF GREENHORN FORMATION EXPOSED IN THE BANKS OF THE CANADIAN RIVER 1 MI (1.6 KM) SOUTHEAST OF TAYLOR SPRINGS, COLFAX COUNTY, NEW MEXICO. Bridge Creek Limestone Member is 21 ft (6.4 m) thick; Hartland Shale Member is 96 ft (29.3 m) thick; bench in foreground is developed on top of Lincoln Limestone Member (see graphic section, fig. 4).

1843, and finally (p. 107, 138) and correctly as *O. lugubris* Conrad, 1857. We collected specimens identical to *O. elegantula* Newberry as illustrated by White (1883) from an oyster coquina in the Lincoln Limestone Member of the Greenhorn Formation at Newberry's measured section, unit 1 (fig. 4). The specimens illustrated by White (1883) were sent to him by Newberry and could only have come from this coquina, which is exposed in continuous section at only the one locality along the banks of the Canadian River. To further complicate matters, the types of *O. elegantula* are identical to the types of *O. beloiti* Logan, 1899. The species name *O. elegantula* thus has priority over the more widely recognized *O. beloiti.* However, since *O. elegantula* has not been used in literature for more than 50 years, it should now be considered a forgotten name (*nomen oblitum*), according to Article 23(b) of the International Code of Zoological Nomenclature.

Newberry's statement (1876, p. 33) that the surfaces of the Juana Lopez calcarenites are covered with *Ostrea congesta* (misspelled *O. congeata*) seems merely to be an uncorrected error. Near Macomb's camp No. 39 in the Four Corners area of New Mexico, Newberry (p. 107) remarks that "This ferruginous stratum marks a distinct horizon, and may be traced over an immense area in New Mexico. It is the same that I have before referred to in my notes on . . . the banks of the Canadian. This stratum is characterized by . . . *Ostrea lugubris* . . . while the overlying shales are filled with fragments of a large *Inoceramus,* covered with the closely-set shells of *Ostrea congesta.*" In Newberry's description of *Ptychodus whipplei* Marcou (p. 138), he stated that "The place of *O. congesta* is a little higher in the series [than *O. lugubris*]."

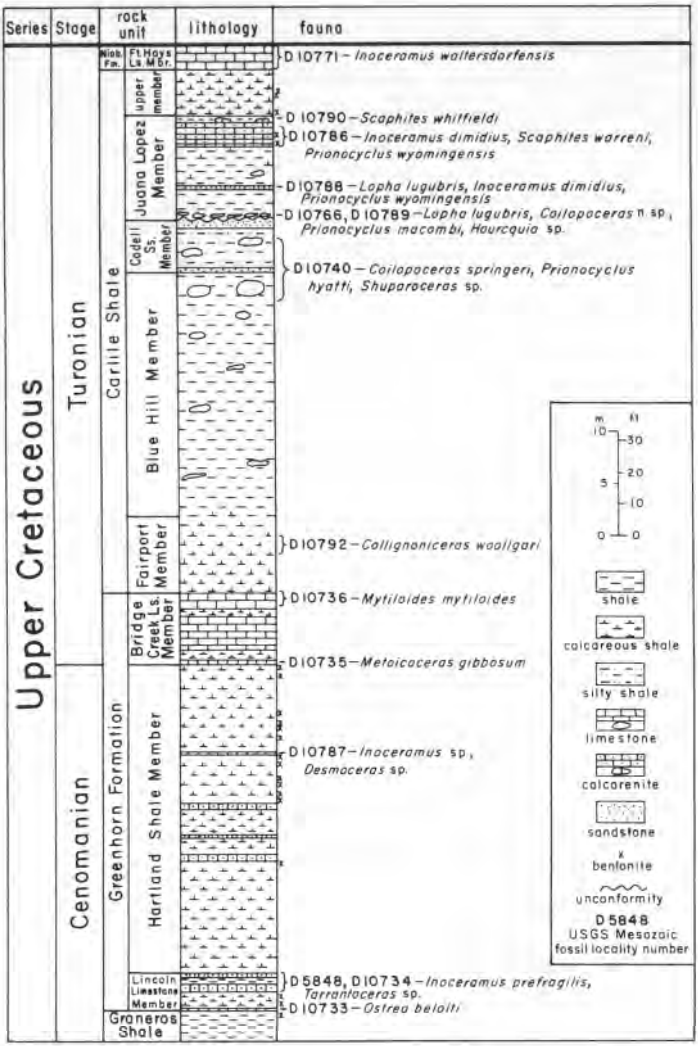

FIGURE 4—COMPOSITE OUTCROP SECTION OF UPPER GRANEROS SHALE THROUGH LOWER PART OF FT. HAYS LIMESTONE MEMBER OF NIOBRARA FORMATION EXPOSED IN THE TAYLOR SPRINGS AREA, COLFAX COUNTY, NEW MEXICO, SHOWING OCCURRENCES OF FOSSILS.

Although the outbreak of the Civil War delayed publication of Macomb's Report until 1876, Newberry did not revise the text that he submitted in 1860. In a prefatory note dated June 1, 1875, Newberry (1876) stated that "the observations made fifteen years ago, if accurately made, have equal value now as then. . . . It is evident that to modify the report so as to conform to all the conclusions more recently reached, would be to falsify the record and greatly impair the independence and value of the statements it includes." From our twentieth century vantage point it is obvious that Newberry's pioneering observations are of more than mere historical interest; they form an important and integral part of the biostratigraphic literature on the Cretaceous of the Western Interior.

Description of fossils

Lopha lugubris (Conrad, 1857, p. 156, pl. 10, fig. 5a, b) is a small inequivalve plicate ostreid species that has a nearly round to subovate outline and large attachment area (fig. 5). The height is usually a little more than the length; most specimens have heights between 15 and 20 mm. Left valves are more convex than right ones and usually have attachment areas of about one-half of the area of the valve. Right valves have a low convexity and tend to be elliptical or subovate and slightly curved. A large area covering most of the right valve is smooth except for fine growth lines. The free areas of both valves have strong radial plicae, which are longer, stronger, and sparser on specimens from the basal part of the Juana Lopez Member than on specimens higher in the member. The species was attached to *Inoceramus* shells, and the attachment areas of left valves reflect the ornamentation of the *Inoceramus* shell.

The holotype of *L. lugubris* is from "east of Red River, New Mexico, Santa Fe road" (Conrad, 1857, p. 123). We examined outcrops along the Santa Fe Trail and determined that the type came from the lower part of the Juana Lopez Member of the Carlile Shale at its outcrop about 2.5 mi (4 km) east of the Canadian River (formerly Red River) and just north of the Santa Fe Trail in the SW¼ sec. 12, T. 24 N., R. 23 E., Colfax County (Taylor Springs 7.5 minute quadrangle).

Lopha lugubris commonly occurs in large numbers of well-preserved, unbroken specimens. Kauffman (1965, p. 38, 39) observed that *L. lugubris* was one of the most distinct and easily differentiated oyster species known to him. These qualities, combined with its short vertical range and wide distribution, make *L. lugubris* an ideal guide fossil. Fig. 1 shows the known distribution of the *L. lugubris-Inoceramus dimidius* fauna in the Western Interior, and fig. 6 shows localities in New Mexico where these two species have been collected by us. *L. lugubris* has also been recorded from west and central Texas (Cragin, 1893, and Stephenson, 1918) and from Coahuila, Mexico (Bóse, 1913).

Inoceramus dimidius White (1874, p. 25; 1877, p. 181, pl. 16, fig. 2a-d) is a small, convex, inequivalve inoceramid that has coarse, concentric rugae usually confined to the early part of the shell. The rest, and greater part, of the shell is typically almost smooth except for growth lines and an occasional rugae. An abrupt change in slope angle marks the boundary between the ornamented and smooth parts of the shell.

White illustrated four specimens and gave their locality as "Ojo del Pescado, New Mexico" (White, 1874, p. 26) and "Ojo del Piscado" (White, 1877, p. 182). The holotype was not designated, but Kauffman (1977, p. 238, pl. 8, figs. 7, 13) designated one of the specimens as the lectoholotype (White, 1877, pl. 16, fig. 2b). Through some error, possibly by White, the label accompanying the lectoholotype gives the locality as "East bank of Rio Puerco, 6 miles below Casa Salazar, New Mexico" (E. G. Kauffman, oral communication, 1979), and this was accepted by Kauffman (1977, p. 238). Hook visited the Pescado area, 13 mi (20.8 km) east of Zuni Pueblo, and collected topotypes of *I. dimidius* (fig. 7) from very fine grained sandstone concretions in the middle of the Pescado Tongue of the Mancos Shale, 1.3 mi (2 km) northwest of Pescado Spring (Pescado 7.5 minute quadrangle, McKinley County), which verifies White's published locality. In addition, Pescado Spring (referred to on older maps as Ojo del Pescado and Piscado, all in reference to the many small fish found in the spring) served as an important watering place on the Indian, Spanish, and early American trails (Van Valkenburg, 1941, p. 112).

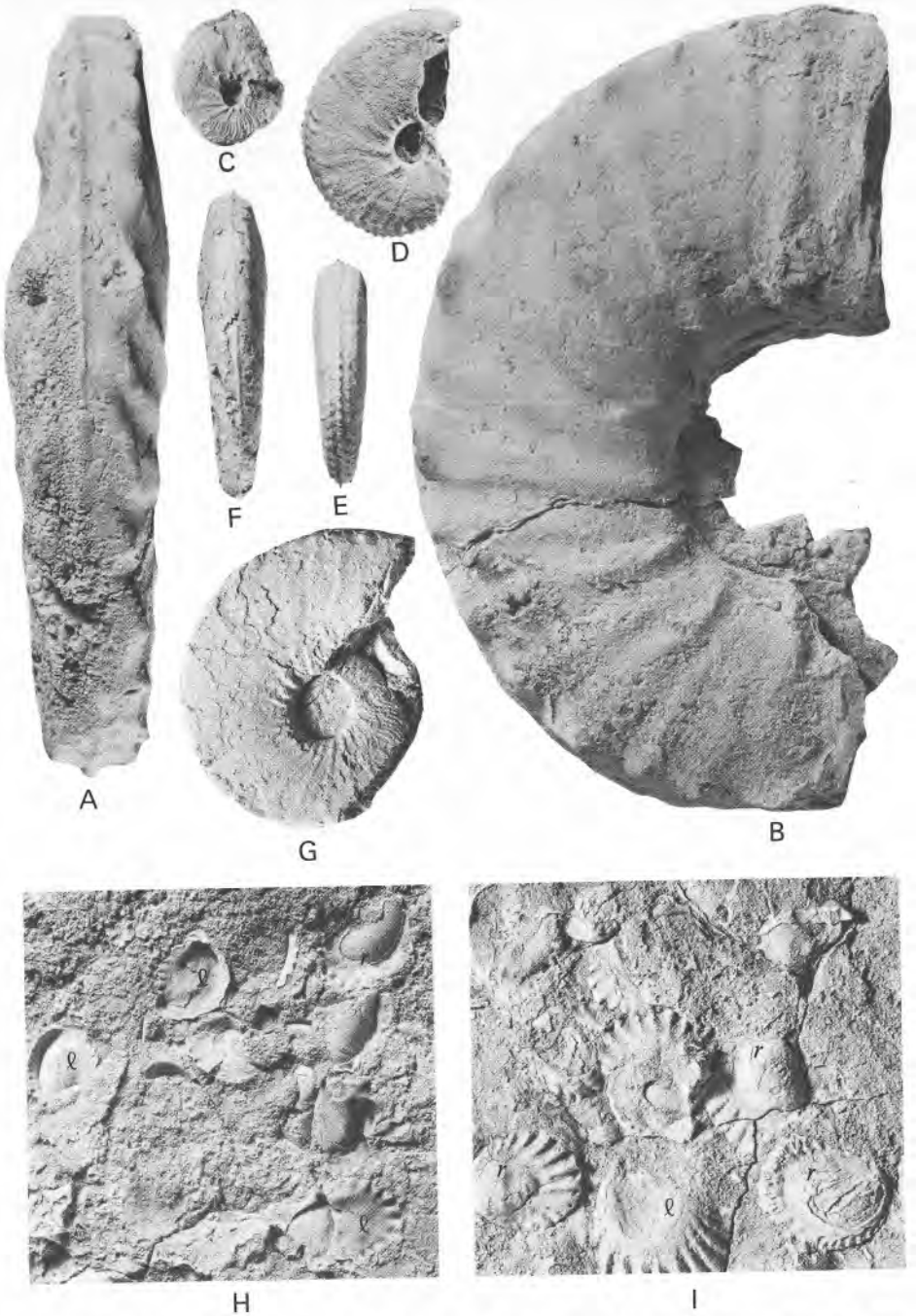

FIGURE 5—*Prionocyclus macombi* Meek (**A-G**) and *Lopha lugubris* (Conrad) (**H, I**), all natural size. **A** and **B**, rear and side views of holotype USNM 20259. **C**, hypotype USNM 283971, showing the densely ribbed inner whorls; from USGS Mesozoic locality D10789 in NE¼ sec. 2, T. 24 N., R. 23 E., Colfax County, New Mexico. **D** and **E**, side and rear views of hypotype USNM 283972, a juvenile from USGS Mesozoic locality D10791 in NE¼ sec. 11, T. 24 N., R. 23 E., Colfax County. **F** and **G**, rear and side views of hypotype USNM 283973, showing change from densely ribbed inner whorls to smoother outer whorls; from the same locality as C. **H** and **I**, left (l) and right (r) valves of *Lopha lugubris;* hypotype USNM 283974 from USGS Mesozoic locality D10738 in SW¼ sec. 12, T. 24 N., R. 23 E., Colfax County, and hypotype USNM 283975 from USGS Mesozoic locality D10767, about 4 mi (6.4 km) east-southeast of Springer, New Mexico.

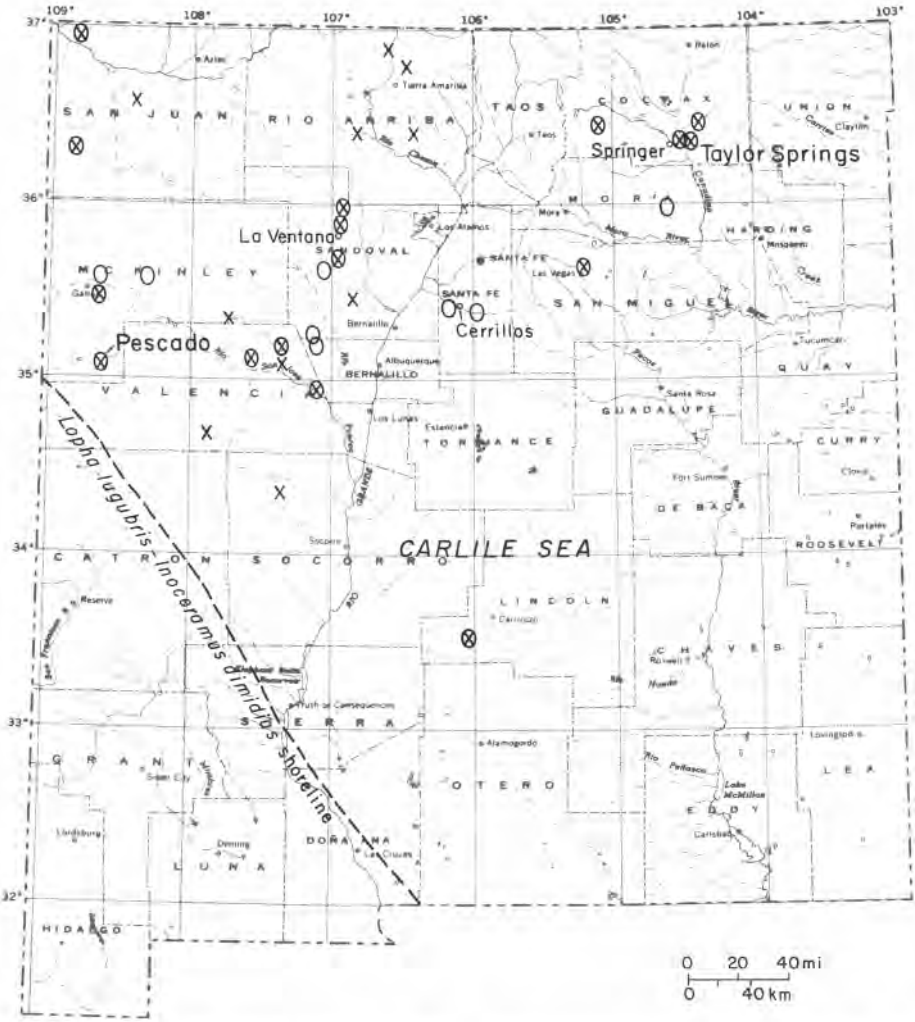

FIGURE 6—LOCALITIES WHERE *LOPHA LUGUBRIS* (0) AND *INOCERAMUS DIMIDIUS* (×) HAVE BEEN COLLECTED IN NEW MEXICO AND THE APPROXIMATE LOCATION OF THE CRETACEOUS SHORELINE (--) DURING THE TIME THAT THE LOWER AND MIDDLE PARTS OF THE JUANA LOPEZ MEMBER WERE BEING DEPOSITED.

Prionocyclus macombi Meek (1876b, p. 132, pl. 2, fig. 3a-d) is a moderately involute ammonite that has a narrow whorl section with flattened flanks, a gently arched venter, and a keel (fig. 5). Ornamentation consists of slightly flexuous, prosiradiate, weak primary and secondary ribs, which rise into clavate ventrolateral tubercles and then bend forward on the venter and disappear before reaching the keel. Primary ribs rise from umbilical bullae. The early whorls are densely ribbed, in contrast to the sparser ribbing of the later ones. The keel is notched into two or three serrations for each ventrolateral tubercle. The compressed whorl section and weak ornamentation are unusual for the genus. Most prionocyclids have rectangular to squarish whorl sections and strong ornamentation. Meek (1876b, p. 133), who named *Prionocyclus* (Meek, 1876a, p. 452), questioned the generic assignment of his *P. macombi*. The species has con-

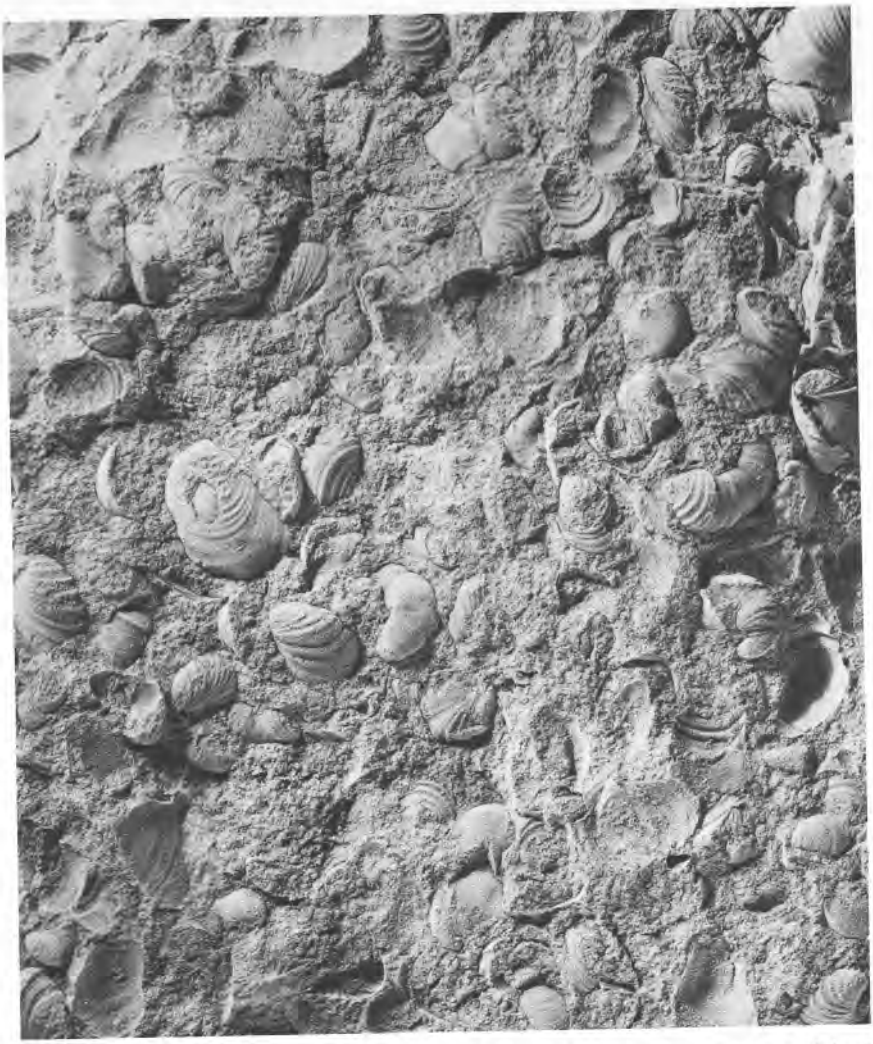

FIGURE 7—*INOCERAMUS DIMIDIUS* WHITE, NATURAL SIZE. Numerous specimens on a slab of very fine grained sandstone from the middle of the Pescado Tongue of the Mancos Shale. Hypotype USNM 283976 from USGS Mesozoic locality D10600 in NE¼ sec. 11, T. 10 N., R. 17 W., McKinley County, New Mexico.

siderable resemblance to *Lymaniceras* Matsumoto (1965, p. 29) from the upper Turonian of Japan; *P. macombi* differs by having larger ventrolateral tubercles and a more rectangular lateral lobe.

The holotype of *P. macombi* is mostly part of a phragmocone about 110 mm in diameter. It came from the "Banks of Canadian." Our field investigation suggests that the specimen probably came from the same outcrop of the Juana Lopez Member of the Carlile Shale that yielded the holotype of *Lopha lugubris* in the SW¼ sec. 12, T. 24 N., R. 23 E., Colfax County, New Mexico. The holotype of *P. macombi* is in the National Museum of Natural History, Washington, D.C., and plaster casts of it are at the New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, and at the U.S. Geological Survey, Federal Center, Denver, Colorado.

Investigations by Cobban in 1964 (unpublished) revealed that *P. macombi* occurs in two forms: an older form with a well-arched venter (like *Lymaniceras*) and a younger form with a more flattened venter. The older form occurs in the lower part of the Juana Lopez Member, and the younger one occurs in the middle part. The stratigraphic ranges of these forms were shown later in a chart (Dane and others, 1966, fig. 3). Our present investigation of *P. macombi* in the type area reveals that holotype came from the base of the Juana Lopez Member, verifying Cobban's earlier work.

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MINERAL PRODUCTION ACTIVITIES IN NEW MEXICO DURING 1978

by Robert W. Eveleth, *Mining Engineer,* and Frank E. Kottlowski, *Director*

Introduction

Mineral production in New Mexico totaled $3.1 billion in 1978, which was a 7 percent increase over 1977 (fig. 1). Almost 76 percent of this total, $2.35 billion, was from the mineral fuels, which are natural gas, crude oil, natural-gas liquids, and coal (table 1). Production of nonmetals increased, but production of metallic minerals decreased; total output of nonfuel minerals was $744 million. In addition, the total value added by manufacturing and processing of mineral raw materials was estimated at $771 million. The state ranked first in production of uranium, potassium salts, and perlite; third in copper; and fourth in natural gas and pumice.

The value of mineral production in New Mexico during 1978 was more than four times as great as the value of the total agricultural output from farms and ranches and was nearly four times the total cost of construction activities in the state.

Mineral commodities are produced throughout the state: Oil and gas production is mainly from the San Juan Basin in the northwest and from southeast New Mexico; uranium production is mainly from the Grants region, and potash is produced in the Carlsbad area. Base metals (copper, lead, and zinc) are from the Silver City region. Also produced are molybdenum (Questa), coal (northwest and north-central areas), perlite (Taos area and Socorro and Valencia Counties), gypsum (Santa Fe County), and cement (near Tijeras).

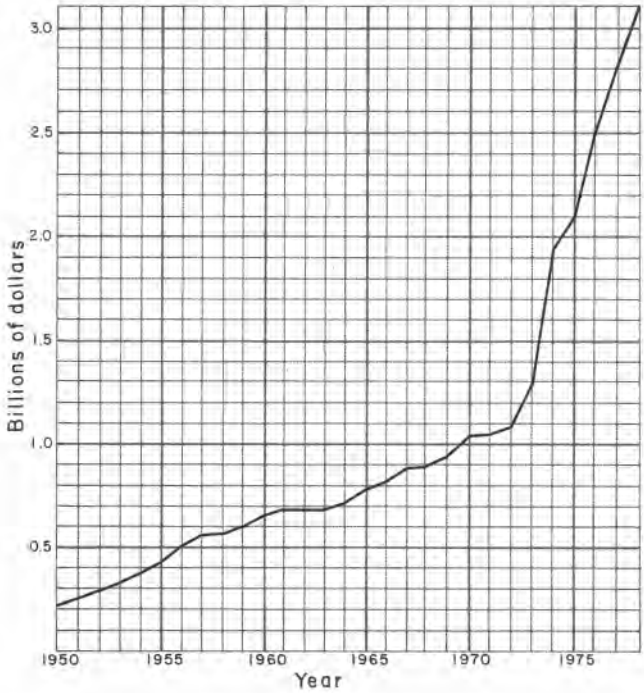

FIGURE 1—VALUE OF MINERAL PRODUCTION IN THE STATE OF NEW MEXICO FROM 1950-1978.

Mineral fuels

During 1978 oil production declined 4.6 percent from 1977 totals; natural gas declined 3.7 percent, but values received from oil and gas increased 3.4 percent and 14.7 percent, respectively. Data from New Mexico Oil Conservation Division show the average wellhead price of New Mexico crude oil in January 1979 was $10.58/barrel, with the average price of natural gas at $1.18/thousand cu ft (MCF). The average oil price includes a range of about $6/barrel for "old" crude to $12/barrel for new oil, and about $14/barrel for oil from stripper wells. As the state severance tax is fixed at 45¢ per barrel on oil and 5¢ per MCF of natural gas, the severance tax collections declined.

Total wells drilled were 1,791, which was the largest number since 1961 when 1,859 wells were drilled. The record year was 1957 with 2,505 completions. The total footage drilled was a record 8.6 million ft. The 1,791 wells included 548 oil wells, 285 dry holes, and 958 natural gas wells; this number of gas wells tops the previous high of 830 drilled in 1977. The Blanco-Mesaverde Field in northwest New Mexico continues as the most active field in the state with 320 natural gas completions, of which 275 were infill wells. Costs to drill the 285 dry holes are estimated at $66 million (New Mexico Oil and Gas Association data).

Wildcat drilling in northwest New Mexico (Baars, 1979) had a 12 percent success rate; of 41 exploration wells drilled 2 produced mainly oil, 3 produced mainly natural gas, and 36 were dry. Two significant discoveries were in west-central Rio Arriba County where the Cotton Petroleum 105 Apache produced 180 barrels of oil per day (BOPD) and 347 thousand cu ft of natural gas per day (MCFD) from the Gallup Sandstone, and the Continental 10 Conoco 29-4 produced 973 MCFD from the Pictured Cliffs Sandstone. In westernmost Sandoval County, the BCO Inc. 2-Fed-B produced 27 BOPD and 108 MCFD from the Gallup Sandstone. Four rank wildcat tests drilled to Precambrian rocks in west-central New Mexico were unsuccessful.

The total number of exploratory wells drilled in southeast New Mexico in 1978 was 133, a 2 percent decrease from 1977 (Gibson and Stichtenoth, 1979). The success ratio was 34 percent with 10 oil discoveries, 35 natural gas discoveries, and 88 dry holes. One significant discovery was the Alantic Richfield 1 Langlie Deep well, located in southern Lea County on an upthrown fault block west of the Central Basin platform, which yielded 4.7 million cu ft per day (MMCFD) and 480 barrels of condensate per day (BCPD) from the Ellenburger limestone at a depth of 15,400 ft. An offset well produced 11 MMCFD and 1,000 BCPD from Ellenburger and Devonian rocks. In southwest Roosevelt County, the Enserch 1 Lambrith well produced 638 BOPD from truncated Fusselman dolomite on the north edge of the Northwest Shelf. In northwest Eddy County, the Phoenix Res. 1 Gardner Draw Unit produced 13.1 MMCFD from Morrow sandstones, the westernmost Morrow production in New Mexico.

In 1978, production of crude oil so exceeded discoveries that the American Petroleum Institute reported a drop of 5 million barrels in proven reserves to 485 million barrels. Aided by extensive infill drilling in the San Juan Basin, proven reserves of natural gas increased to 13.3 trillion cu ft.

Production of coal in 1978 increased to 12,863,000 tons from 11,645,000 tons produced in 1977. Utah International's Navajo mine led with 6,207,000 tons, followed by Pittsburg and Midway Coal Mining Co.'s McKinley mine with 2,992, 958 tons, Western Coal Co.'s San Juan mine with 2,613,030 tons, Kaiser Steel Co.'s York Canyon mine with 770,455 tons (673,466 tons underground and 96,989 tons strip mined), and Amcoal's Sundance mine with an estimated 100,000

TABLE 1—MINERAL PRODUCTION IN NEW MEXICO (short tons unless noted; NA = not available; XX = not applicable; E = estimated; W = withheld. Data from Sheffer and Eveleth, 1979; U.S. Bureau of Mines, unpublished data; U.S. Department of Energy, unpublished data; New Mexico Oil Conservation Division of Energy and Minerals Department, unpublished data; and Keystone Coal Industry Manual).

	1977		1978	
Mineral	Quantity	Value (thousand dollars)	Quantity	Value (thousand dollars)
Clays, excluding fireclay (tons)	69	113	53	89
Coal (thousand tons)	11,645	101,432E	12,863	98,728
Copper (tons)	164,698	220,037	139,645	185,169
Gem stones	NA	170	NA	180
Gold (troy ounces)	13,560	2,011	10,100	1,946
Gypsum (thousand tons)	182	1,227	265	3,057
Manganiferous ore (tons)	29,120	W	W	W
Mica (tons)	14,000	W	W	W
Natural gas (millions cu ft)	1,202,973	974,408	1,159,150	1,117,997
Natural gas liquids (thousand barrels)	44,916	286,299	44,000E	298,313
Peat (tons)	2,000	55	2,000	60
Perlite (thousand tons)	521	9,543	548	12,382
Petroleum, crude (thousand barrels)	87,223	805,065	83,365	832,550
Potash (thousand metric tons K_2O)	1,892	169,616	1,943	183,554
Pumice (thousand tons)	457	1,835	475	2,185
Salt (thousand tons)	142	1,355	120	1,839
Sand and gravel (thousand tons)	8,604	17,685	9,000	18,000
Silver (thousand troy ounces)	918	4,242	902	4,871
Stone, crushed (thousand tons)	1,950	4,786	2,400	5,870
Stone, dimension (thousand tons)	17	106	19	112
Uranium (U_3O_8) (thousand pounds)	13,167	260,037	16,000E	278,400
Combined carbon dioxide, cement, fireclay, helium, iron ore, lead, lime, molybdenum, tin, vanadium, zinc, and W	XX	65,617	XX	54,364
Total	XX	2,925,639	XX	3,099,666

tons. Carbon Coal began production in early 1979; it ships about 1.2 million tons of coal per year by unit train from Mentmore through Gallup, Grants, Belen, Socorro, Rincon, and Deming to Cochise, Arizona, for use in the Arizona Electric Power Cooperative's Apache power plant. The McKinley mine supplied this coal during 1978.

Permits to strip mine coal have been issued by the New Mexico Coal Surface Mining Commission and the New Mexico Bureau of Surface Mining to Consolidation's Con Paso mine near Burnham, Alamito Coal Co.'s Gallo Wash mine, Western Coal Co.'s Bisti mine, and Chaco Energy Co.'s South Hospah mine. However, none of these operations have been approved by the Federal Office of Surface Mining.

Metallic minerals

From 164,698 tons in 1977, copper production declined in 1978 to 139,645 tons, mainly owing to depressed prices for copper. ASARCO, Inc. closed its Groundhog mine because of low prices for copper, lead, and zinc; and Occidental Minerals Corp. suspended its in-situ copper leaching project near Cerrillos. However, Exxon Minerals continued exploration near Pinos Altos where drilling

has suggested the existence of 5 million tons of copper-zinc ore, and UV Industries revealed a new discovery at its Fierro property of more than 10 million tons of ore containing at least 0.6 percent copper.

With the sharp increase in the prices of silver and gold, exploration and planned production were stimulated; however, in 1978 production dropped because copper production slowed, and most of the state's gold and silver is a by product of copper mining. Gold and/or silver mines beginning operations were the Eberle mine at Mogollon, owned by Challenge Mining Co.; the Ortiz mine, owned by Gold Fields Mining Co., in the Ortiz Mountains; and in the Steeple Rock district, the Center mine of Dresser Minerals, and the Summit mine of Summit Mining Co.

Production of uranium increased from the numerous mines in the Church Rock, Ambrosia Lake, Grants, and Laguna districts, with the yellowcake milled by Kerr-McGee Corp., Anaconda Co., and United Nuclear-Homestake Partners. The two 3,400-ft shafts of Gulf Mineral Resource Co.'s Mount Taylor project near San Mateo were almost complete; Kerr-McGee is developing 4 new/expanded mines near Church Rock, Rio Puerco, eastern Ambrosia Lake at Roca Honda, and near Marquez. Phillips Uranium Corp. began development of its Nose Rock mine north of Crownpoint. Mobil Oil Corp. began a test program on in-situ leaching at its Crownpoint uranium project. Exploration continued in Catron and Socorro Counties in west-central New Mexico and southwest and northwest of Cerrillos in Santa Fe County.

Molycorp, Inc.'s Questa mine was the leading producer of molybdenum with by-product production from Kerr-McGee's uranium mill and Kennecott's copper concentrator.

Most of the manganiferous iron ore was produced by Luck Mining Co. at their Boston Hill mine. Sales of magnetite were from UV Industries' stockpile, a by product of their copper mining operation, and by Lincoln Mining and Milling Co., near Carrizozo.

Industrial minerals and rocks

Production of most "nonmetallic" minerals increased in both quantity and value. Dollar amounts increased 8 percent for potash, 149 percent for gypsum, 30 percent for perlite, 19 percent for pumice, 36 percent for salt, 7 percent for sand and gravel, and 22 percent for crushed and dimension stone. Duval Corp. shut down its North mine, which mined sylvinite ore, but continued production of its langbeinite ore. The Rosario gypsum plant southwest of Santa Fe was reopened by Western Gypsm Co.; with the American Gypsum Co. in Albuquerque, adequate gypsumboard is available for construction uses.

Revenue

Income from New Mexico's various taxes on mineral production during 1978 totaled $155 million from oil and gas and $30 million from other minerals (Sheffer and Eveleth, 1979). The state's share of federal bonuses, royalties, and grants was about $71 million; and state bonuses, royalties, and grants were about $106 million. This gives a total from state taxes and the state's share from bonuses, royalties, and grants of $362 million or about $302 per person living in New Mexico. Without the minerals industry in New Mexico, other taxes would need to be raised $302 per person to replace the revenue from mineral production.

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PALEONTOLOGY OF FRUITLAND FORMATION NEAR BISTI, SAN JUAN BASIN, NEW MEXICO—A PROGRESS REPORT

by Donald L. Wolberg, *Vertebrate Paleontologist,* New Mexico Bureau of Mines and Mineral Resources, and
David V. LeMone, *Associate Professor of Geology,* Department of Geological Sciences, University of Texas (El Paso)

While conducting a paleontological inventory of State lands in the Bisti badlands, near the old Bisti Trading Post, a substantial surface collection of fossil material was recovered. This inventory, under the direction of LeMone, was conducted for Western Coal Company. The collecting sites are within a larger area of stratigraphic and paleontologic interest presently under study by Wolberg; Wolberg and J. Hartman (University of Minnesota); and Wolberg and J. K. Rigby, Jr. (Bureau of Land Management, Albuquerque). The addition of the material collected by the University of Texas at El Paso (UTEP) is both natural and appreciated; the New Mexico Bureau of Mines and Mineral Resources has gladly cooperated with the UTEP effort as a part of its service function in matters concerning the geology and paleontology of the state. The Bureau is offering this progress report because of the long-term nature of its commitment.

The paleontological material collected from the 619 UTEP identified localities has been combined with collections made in the same area by the Bureau. The fossil material currently being prepared, curated, and studied at the Bureau consists of several thousand bone fragments of varying completeness. The material includes at least two partial turtle skulls and a portion of a hadrosaur vertebral column, as well as a complete baenid carapace. Several hundred specimens of freshwater mollusks also collected are presently being studied by J. Hartman, University of Minnesota, as part of his continuing investigations of Late Mesozoic-Early Tertiary freshwater molluscan faunas. A collection of fossil wood samples is presently under study by Maxine Abbott, Alpine, Texas.

The UTEP inventory effort concentrated on surface and near-surface collection of fossil materials; UTEP also bagged some sediments at selected localities for washing and screening in order to sample the microvertebrates that might be present. Bureau efforts in this area and elsewhere have concentrated on the identification of "point localities" for the collection of relatively complete material, fossil concentrations for very intensive sampling, and the location of potential quarry localities for the sampling of very large quantities of material. Both programs are complementary and necessary. A goal of these continuing programs is the development of a statistically valid data base to be used in establishing rational models to assess the paleontological impact of increased coal mining in the San Juan Basin, especially in the Fruitland Formation.

All collections considered here were made in the Fruitland Formation and derive from a limited area of approximately 1,600 acres within T. 23 and 24 N., R. 13 W., San Juan County (specific locality data is on file). The Kirtland Formation, overlying the Fruitland, is present in the area, although the identification of an easily discernible boundary between the Fruitland and Kirtland Formations has proven difficult. The Fruitland Fromation was named for exposures in the vicinity of Fruitland, New Mexico. Within the study area, the Fruitland develops badland topography and consists of alternating fine-grained sandstones, siltstones, claystones, carbonaceous shales, and coals. These sedimentary units show great variability in terms of thickness and areal extent; they appear to be

traceable only over short distances. The coals and carbonaceous shales appear to have broader areal distribution and serve as important stratigraphic marker horizons (see Wolberg and Kottlowski, this volume, for additional stratigraphic information).

As presently understood, the material in this collection (see preliminary faunal list at end of article) appears to represent a fairly typical Late Cretaceous vertebrate fauna of San Juan Basin aspect. Little separates this assemblage from previously collected samples. Some new forms probably occur within this assemblage, but that determination must await further collection and detailed analysis.

As expected, the vertebrate fauna is dominated by reptiles; turtle remains make up the largest proportion of the assemblage, but this is not presently viewed as especially significant. The relatively large number of turtle fragments present may well be related to the method of sampling as well as to differential preservation favoring turtle skeletal elements. Several of the specimens recovered are of display quality, and suitable arrangements will be made upon completion of the study. In comparison to the known and/or published record of Fruitland/Kirtland faunas, this sample is relatively impoverished in terms of diversity, which is probably the result of the sampling methods used as well as the need for a larger sample. The relatively small extent of the sampling area is not significantly detrimental to the acquisition of a sample comparable in diversity to the known record. Continued collection probably will remove the impoverished aspect of the fauna, and any paleoenvironmental disparities between this and previously recovered samples are likely to be ameliorated.

On the basis of the known record of the respective vertebrate faunas of the Fruitland and Kirtland Formations, the Fruitland appears relatively impoverished when the reptilian elements alone are considered. On the basis of the known mammalian faunas of the Fruitland and Kirtland Formations, the Kirtland is impoverished relative to the Fruitland. When Fruitland/Kirtland faunas are considered together, the vertebrate assemblage assumes a much more balanced character but still appears relatively impoverished when compared to Late Cretaceous assemblages elsewhere in North America. Similarly, distinctions between Fruitland and Kirtland vertebrate faunas have yet to be adequately demonstrated; these apparent distinctions cannot yet be proved real and therefore may be the result of sampling biases. Work in progress will help to provide a more reasonable basis for faunal determinations. Wolberg and Kottlowski (this volume) provide citations of previous paleontological work.

A fossil sample is not really a sample of a once-living community; a fossil sample is a portion of the total fossil content of a body of rock. The original composition of a once-living community is virtually impossible to define; at best, the total fossil content of a stratum is a biased sample of a once-living community. From the total fossil content of a stratum, such as the Fruitland Formation, it is possible to extract the maximum recoverable sample that would be representative of the total fossil content of the formation but would in fact never be as diverse as the total fossil content of the Fruitland Formation. The point is that fossil samples, as samples of the fossil material actually in the rocks, are really samples of samples of samples. Each sampling step, whether natural (such as differential preservation or variability in sediment type), introduced by man (the paleontologist doing the sampling), or differential preservation of habitats, leaves an imperfect record.

Because surface collection only recovers material at or near the surface, it is the most easily biased sampling method. Surface collection tends to yield the sorts of

material previously recovered. Significant material tends to represent forms that were not abundantly present, were small or in other ways fragile, or material that is still articulated and relatively complete if only because the material remains buried. Surface collection tends to emphasize material that is easy to see or is resistant to natural destructive processes.

Quarrying and bulk processing of materials also have limitations and inherent biases. Apart from difficulties encountered in quarrying (such as problems with personnel, equipment, or funds), specimen numbers yielded may be too small for valid statistical analyses if the goal is to recover whole, intact skeletons. If the aim is the recovery of microvertebrate materials, primarily by washing and screening of sediments from likely localities, sample sizes may be very large and statistically valid for the determination of important paleobiologic models; however, the range of faunal diversity is severely narrowed.

Each methodology offers a range of advantages and disadvantages; however, no single technique will do everything. Before any determinations are made, a rational program of study with clearly defined goals must be designed and implemented.

Preliminary faunal list

Class Chondrichthyes
- Subclass Holocephali
  - Order Chimaeriformes
    - Suborder Chimaeroidei
      - Family Chimaeridae
        - *Myledaphus* sp.

Class Osteichthyes
- Subclass Actinopterygii
  - Infraclass Holostei
    - Order Semionotiformes
      - Suborder Lepisostoidei
        - Family Lepisosteidae
          - *Lepisosteus* sp. A
          - *Lepisosteus* sp. B
    - Order Amiiformes
      - Suborder Amioidei
        - Family Amiidae
          - *Amia* sp.

Class Reptilia
- Subclass Anapsida
  - Order Chelonia
    - Suborder Amphichelydia
      - Superfamily Baenoidea
        - Family Baenidae
          - *Baenia* sp. A.
          - *Baenia* sp. B
    - Suborder Cryptodira
      - Superfamily Testudinoidea
        - Family Dermatemydidae
          - *Adocus* sp.
      - Superfamily Trionychoidea
        - Family Trionychidae
          - *Trionyx* sp. cf. *T. vorax*
          - *Trionyx* sp. cf. *T. austerus*
- Subclass Lepidosauria
  - Order Eosuchia
    - Suborder Choristodera
      - Family Champsosauridae
        - *Champsosaurus* sp.
- Subclass Archosauria
  - Order Crocodilia
    - Suborder Eusuchia
      - Family Crocodylidae
        - *Crocodylus* sp.
        - *Brachychampsa?* sp.
  - Order Saurischia
    - Suborder Theropoda
      - Infraorder Carnosauria
        - Family Tyrannosauridae
          - *Gorgosaurus* sp.
  - Order Ornithischia
    - Suborder Ornithopoda
      - Family Hadrosauridae
        - cf. *Kritosaurus*
    - Suborder Ankylosauria
      - Family Nodosauridae
        - *Euoplocephalus* sp.

Class Mammalia
- Order Multituberculata
  - Suborder Ptilodontoidea
    - Family Ectypodontidae
      - *Mesodma* sp.
    - Family Cimolodontidae
      - cf. *Cimolodon*
- Order Insectivora
  - Family Leptictidae
    - cf. *Gypsonictops*

ESTIMATE OF ENERGY RESOURCES OF NEW MEXICO 1979

by Frank E. Kottlowski, *Director,* and Sam Thompson III, *Petroleum Geologist*

Introduction

New Mexico's energy resources are diverse and abundant; the state ranks high in the nation as an energy producer and as a storehouse of energy. The subsurface energy resources are ranked in order of amount in quads (a quad is a quadrillion Btu; that is, 10^{15} Btu): 1) uranium 79,000 (1,387,800 tons U_3O_8), 2) coal 4,001 (181 billion tons), 3) natural gas 19.4 (18.3 trillion cu ft), 4) crude oil 7.7 (1,253 million barrels), and 5) geothermal energy 6 (1.75 trillion kwh). These estimates of potential energy include proved reserves and probable resources of producing districts but exclude the speculative resources of unexplored areas that could increase the totals by several orders of magnitude.

The northwestern part of New Mexico contains the largest reserves of uranium (in Jurassic sandstones) and of coal (in Cretaceous formations), nearly half of the gas resources (in Cretaceous sandstones), a small part of the oil resources (in Pennsylvanian limestones and Cretaceous sandstones), and some of the best geothermal prospects (in the Jemez area on the western margin of the Rio Grande rift). The southeastern part contains the largest reserves and resources of oil and gas (in Paleozoic carbonate rocks and sandstones). The energy resources of the northeastern (excluding the Raton coal field) and southwestern parts of the state are still being explored.

Surface resources include solar, hydroelectric, and wind power. Of these, solar energy has the greatest potential.

Energy resources

As a result of the state's geologic history, the energy wealth in the subsurface of New Mexico is apportioned as follows: 1) oil and gas in the Paleozoic rocks of the Permian Basin; 2) uranium deposited in Upper Jurassic fluvial sandstones in the northwest; 3) coal, oil, and gas in the Cretaceous strata of the San Juan Basin; and 4) geothermal resources related to Cenozoic faults and volcanism along the Rio Grande rift and in the Basin and Range province of the southwest. Until recently, the highest production values came from the older formations.

TABLE 1—ENERGY RESOURCES OF NEW MEXICO IN ORDER OF BTU (British thermal units).

Resources	Proved	Probable	Total Btu	Total quads[1]
1) uranium (tons of U_3O_8)	473,900	913,900	79×10^{18}	79,000[2]
2) coal (millions of tons)	7,772	173,019	4×10^{18}	4,001
3) gas (trillions of cu ft)	13.3	6.36	19.4×10^{15}	19.4
4) oil (millions of barrels)	485	768	7.7×10^{15}	7.7
5) geothermal (trillions of kwh)	in progress	1.75	6×10^{15}	6
6) solar	in progress	unlimited	—	—
7) hydroelectric	small	insignificant	—	—
8) wind	small	small	—	—

[1]A quad (quadrillion Btu) is a billion mega Btu = 10^{15} Btu = 1,000,000,000,000,000 Btu = 293,083,000,000 kwh
[2]Uranium used in a breeder reactor

These estimates as of January 1, 1979, updated from Kottlowski and Thompson (1979), include proved reserves and probable resources in producing districts, but they exclude speculative resources in unexplored areas that could substantially increase the totals.

Uranium

Through 1978, a total of 68,190,000 tons of 0.208-percent uranium ore yielding 141,800 tons of U_3O_8 had been produced in New Mexico. According to the U.S. Department of Energy (1979a), the reserves of ore-grade uranium (at $50.00 per lb of U_3O_8 concentrate) as of January 1, 1979, were 539,000,000 tons (average grade of 0.09 percent) containing 473,900 tons of U_3O_8 in 175 deposits. This is 52 percent of the total United States reserves. Estimates of how much more uranium will be found in New Mexico are speculative, despite present geologic knowledge of the deposits. The Department of Energy (1979b) lists the total potential resources as about 913,900 tons of U_3O_8 with 467,900 tons considered probable, 445,400 tons possible, and 600 tons speculative.

The Grants region in northwest New Mexico contains most of these uranium reserves in fluvial sandstones of the Morrison Formation (Jurassic), with small amounts in the Todilto Limestone (Jurassic) and the Dakota Sandstone (Cretaceous). Peripheral to the Church Rock-Ambrosia Lake-Laguna-Mount Taylor mining districts of the Grants region and scattered in other sandstones of Permian through Eocene age are submarginal deposits of uranium containing 0.1- to 0.01-percent U_3O_8.

Recent deep drilling in the Chaco Canyon area has confirmed projection of deposits in the Morrison sandstones northward from the present mining areas. Other possible reserves and resources are in the Eocene Baca sandstones of west-central New Mexico, called the "Red Basin" by DOE, Morrison-Burro Canyon-Dakota sandstones in the southern Chama Basin area, Sangre de Cristo sandstones near Las Vegas, Triassic rocks in northeast New Mexico, Espiñaso and Galisteo Formations near Hagan, Popotosa Formation north of Socorro, Precambrian rocks in the Burro Mountains, and calcretes in the Ogallala Formation of the High Plains. Vein deposits bearing thorium minerals occur in the Laughlin Peak area of northeast New Mexico, the Capitan Mountains west of Roswell, and at Gold Hill in the Burro Moutains of southwest New Mexico.

New Mexico's total reserves and resources of uranium were estimated at 1,387,900 tons of U_3O_8 by DOE; this estimate would yield 554 quadrillion Btu (quads) or 162 trillion kwh in the present light-water nuclear reactors (which utilize about 1½ percent of the uranium) or 79,000 quads or 23.1 quadrillion kwh in a breeder reactor. These calculations are made by using a productive rate of 74 million Btu per gram of fissionable U^{235}. In one ton (910,000 grams) of average uranium ore, there are 6,370 grams (0.7 percent) of U^{235}, which would yield 470 billion Btu in a light-water reactor. In a ton of U_3O_8, extracted from the ore, a maximum of 399 billion Btu (470 billion x 714 ÷ 842) is available from U^{235}; the energy equivalent is 117 million kwh. The amount of energy that can be produced from a ton of U_3O_8 using a breeder reactor may range from 16.7 billion kwh to 35 billion kwh (Donnelly, 1977, p. 285). The smaller amount, 16.7 billion kwh, is 57 trillion Btu, which is the energy in a ton of U_3O_8.

Much of the economy and utility of uranium used to produce electricity depends on the resolution of scientific, technical, and political problems dealing with nuclear plants and with safe disposal of radioactive wastes.

Coal

New Mexico's major coal reserves and resources are in the Mesaverde Group (Cretaceous) and Fruitland Formation (Cretaceous) in the San Juan Basin of the northwest, and in the Vermejo and Raton Formations (Late Cretaceous to Early Tertiary) in the Raton Basin of the northeast (Kottlowski and others, 1979). Smaller deposits occur in the Mesaverde Group of several areas, including Cerrillos, Hagan, Tijeras, Rio Puerco, Datil Mountain, Jornada del Muerto, Carthage, Sierra Blanca, Salt Lake, and Engle (fig. 1; also Tabet and Frost, 1978). Most of the coal in the Raton, Carthage, and Cerrillos fields is coking coal—too valuable to be used in the generation of power at a time when coking coal brings a price about four times that of steam coal.

Reserves of coking coal, therefore, should be excluded in calculating coal reserves and resources to be used in producing electric energy, synthetic gas, or synthetic oil. Coking-coal reserves, as calculated by Pillmore (1976) chiefly from the Casa Grande area of the Raton field in northwest New Mexico, are at least

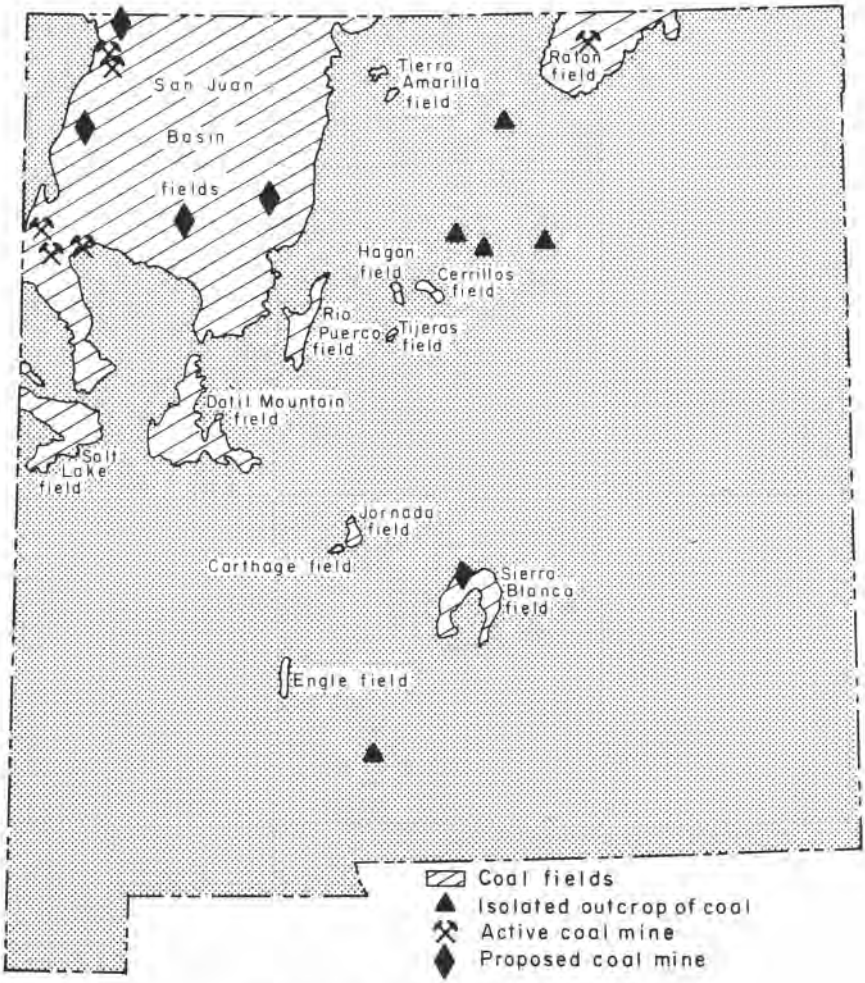

FIGURE 1—COAL FIELDS IN NEW MEXICO.

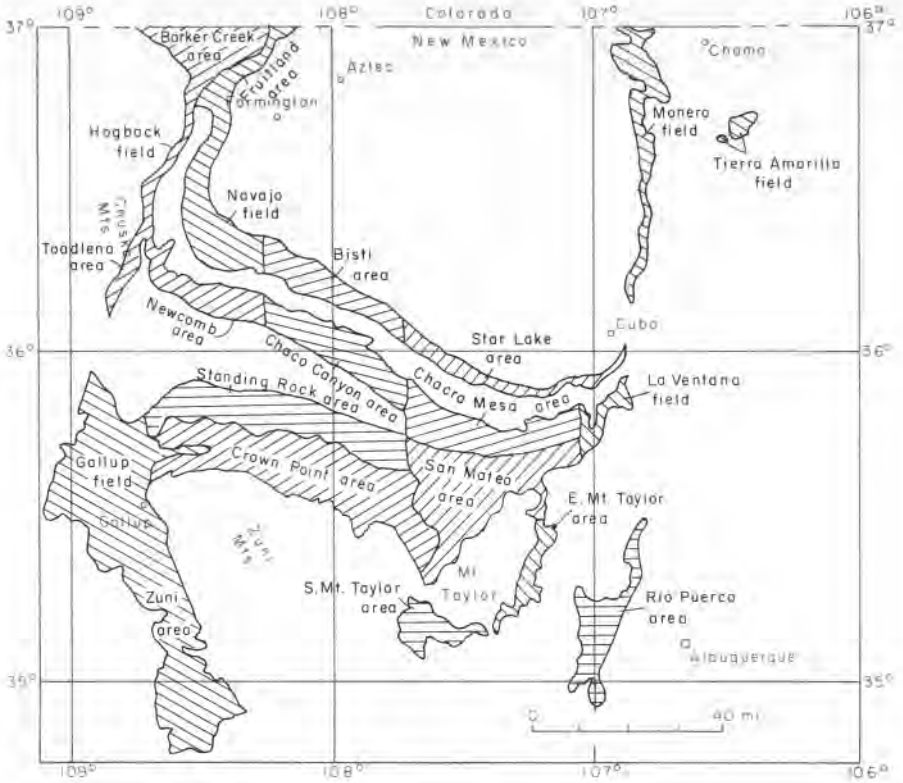

FIGURE 2—COAL FIELDS IN SAN JUAN BASIN REGION.

715 million tons of coal. At an average of more than 13,000 Btu per lb, a total of 18.6 x 10^{15} Btu is calculated (13,000 x 2,000 x 715,000,000). Read and others (1950) estimated coking coal for the entire Raton region, including measured, indicated, and inferred reserves, to be 2,461 million tons to depths of 1,000 ft, 1,846.2 million tons between 1,000 and 2,000 ft, and 402.1 million tons between 2,000 and 3,000 ft. This is a total of 4.709 billion tons of coking coal averaging more than 13,000 Btu per lb, giving an equivalent of 122 x 10^{15} Btu (122 quads).

The total coal available in the smaller fields in New Mexico (Tijeras, Sierra Blanca, Hagan, Cerrillos, Carthage, and Jornada del Muerto fields), probably is about 1,761 million tons of bituminous and anthracite coal, averaging about 12,500 Btu per lb, or a total of 44 billion Btu. The total amount of coal may be subdivided by depth into 841 million tons down to 1,000 ft, 601 million tons between 1,000 and 2,000 ft, and 319 million tons between 2,000 and 3,000 ft.

Most of New Mexico's steam coal occurs in the San Juan Basin (fig. 2). The coal rank ranges from subbituminous to bituminous. The average yield is about 11,000 Btu per lb.

Fassett and Hinds (1971), Shomaker and others (1971), and Speer and others (1977) estimated 172.68 billion tons of coal reserves in the San Juan Basin, indicating that more coal will be found between the surface and depths of 3,000 ft. At depths below 3,000 ft, the coal resources are probably as large as those above 3,000 ft, but estimates of their occurrence are based on widely scattered data.

In the San Juan Basin, strippable coals of mineable thickness, as calculated to depths of 250 ft, total at least 6.5 billion tons. This estimate will be revised upward by further exploration, particularly in the southern part of the basin. The Navajo mine west of Farmington is the largest in the state. It produces 7 million tons annually by strip mining and contains 1.9 billion tons in reserves to a depth of 150 ft.

Using the estimated 173 billion tons to a depth of 3,000 ft, with a heating value of 22 million Btu per ton, the total heating value of 3.8×10^{15} Btu is calculated for the resource in the San Juan Basin.

The Datil Mountains coal area west of Socorro has not been explored in detail; it is in a rugged region remote from transportation. Read and others (1950) estimated that 1.3 billion tons of subbituminous coal may be available in that area, but thorough geologic exploration is needed to verify this figure. The New Mexico Bureau of Mines and Mineral Resources has several mapping projects in the region. Much of this coal probably could not be obtained by strip-mining methods, mainly because thick volcanic sequences overlie the Cretaceous coal-bearing formations.

The Salt Lake field is located near the Arizona border, along the junction of the Catron-Valencia County line, in the Fence Lake-Salt Lake area. Coal-bearing Mesaverde Group rocks there are being mapped by New Mexico Bureau of Mines and Mineral Resources geologists David Tabet, Stephen Frost, and Frank Campbell. Coal beds 7-12 ft thick have been found, but more exploration is needed. In 1905 estimates by the State Inspector of Mines suggested resources of as much as 320 million tons of coal, but this figure has not yet been verified.

The main coal that can be used to produce energy during the next few decades is the strippable coal in the San Juan Basin; it totals more than 6.5 billion tons, or an equivalent 143 quads. The San Juan Basin coal between depths of 250 and 3,000 ft, coking coal mainly in the Raton Basin, and coal in other areas could yield an additional 175 billion tons, or an equivalent of 3,858 quads. However, under present economic conditions, not much of the coal deeper than 500 ft will be mined.

At the present time, the only underground coal mine in the state is at York Canyon west of Raton. Plans have been made for underground operations east of the San Juan mine near Farmington and in the La Ventana area south of Cuba.

Oil

Ultimate oil production from New Mexico is estimated conservatively at 4.58 billion barrels (bbls). About 4.31 billion bbls are estimated for the Permian Basin in the southeast and 0.27 billion bbls for the San Juan Basin in the northwest (Miller and others, 1975; American Gas Association and others, 1979). This evaluation does not include the speculative resources in the northeast and southwest parts of the state where significant commercial production has not yet been established.

From 1924 through 1978, the cumulative production in the southeast was 3.23 billion bbls; of this, 83 million bbls were produced in 1978 (New Mexico Oil and Gas Engineering Commission, 1979). All came from reservoirs in Paleozoic rocks; the most prolific ones are in Permian dolomite reefs and banks along the margin of the Delaware Basin. The 1.17 billion bbls of proved and probable resources do not include natural-gas liquids, enhanced (tertiary) recovery, prospects that are shallower or deeper than the producing fields, or discoveries of new fields outside of currently producing areas.

TABLE 2—ESTIMATED COAL RESOURCES OF NEW MEXICO (millions of short tons).

Fields	Coal			Quads
	Strippable	Combined	Deep	
San Juan Basin				
Fruitland Formation	5,716	—	154,177	3,517.6
Mesaverde Group	788	—	12,000	281.3
Raton Basin	—	4,709	—	122.4
Sierra Blanca field	—	1,644	—	41.1
Datil Mtn. area	—	1,320	—	29.0
Salt Lake area	—	320	—	7.0
Cerrillos field	—	—	59	1.5
Carthage field and Jornada del Muerto area	—	39	—	1.0
Hagan field	—	17	—	0.4
Tijeras area	—	2	—	—
Engle area	—	unknown	—	—
Total		180,791		4,001.3

	Proved	Probable and possible
San Juan Basin	6,504	166,177
Raton Basin	1,200 est.	3,509
Other fields	68	3,333
Total (short tons)	7,772	173,019
Quads	172	3,829

From 1922 through 1978, the cumulative production in the northwest was 0.17 billion bbls. The most important reservoirs are in Cretaceous sandstones (Dakota and Gallup) and Pennsylvanian carbonate rocks (Hermosa), but there are some of interest in other parts of the Paleozoic and Mesozoic section. Again, the 0.10 billion bbls of proved and probable reserves is a conservative estimate.

According to the estimate of the American Petroleum Institute, the proved reserves of the entire state are only 485 million bbls. If no new oil is found, these reserves could be depleted within 6 years. The probable resources of 768 million bbls will suffice for the immediate future, but exploration needs to be accelerated in both the producing provinces and in the frontier areas if oil is to continue as the most valuable commodity in the state.

In the northeast, the Santa Rosa Sandstone (Triassic) at the surface contains an impregnation of 4-percent light oil that migrated from Permian or Pennsylvanian strata. About 57 million bbls of oil are estimated over an area of 900 acres (Ball Associates, 1965). Unfortunately, the planned Los Esteros dam will flood the area, but in New Mexico water is more precious than oil! At least this occurrence gives incentive to further exploration.

The southwest corner of the state includes part of the Pedregosa Basin, which contains many Paleozoic formations correlative with producing formations in the Permian Basin. Prospects also exist in the Lower Cretaceous strata. Unfortunately, the Cenozoic geologic history was complex, with thrusting, volcanism, and deep, high-angle faulting. Shows of dead oil were found in a recent test well along the Permian shelf margin. The location is on an anticline with Permian rocks at the surface, and the section below was metamorphosed by a Tertiary intrusive

(Thompson and others, 1977). Nevertheless, many deep prospects in the grabens await the drill.

Other areas deserving more exploration include Tularosa Basin, Otero Mesa, Raton Basin, Las Vegas Basin, the Tucumcari area, and the Acoma-Albuquerque area.

The remaining proved reserves and probable resources total 1.34 billion bbls, or an equivalent energy value of 7.77 quads (10^{15} Btu).

Gas

Ultimate recovery of natural gas in New Mexico is estimated conservatively as 47.4 trillion cu ft. The estimate for the southeast is 26.5 trillion cu ft, and for the northwest is 20.9 trillion cu ft (American Gas Association and others, 1979; Miller and others, 1975). Cumulative production to 1979 is 30.3 trillion cu ft, including 19.0 trillion from the southeast and 11.3 trillion from the northwest (New Mexico Oil and Gas Engineering Committee, 1979). The proved reserves of 13.26 trillion cu ft, including 9.64 trillion in the southeast and 3.62 trillion in the northwest, will be depleted within 10 years if no new gas is discovered. The probable resources are 6.36 trillion cu ft, with 4.27 trillion in the southeast and 2.09 trillion in the northwest.

In the southeastern part of the state, the Paleozoic reservoirs yielded 85 percent of the gas in association with (or dissolved in) oil. In recent years, the most important gas development in this area is in the basal Pennsylvanian (Morrowan) sandstones. In the northwest, the main gas reservoirs are in Upper Cretaceous sandstones, specifically those of the Mesaverde and Pictured Cliffs Formations; in contrast to the southeast, 95 percent of the production was not associated with oil. The most prolific gas pool in the state is the Blanco Mesaverde, with cumulative production from 1927 to 1977 of 4.40 trillion cu ft. In 1974, a program of infill drilling was begun to increase production (Arnold and others, 1978, p. 11-16).

Kerogen analyses indicate that the prospects for gas in the Pedregosa Basin are better than those for oil. Some wells have encountered shows of gas in the Permian and Ordovician strata, but tests have not reached economic levels. Nevertheless, with the decrease in federal price control in recent years, the rising price of gas should encourage development in producing provinces and exploration in the frontier areas.

The first commercial production in the northeastern part of the state began in 1976; after one year 55 million cu ft had been accumulated. The wells near Wagon Mound produce from Dakota (Cretaceous) and Morrison (Jurassic) sandstones at depths of less than 1,000 ft. The pressure of 5 lbs per square inch is so low that multistage compressions is needed before injection into the pipeline (Arnold and others, 1978, p. 17-19). Also in the northeast, in the Bueyeros area, the development of carbon dioxide has provoked interest because of its use in enhanced (tertiary) recovery of oil.

The total proved reserves and probable resources are 18 trillion cu ft of natural gas, which has a heating value of 19.4 quads (10^{15} Btu).

Geothermal energy

Geothermal prospects occur in the central and southwest parts of New Mexico where the lithospheric crust is thin, deep faults reach the mantle, magma bodies are relatively shallow, heat flow is high, and surface evidence exists for recent volcanism and hot springs. Projects of the last few years are scientific ex-

periments rather than commercial operations, but in 1977 leasing and drilling of shallow tests began. Within the next few years, basic questions should be answered about whether it is possible to: 1) find large reservoirs with steam or hot water; 2) transport hot water through pipelines over distances greater than 10 mi; 3) use hot water without technical problems in heating, refrigeration, and generation of electricity; and 4) prove that geothermal energy in New Mexico is as economical as other energy resources.

Many prospects lie along the Rio Grande rift, from north of Santa Fe to south of Las Cruces. The main ones are in the Jemez Mountains, in the Valles Caldera. Wells producing hot water and some steam from depths of 2,700 to 4,500 ft in the Bandelier Tuff are to be used in a demonstration plant that will generate 50 megawatts of electricity. Union Geothermal Company of New Mexico, Public Service Company of New Mexico, and the U.S. Department of Energy are cosponsors of the project, which will tap a 60-cu-mi reservoir of 550°F water for the project. If the demonstration plant is successful, a plant to generate 400 megawatts will be constructed.

The Rio Grande rift (Hawley, 1978) shares many characteristics with the Imperial Valley of California, where projects of 10,500 megawatts are being developed. Part of the optimism is based upon the successful plant at Cerro Prieto in Baja California, which is planned to reach 400 megawatts in 1982. With the same technology, New Mexico may be able to produce 1,000-2,000 megawatts; some estimates suggest that with foreseeable improvements the production could reach 5,000-10,000 megawatts. Over a 20-year period, this resource may provide 1.75×10^{12} kilowatt hours of electricity. Many of the geothermal areas in the state are of moderate-temperature waters and would be useful mainly for space heating.

Areas outside of the Jemez Mountains with geothermal potential are: 1) the Lightning Dock area in the Animas Valley of southwest New Mexico; 2) Socorro Peak area; 3) the Las Alturas, Radium Springs, and Kilbourne Hole areas near Las Cruces; 4) Jemez Springs area; 5) Ojo Caliente area in Taos County; 6) Truth or Consequences area; 7) Lower Frisco area near Reserve; and 8) Gila Hot Springs and Mimbres area in Grant County (Stone and Mizell, 1977; Summers, 1979).

Surface resources

Surface resources of New Mexico include solar energy, hydroelectric energy, and wind power. Geologic controls of these are not as important as those of the subsurface resources.

New Mexico is situated in one of the major high-intensity sunshine belts of the United States. When technology is developed to the stage where solar power reaches maximum commercial feasibility, New Mexico will be in a favorable position for its utilization. Solar energy is practically unlimited but is very diffuse. Production depends upon the availability of sunshine and upon technological developments of gathering solar energy and converting it to other usable forms. Space heating and cooling appear to be the main practical uses of solar energy at the present time.

In New Mexico most of the better dam sites for hydropower have been used; therefore, little additional power can be gained from running water. Also, some of the reservoir impoundments are being filled with silt, thus diminishing their power-producing capacity.

How can wind be used as an energy resource? During the 1950's, almost every ranch had a wind generator. However, as uses for electricity increased and the Rural Electrification Agency (REA) strung power lines to remote areas, these wind generators were abandoned. Some innovators in southeast New Mexico have used windmills to pump oil from shallow pools. Others are experimenting with the generation of electricity, such as the Department of Energy project near Clayton. But, as shown by the famous Don Quixote, one rarely wins jousting with windmills. Wind power appears to be less dependable and more costly than solar power.

Definitions, conversions, and comparisons[1]

1 British thermal unit (Btu) = amount of heat energy required to raise temperature of 1 pound of water 1 °F

1 small calorie (gcal) = amount of heat energy required to raise temperature of 1 gram of water 1 °C

1 large (great) calorie (kgcal) = amount of heat energy required to raise one kilogram of water 1 °C = 1,000 gcal (calorie used in energy-producing value of food)

1 Btu = 252 gcal

1 kilowatt-hour (kwh) = 3,413 Btu

1 quad = 10^{15} quadrillion Btu = 1,000,000,000,000,000 Btu = 172,414,000 bbl oil = roughly 1 trillion cu ft of natural gas = 293,083 million/kwh = about 50 million tons of New Mexico coal

1 bbl of oil = 5,800,000 Btu

1 cubic foot of New Mexico natural gas = 1,075 Btu

1 pound of average New Mexico coal = 10,000 Btu

1 ton of average New Mexico coal = 20 million Btu

Light-water reactors without recycle produce about 28 million kwh electricity per ton U_3O_8; with fuel recycle, 43 million kwh/T. Breeder reactors could produce 35 billion kwh/T U_3O_8. These calculations are based on 25-35 percent efficiency by the power plant for light-water reactors.

[1]sources: Donnelly, 1977 (p. 285); Moore, 1977 (p. 393)

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DINOSAURS, TURTLES, BADLANDS, AND COAL IN NORTHWEST NEW MEXICO

by Donald L. Wolberg, *Vertebrate Paleontologist,* and Frank E. Kottlowski, *Director*

Introduction

New Mexico's paleontological wealth is abundant and diverse; contained within the rocks of the state are many fossil remains that span hundreds of millions of years and help to document the history of life forms on this planet. One segment of the state's paleontological record, the Upper Cretaceous, is intimately associated with a major economic resource: coal. Significantly, most of the strippable coal present in the San Juan Basin of northwest New Mexico occurs within the Fruitland Formation, also long known for its contained fossils and, in some areas, for its characteristic development of badland topography. One such badlands region, the Bisti badlands, has become the center of debate and controversy.

The Bisti badlands, around and mostly to the east of the old Bisti Trading Post (northwest corner of sec. 32, T. 24 N., R. 13 W.), expose broad outcrops of the Fruitland Formation, as well as the underlying Pictured Cliffs Sandstone and overlying Kirtland Formation. The badlands are typical of hundreds of square miles of badlands developed on the Cretaceous rock units of the San Juan Basin and occupy about 75 sq mi near the ruins of the burned-out trading post. The resistant Picture Cliffs Sandstone and the Ojo Alamo Sandstone that overlies the Kirtland Formation form, respectively, lower and upper stratigraphic boundaries to the badlands development. The bare-rock exposures are concealed to the north and south, as well as along interstream divides, by eolian sand that blankets much of the surrounding region.

Hunter's Wash, Willow Wash, and Alamo Wash cut through the badlands and serve as the base level for erosion; additionally, they are being choked by the tremendous amount of sediment derived from the badlands. This naturally derived sediment is carried downstream to the Rio Chaco and then to the San Juan River. Weathering of the siltstones and the claystones of the Fruitland and Kirtland Formations also provides fine-grained particles for the region's dust storms; thus, the Bisti badlands, along with many of the numerous badlands in the San Juan Basin, are a major source of natural pollution of the streams and atmosphere.

The Bisti area is traversed on its west side by NM-371, the main road from Farmington to Crownpoint, and is relatively heavily traveled. Since similar badlands are common throughout the San Juan Basin, much of the recent interest in the Bisti badlands is possibly the result of the relative ease of access as much as the scenic interest.

The badlands do expose almost complete sections of the upper part of the Pictured Cliffs Sandstone, the Fruitland and Kirtland Formations, and the lower part of the Ojo Alamo Sandstone. To the north and northeast, the Nacimiento Formation crops out with poor exposures on the sand-covered uplands. The Fruitland Formation consists of intertonguing, fine-grained, light-gray sandstones, brownish siltstones, and clay shales; thin pelecypod-coquina limestones; dark carbonaceous shales; and coal beds. Few fresh coal outcrops occur; most are weathered or consist of reddish-brown clinkers where the coal has burned and the adjacent beds have baked. The sedimentary units are typical of terrestrial stream and floodplain deposits and show great variability in thickness and areal extent,

cut-and-fill features, and limited traceability of individual beds. The coal beds and carbonaceous shales represent wide-ranging swamp deposits and appear to have broader areal distribution. They serve as useful stratigraphic marker horizons.

The contact with the overlying Kirtland Formation is chosen at different places by different geologists. Relatively thick brown sandstones above the uppermost coal bed were considered to mark the top of the Fruitland by Dane (1936). Fassett and Hinds (1971) mapped the uppermost coal or carbonaceous shale as the highest unit of the Fruitland Formation. Some persons have difficulty distinguishing dark-brown shales in the Kirtland Formation from bone-coal beds. The Kirtland Formation does not contain any coal lenses; the lower part of the Kirtland consists mainly of gray shale with thin lenses of sandstone. The middle Farmington Sandstone Member consists of a series of lenticular intertonguing sandstones and shales.

Along with relatively complete exposures of the Fruitland Formation, which are characteristic of the badlands, fossiliferous horizons also are well developed. The active erosion of the badlands is both boon and bane to paleontology; fossils exposed to erosional processes are destroyed, while new material is constantly being uncovered. Thus the Bisti area has been a collecting locality for at least 70 years.

Previous work

Many published studies dealing with the geology and paleontology of the Bisti area and adjacent regions are available; also available are unpublished studies, primarily related to various aspects of projected coal development in the area. Published studies include Bauer (1916), Stanton (1916), Gilmore (1916, 1919, and 1935), Osborn (1923), Reeside (1924), Dane (1936), Barnes (1953), Anderson (1960), Baltz and others (1966), Fassett and Hinds (1971), Shomaker and others (1971), O'Sullivan and others (1972), Fassett (1973), Clemons (1973), Powell (1973), Tschudy (1973), D. Russell (1975), L. S. Russell (1975), Butler and others (1977), Rigby and Lucas (1977), Lindsay and others (1978), and Wolberg and LeMone (this volume).

Recent paleontologic inventories have been paid for by the U.S. Bureau of Land Management (Kues and others, 1977), Chaco Energy Company, or by Western Coal Company (LeMone and others, 1977 and 1979, respectively). These inventories attempt to compile site-specific inventory data, assemble previously documented work, identify significant occurrences of fossils, and suggest mitigative techniques.

Coal development and paleontology

Shomaker (1971) estimated that the Fruitland Formation in the Bisti area contained 1,870 million tons of coal beneath less than 250 ft of overlying deposits. Much of this coal lies within public lands managed by the U.S. Bureau of Land Management. Barring unforeseen developments, it is apparent that paleontological mitigation will be required of companies seeking to mine this coal. The BLM, acting under the Federal Land Policy and Management Act of 1976, holds that:

> The public lands be managed in a manner that will protect the quality of scientific, . . . and archaeological values. . . . Section 102(a)(8)

> The Secretary shall prepare and maintain on a continuing basis an inventory of all public lands and their resources and values. . . . Section 201(a)

On the surface, this new cognizance of paleontological values may appear to be a boon to the science; however, the issues involved and the subject matter itself are of greater complexity than might be apparent. The implications of Section 102(a)(8) are numerous: for example, paleontology obviously is not mentioned. Equally obvious is the fact that paleontology cannot be included within archaeology and thus must be a part of "scientific values." Since archaeology is distinguished from scientific values, archaeology may not be considered a science; most archaeologists would not be very happy with this implication.

Paleontology and fossils are included by the BLM in the section of the Federal Land Policy and Management Act of 1976 that treats scientific values. What are the values or uses of fossils? In general, they may be listed as follows:

1) Fossils make up the record of ancient life forms, and they may be interpreted to demonstrate the course of evolution during geologic time.

2) Fossils are valuable as indicators for the correlation, or matching, of sedimentary rock layers and are used as aids in determining geologic age; this may be of particular importance if the strata concerned contain coal seams, metallic orebodies, petroleum, or other mineral resources.

3) Fossils provide evidence of ancient environments (such as shallow or deep seas, swamps, deserts, and floodplains); they may indicate ancient climatic conditions and changing geographic relationships or patterns during geologic history.

Fossils also are used as educational resources in secondary schools and universities. They are popular exhibits in museums, such as the University of New Mexico's geology museum and the mineral museum at the New Mexico Bureau of Mines and Mineral Resources.

Unlike archaeological remains, which generally consist of individual sites or limited regional loci, paleontological remains are generally distributed through rock strata. The only limitations upon the distribution of individual paleontological components, the various types of fossils, are the environments represented and a vertical component that may be taken to represent time. Because marine rocks and environments are far more prevalent than nonmarine, the great majority of fossils are of marine origin and consist mainly of invertebrate animals. In terms of potential numbers of individual specimens available for collection, most fossils are barely visible to the naked eye. The numerical abundance of most fossil types is truly astounding. Just a few pounds of a Devonian marine limestone, when properly digested in the appropriate acids, may yield hundreds of intricate conodonts. By far the great majority of fossils consists of ancient life forms whose individual place in the scheme of things is barely intelligible by any but a narrow, hyperspecialized audience tutored in the complexities of foraminiferal classification, ammonite shell morphology, or cusp morphology of primitive mammalian teeth.

Paleontology is the study of fossil organisms and, as such, is obviously dependent upon the collection of specimens to be studied. Fossils that remain in the ground generally are of little value to paleontologists and generally do not enhance our knowledge of ancient life. Many fossils are destroyed by erosion and never get into the hands of a paleontologist. The rate of destruction of fossil material is dependent upon a wide variety of environmental factors, but it is inexorable. Under normal circumstances, given the choice of allowing significant fossil material to be destroyed by natural processes or retrieved for future study, collection would be favored by most individuals.

As large volumes of fossil-bearing sediments are alternately exposed and removed, expanded development of the state's coal resources will also vastly expand the potential availability of fossil specimens from those rock units that will be affected by mining operations. Coping with the increased volume of available material may be a major problem. Under the best of circumstances, a broadly based paleontological mitigation program would be very expensive; that expense must, in the end, be carried by the energy consumer, the public. The question arises: will every potentially available fossil have to be retrieved, prepared, curated, and studied?

In general, the recovered or recoverable fossils of an area are a poor representation of a once-living community. Clarke and Kietzke (1967) demonstrated that a series of natural processes are involved in the development of a fossil assemblage. Each phase of fossil development suffers distortion; the reconstruction of the once-living assemblage involves the successive removal of those distorting effects. The disparity between a fossil assemblage (the total fossil content of a body of rock), a fossil sample (a fossil collection taken from a fossil assemblage), and the life assemblage has generated a great deal of confusion regarding the impact of expanded mining on the paleontology of New Mexico. There has never been a complete study of the actual impact of coal mining or other surface operations on the paleontology of an area.

Obviously, if mining activities destroy all of the fossils present, the impact is severe; fossils from that area are lost. Is the impact as severe if the fossils are duplicated or represented in collections already available or if the same strata with the same fossil content are present elsewhere in areas with no mining? Is it reasonable to forestall mining on the basis that important fossils may be destroyed by mining operations if they are present? Many of the current resource-management ideas regarding paleontology are viewed in an anthropological/archeological/sociological context. Archaeological materials are most frequently restricted to relatively small areas and as such are more amenable to "clearance" procedures; they can be removed completely with relatively little effort. Paleontological materials, however, are strata-bound and occur in rock units that frequently extend many thousands of square miles. It is absurd to think that every fossil can be removed or even found, especially when one remembers that most fossils are barely visible to the unaided eye or are truly microscopic in size.

Archaeological materials are easily appreciated by the layman and are readily identifiable as the product of human activity, whereas paleontological materials are not often as easily understood by the layman. The paleontological material is not in itself a cultural resource; the interpretation of the material provided by the paleontologist is what assumes the cultural significance to the untutored viewer. In this sense, paleontological activities are elitist and are very much dependent upon formal presentations such as museum exhibits and popularized discussions.

Any concerted effort to recover a significant portion of the fossil materials from deposits that will be affected by mining or any surface disturbance must go hand in hand with a program for the disposition of that material. Such a program might involve established institutions, in which case the material would be removed from the state, or a New Mexico institution would have to be developed, in which case a large and continuing series of dollar appropriations would have to be made by the State. Here again, paleontology would be singled out for special treatment and perhaps rightly so; most paleontologists feel that funding of paleontology has lagged behind that of other sciences. However, full-scale scien-

tific institutions are expensive undertakings, all the more so in these days of significant inflationary pressures. In the end, it is the taxpayer who would bear the burden of financing an institution that may or may not be needed, depending on the individual's perspective, or in which little genuine interest exists. Any such institution may in fact be paid for by the many for the benefit of the few. At a minimum, the taxpayers ought to be granted the opportunity to express their views.

Summary

The bulk of projected surface coal mining in the San Juan Basin will be in deposits of the Fruitland Formation. Fruitland (and overlying Kirtland) strata contain and have already yielded a rich Late Cretaceous fossil assemblage of plants and animals. Of course, Late Cretaceous assemblages occur elsewhere in North America and the world, and many of the taxa recorded from the Fruitland/Kirtland Formations have also been recorded elsewhere. However, the fact that a Fruitland/Kirtland dinosaur or turtle is also found in Montana has little to do with the issue of BLM paleontologic mitigation. By the same token, if a fossil taxon were only known from the Fruitland/Kirtland, that fact alone should have no bearing on the problems inherent in paleontologic mitigation. Paleontologic ubiquitousness or endemism is very different from its neontologic analogs. The paleontologic "treasures" of the Fruitland/Kirtland are obviously worth examining, understanding better, and mitigating within reason, in terms of the potential impact of coal mining. Problems have arisen over how, what, how much, and why, and—remarkable as it may seem—no fully documented study of the actual effects of mining on the paleontology of an area has been conducted.

The potential impact of mining may be as paleontologically rewarding as it may be negative. If a potentially rich fossil-bearing stratum is progressively exposed by stripping away overburden that obscures the contained fossil material, the fossils become available for collection, study, and preservation. If the fossil material is exposed and remains uncollected, it eventually ends up in a spoils pile to be finally backfilled, and so specimens are lost. Not every fossil fragment can or should be collected. Some discretion and order of priorities are needed to ensure the maximum amount of data with the minimum expenditure of effort, time, and funds. An adequate data base specifically related to the Fruitland/Kirtland units is necessary for complete determinations.

Before any formulation of mitigation procedures reaches the regulatory phase, paleontological "ground truthing" is in order. Although the Fruitland/Kirtland has been collected sporadically for about 70 years, it is possible that a comprehensive faunal and floral sample has yet to be taken. Such basic facts as the exact age(s) of the fossils (and rocks) and what taxa are present still have to be adequately determined.

An intensive paleontologic study could provide an adequate data base. Then about 85 percent of the fossil taxa present in the Fruitland/Kirtland might be known. This relatively complete Fruitland/Kirtland sample could allow realistic evaluation of potential mining impact on the paleontology of specific areas. Samples collected from these areas would have a basis for comparison. Such an intensive study (surface collection, core drilling, and large-scale quarrying) would be expensive. The scientific merit must be weighed against the funds, time, and personnel that would be used.

A detailed analysis of the impact of paleontological mitigation on the economics of mining and on the actual mining operations would be helpful. If a

continuing monitoring program is suggested, the realities of mining procedures, schedules, and costly equipment must be taken into consideration; demanding unrealistic requirements of the mining industry that would hinder efficient and safe mine operations is self-defeating. A middle ground should be determined between the scientific use of paleontological resources, ephemeral scenic values, and the extraction of badly needed energy resources. Most of the badlands will not be touched by coal mining, most of the significant fossils can be collected, and coal can be mined to light and heat New Mexico.

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EVALUATION OF SCORIA DEPOSITS IN NEW MEXICO

by JoAnne Cima Osburn, *Geologist*

Introduction

Scoria (volcanic cinder) is highly vesicular, dark, volcanic rock of basic composition. It comprises extremely small crystals of basic feldspars, pyroxene, and glass in a groundmass of the same minerals. Scoria is formed when gases, especially water vapor, expand as molten lava is thrown from a volcanic vent during an eruption. The ejected material (tephra), including scoria, volcanic bombs and blocks, and lava, piles up around the vent and forms an elliptical to circular cone. Only moderately explosive eruptions produce economically useful scoria (or cinder) cones.

The significant differences among scoria, bombs, and blocks lie in variations in size and texture of the materials. Scoria is made up of coarse to fine cellular clasts that range from 2 to 100 mm (4 inches) in diameter. Scoria includes both equant, fracture-bound fragments and elongate, glassy forms in this size range. Both volcanic bombs and blocks are clasts greater than 100 mm in diameter. Blocks have broken surfaces and are equant in shape; bombs have a smooth skin formed while the bomb is in flight from the vent and are usually elongate in shape.

Approximately 75 percent (by volume) of a cone is made up of scoria ranging from 10-50 mm in size. The remainder comprises blocks and bombs (0-25 percent), lava flows (0-15 percent) and minor amounts of volcanic ash. The conical shape is that expected of mounded material emanating from a point source, which in this case is the vent. Deposition of the largest fragments is near the vent; a gradual decrease in particle size away from the vent enhances this shape and yields slope angles of 25-35 degrees.

The color of volcanic ejecta ranges from dark-reddish-brown in the center of a cone to very dark gray around the perimeter. The volcanic material at intermediate distances is transitional and often shows blue surface iridescence. These color variations reflect a greater degree of oxidation of iron minerals in areas near the vent. This oxidation probably is caused by greater amounts of volatiles and heat in the vent area (Cima, 1978). Knowing that this color variation is systematic about the vent area (crater) should allow scoria quarry operators to more efficiently predict the color of the tephra in a given part of a cone.

Economic importance of scoria

Although only 11 scoria deposits are being commercially exploited presently, large numbers of scoria deposits occur in widely separated parts of New Mexico (fig. 1). The state's scoria resources are very large; a conservative estimate indicates reserves of at least 320 million cu yd within 10 mi of major roads or railroads.

The primary industrial use of scoria is in concrete, mainly used in the manufacture of lightweight cinder blocks. Pumice, a light-colored volcanic rock sometimes confused with scoria, is also used in cinder-block manufacture. Because of differences in the structural properties of the two materials, scoria makes stronger, superior cinder blocks. Because scoria is formed from basaltic magmas, it has thicker cell walls and greater strength than pumice, which forms from more silica-rich magma and has more cells with thinner cell walls. Cinder blocks made from both scoria and pumice concretes have such desirable

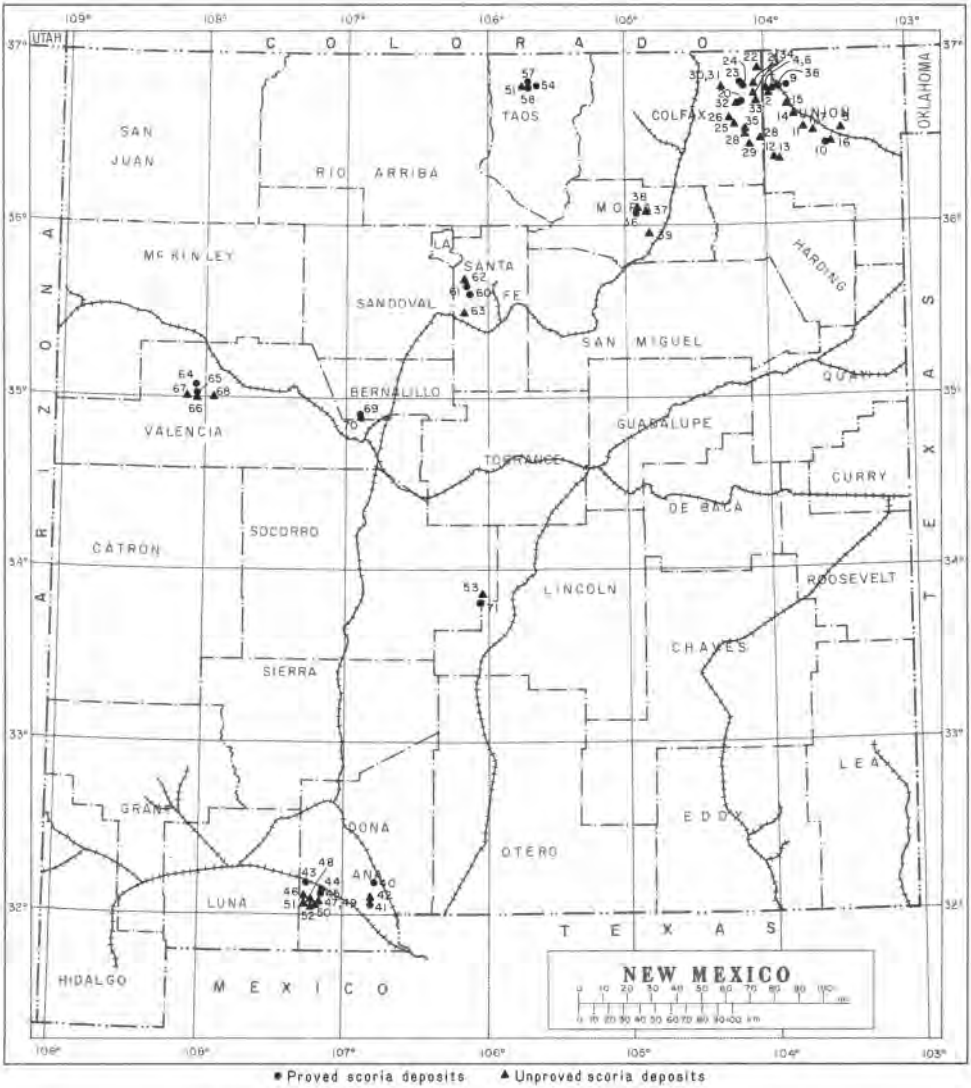

FIGURE 1—LOCATION MAP OF NEW MEXICO SCORIA DEPOSITS.

characteristics as high elasticity, fire resistance, and good insulation and verminproof properties (Schmidt, 1956).

Scoria is rapidly becoming a popular decorative stone for roofing and for desert landscaping material. Large bombs and blocks are also used in landscaping. As decorative material, the dark-reddish-brown scoria and bombs are slightly more marketable than the dark-gray scoria. Less attractive, dense, flow materials are used as ballast and for slope-erosion control. Large amounts of scoria and flow material have been used in road construction, especially in Arizona and California.

Economic potential in New Mexico

Because of transportation costs, only those scoria cones within 10 mi of railroads or major highways were examined for economic potential. Scoria is a

low-cost commodity (about $4.00 per cu yd) and requires a nearby market place to maintain low shipping costs.

The shipping price of scoria varies considerably with quality and intended use of the aggregate. For example, ¾-inch and 1½-inch aggregate for landscaping and roofing materials averages $6.75 per cu yd in the Santa Fe area and $8.75 per cu yd in the Las Cruces area (Morton Brothers, Inc. 1979, personal communication). In contrast, a typical price for cinder-block aggregate is only $4.00 per cu yd. Uniform size of fragments and general appearance are not as important for cinder-block manufacture as for decorative uses; hence, block aggregate contains small amounts of fines and waste material.

In terms of uniform size and sorting of aggregate, the ratio of cone height to average basal diameter of the cone (aspect ratio of Porter, 1972) falls within discrete limits for scoria deposits with economic potential. The cones included in this study have aspect ratios limited to between 0.10 and 0.20. Cones with aspect ratios outside of this range commonly are poorly sorted deposits or have large quantities of waste material. In addition, cones with lower aspect ratios, hence lower slope angles, are high in lava-flow materials and are poorly sorted. Cones with aspect ratios greater than 0.20 and higher slope angles usually have large amounts of agglutinated material (spatter).

The presence of lava flows or agglutinated material complicates mining procedures. These materials must be blasted aside to expose loose scoria beneath the more consolidated materials. Because of the vesicular nature of scoria, shot holes must be closely spaced for successful blasting. Use of blasting decreases mine safety, increases production costs, and therefore reduces the utility of the deposit.

Active scoria operations were visited to compare physical properties of successful scoria deposits. The most workable scoria cones shared the characteristics of good overall sorting and very limited lava flows and agglutinated material. These two features strongly influence the overall morphology of the cones and give all potentially economic cones a strikingly similar shape and map pattern; therefore, topographic maps of known basaltic fields could be used to select favorable scoria cones for field study.

Scoria deposits that showed possible economic potential from map studies were field checked and sampled. Particular attention was given to the sorting, color, and density of the volcanic fragments in each deposit (table 1). All of the information in table 1 has been verified either through field examination or citation in previous literature; no unexposed volcanic product that is probably present is included. The amount of usable scoria was estimated by simple, geometric calculations. Estimates were conservative to allow for waste and overburden. Waste materials commonly make up at least 11 percent of a given cone. Many abbreviations were used in the descriptions of deposits in table 1 to conserve space. These abbreviations are explained and clarified below.

Location: township and range designation (fig. 2)
Quadrangle: name of USGS topographic quadrangle map where cone is located
Name: common or published name (if any)
Estimated material: volume of usable scoria in deposit (millions of cu yd)
Aspect ratio: ratio of cone height to average basal diameter
Status: status with respect to quarrying operations

- A: actively quarried at present
- D: dormant at present but has been quarried at some time
- P: proved scoria deposits with at least one cut to expose underlying material
- U: unproved surficially promising deposit with no cut in cone to expose internal material

TABLE 1—NEW MEXICO SCORIA DEPOSITS (explanation of symbols on page 80).

Location	Quadrangle	Name	Reserves (m cu yd)	Aspect ratio	Status	Comments	Ref. no.
BERNALILLO COUNTY							
8N. 1E. 18.3	Wind Mesa	Blackbird Hill	1.2	0.13	A	B, R, SP, sFL	69
8N. 1E. 20.3	Wind Mesa	-	0.6	0.15	D	B, R, SP, sFL	70
COLFAX COUNTY							
28N. 27E. 36.3	Palo Blanco Mountain	-	0.9	0.12	U	R, B, FL	19
30N. 26E. 22.2	Johnson Park	B.T.O.	13.0	0.14	A	R, B, DB	20
32N. 27E. 21.3	Trinchera Pass	-	5.0	0.10	U	1R, 1FL, MV, BD	21
32N. 27E. 24.2	Trinchera Pass	-	0.85	0.15	U	R, 1DB, BL	22
31N. 26E. 16, 17.CL	Dale Mountain	Dale Mountain	3.0	0.12	P	1R, 1B	23
31N. 26E. 23.1	Dale Mountain	Red Mountain	10.0	0.11	P	1B, 1R, mDB	24
28N. 26E. 6.1	Mesa Larga	-	0.89	0.10	U	1FL, B, BL, R, MV	25
29N. 25E. 35, 36.CL	Mesa Larga	-	4.0	0.13	U	R, sDB	26
28N. 27E. 1, 2.CL	Kiowa	Horse Shoe Crater	45.0	0.17	U	R, B	27
28N. 26E. 36.3	Palo Blanco	Cook Hill	0.76	0.15	U	R, DB	28
27N. 27E. 19.1	Palo Blanco	-	0.20	0.13	U	R, B, DB	29
31N. 25E. 21, 22.CL	Yankee	-	0.30	0.14	U	DB, B, R, MV	30
30N. 25E. 22, 23.CL	Yankee	Tondrow Peak	1.6	0.17	U	B, R, DB	31
30N. 27E. 31.1	Robinson Peak	Cinder Butte	1.8	0.15	P	B, R	32
30N. 27E. 27.2	Robinson Peak	Jose Butte	5.0	0.15	U	B, R, DB	33
30N. 27E. 4.2	Robinson Peak	-	0.97	0.12	U	B, R, MV	34
30N. 26E. 23.CL	Johnson Park	-	5.8	0.13	D	B, R, MV	35
DONA ANA COUNTY							
24S. 2E. 31.3	Afton	Santo Tomas Mountain	0.6	0.13	A	B, R, FL	40
26S. 1E. 1.4	Afton	Black Bear Mountain	2.2	0.15	A	1B, R	41
25S. 1E. 24.2	Afton	Little Black Mountain	0.4	0.13	U	R, DB, SP	42
24S. 4W. 15.E[2]	Aden	Donna Mountain	2.6	0.13	A	1R, 1B	43
25S. 4W. 9.W[2]	Aden	Aden Cinder Cone	1.9	0.15	D	1R, mB, sFL, DB, SP	44
25S. 3W. 22.2	Aden	Volcano #1	3.8	0.17	D	1B, 1R, BL	45
25S. 4W. 19.1	Aden	-	4.6	0.14	U	R, B, DB	46
25S. 3W. 23.CL	Aden	-	3.0	0.13	U	R, B	47
25S. 4W. 36.2	Aden	-	4.6	0.18	U	R, B	48
26S. 3W. 5.CL	Aden	-	0.4	0.10	U	R, MV	49
26S. 3W. 6.EL	Aden	-	9.3	0.13	U	R, B	50
26S. 4W. 7.CL	Aden	-	2.9	0.16	U	R, B	51
26S. 4W. 13.1	Aden	-	1.3	0.17	U	R, B	52
MORA COUNTY							
Mora Grant	Cerro Negro	Cerro del Oro	6.9	0.16	P	R, B, sDB	36
Mora Grant	La Chata Crater	La Chata Crater	0.9	0.14	U	1FL, R, B, DB	37
Mora Grant	Cerro Negro	Cerro Negro	1.1	0.10	U	1FL, R	38
Mora Grant	Cerro Negro	-	1.8	0.15	U	DB, R	39
RIO ARRIBA COUNTY							
31N. 9E. 28.4	Pinabetoso Peaks	San Antone Mtn.	2.0	0.14	A	1B, 1R	57
29N. 9E. 5.3	San Antonio Mountain	Red Hill	4.0	0.16	P	1R, B	58
30N. 8E. 23.3	San Antonio Mountain	Los Cerritos de la Cruz	17.0	0.12	U	1B, R	59
SANTA FE COUNTY							
16N. 8E. 18.2	Tetilla Peak	La Ciénega	1.0	0.11	A	1R, DB, B	60
17N. 7E. 36.4	Montoso Peak	Cerrito Pelado	6.1	0.14	A	R, B, FL (includes Red Bird, N. Red Bird, and Cerrito Pelado)	61
Caja del Rio Grant	Montoso Peak	Twin Hills	2.0	0.19	U	R, B, FL	62
15N. 7E. 14.1	Tetilla Peak	-	4.0	0.12	P	B, R	63

Location	Quadrangle	Name	Reserves (m cu yd)	Aspect ratio	Status	Comments	Ref. no.
SOCORRO COUNTY							
5S. 8E. 35.3	Broken Back Crater	Cerros Prietos	0.5	0.11	U	1FL, B, 1R, DB	53
6S. 8E. 1.2	Broken Back Crater	Twin Peaks	0.5	0.11	A	1R, 1B, BL	71
TAOS COUNTY							
30N. 9E. 26.4	La Segita Peaks	Black Pit	3.0	0.11	D	B, MV	54
29N. 10E. 14.1	Cerro de la Olla	Cerrito Negro	12.0	0.15	U	B, FL, BL	55
27N. 11E. 3.EL	Cerro de los Taoses	-	4.0	0.12	U	B, MV	56
UNION COUNTY							
27N. 31E. 34.2	Grenville	Mt. Clayton	7.5	0.16	U	sFL, DB, 1R, BL	1
29N. 28E. 2.1	Folsom	-	0.3	0.11	U	DB, R, SP	2
30N. 29E. 19.1	Folsom	Twin Mountain	1.4	0.17	A	sFL, DB, R, B, BL	3
30N. 28E. 27.3	Folsom	Mud Hill	0.4	0.11	U	R, B, 1FL, BL	4
27N. 33E. 30.3	Mt. Dora	-	4.6	0.09	P	1R, Bl, FL, mDB	5
29N. 28E. 4.1	Folsom	Capulin Mountain	52.0	0.17	P	1B, sR, 1DB	6
30N. 28E. 36.1	Folsom	Baby Capulin	1.0	0.15	P	1B, sR, 1DB	7
30N. 29E. 20.4	Des Moines	-	0.8	0.17	P	1R, DB	8
30N. 29E. 23.4	Des Moines	M-19204	1.2	0.15	A	1R, DB, BL	9
26N. 32E. 17.2	Snyder Lake	Cinder Mountain	4.3	0.10	P	1B, sDB	10
27N. 30E. 24.CL	Grenville SW	-	4.2	0.16	U	sFL, mR, BL	11
25N. 29E. 19.1	Gladstone NW	Don Carlos Hills	0.99	0.13	U	1FL, 1R, 1DB, MV	12
25N. 29E. 13.4	Gladstone NW	Don Carlos Hills	0.83	0.14	U	1FL, R, mDB, MV	13
28N. 30E. 18.SL	Little Grande	Little Grande	3.3	0.13	U	R, mFL, mDB, BL	14
29N. 29E. 36.1	Little Grande	-	0.55	0.12	U	1R, 1FL, mDB, BL	15
26N. 32E. 15.2	Snyder Lake	-	4.4	0.10	U	1DB, 1R, MV	16
27N. 31E. 33.4	Grenville SW	-	0.3	0.20	U	mR	17
VALENCIA COUNTY							
10N. 12W. 25.3	Paxton Springs	-	1.2	0.11	D	1R, 1B, DB	64
9N. 12W. 23.2	Paxton Springs	-	6.1	0.13	D	R, B, DB	65
9N. 12W. 26.4	Ice Caves	Twin Craters	3.9	0.13	U	R, B	66
8N. 11W. 32.SL	Ice Caves	-	2.8	0.13	U	R, FL	67
9N. 11W. 25.2	Ice Caves	-	7.3	0.14	U	B, FL	68

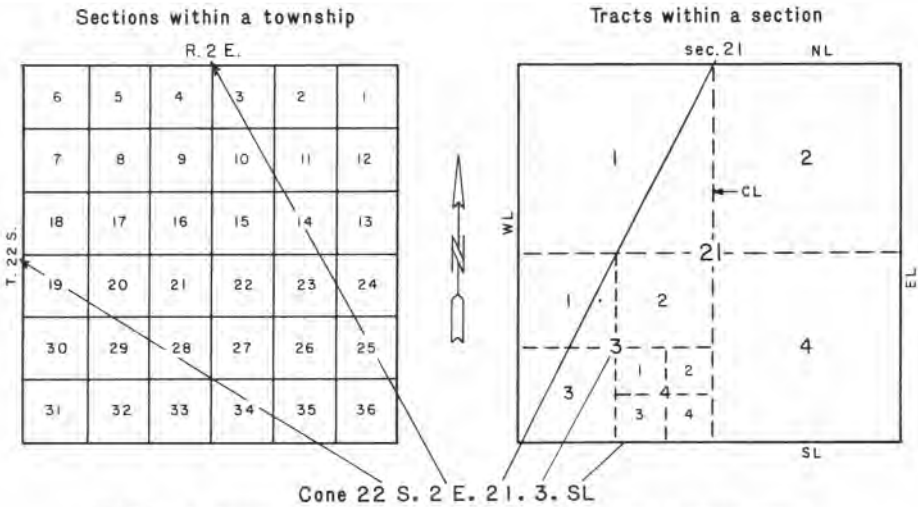

FIGURE 2—NUMBERING SYSTEM USED IN TABLE 1 FOR LOCATING SCORIA DEPOSITS.

Comments:

FL: flow; lava flows exposed or inferred by erosional patterns
R: red, loose scoria exposed
B: black, loose scoria exposed
DB: decorative bombs available
MV: multiple vents; two or more hills make up deposit
SP: spatter, or agglutinated materials exposed
BL: ballast; material suitable for railroad ballast exposed
s: small
m: moderate
l: large

These size terms indicate the relative amounts of each material if known. For example, "sFL, lR, DB" would describe a cone with much red scoria, a few lava flows, and some decorative bombs (relative quantity unknown).

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Financial statement

New Mexico Bureau of Mines and Mineral Resources
July 1, 1978 to June 30, 1979

Funds available			
Beginning balance July 1, 1978		$ 12,271	
State appropriation		1,289,100	
Publication receipts		56,829	$1,358,200
Expenditures			
Salaries:			
Full-time staff	$682,903		
Part-time staff (students)	100,096	$ 782,999	
Employee benefits		98,387	
Project contracts		79,721	
Travel & vehicles		56,155	
Scientific laboratories:			
Maintenance	$ 18,152		
Materials & supplies	27,941	$ 46,093	
Office supplies		11,855	
Postage & freight		9,822	
Printing		82,541	
Equipment		90,429	
General expenses:			
Telephone	$ 17,519		
Subscriptions & dues	3,885		
Computer service	2,275		
Overhead & audit (to Tech)	41,700		
Heat, water, electricity	24,045	$ 89,424	$1,347,426
Balance June 30, 1979			$ 10,774