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

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Information: 505/835-5420
Publications: 505/835-5410

April 23, 1982

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

We have the honor of transmitting to you a detailed Annual Report of the New Mexico Bureau of Mines and Mineral Resources for the fiscal year July 1, 1980 through June 30, 1981 as required by law (Section 3, Chapter 115, Eighth New Mexico Legislature, approved March 14, 1927).

In this, our 54th year of service and applied research, the Bureau provided information concerning exploration, development, and conservation of New Mexico's geology and mineral resources.

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

We hosted the 17th Annual Forum on the Geology of Industrial Minerals in Albuquerque, under the chairmanship of George Austin. Our Chief Scientific Illustrator, William Arnold, retired after 27 years of service. Frank Kottlowski received the Distinguished Service Award from the American Association of Petroleum Geologists. In many ways, other staff members served professional and scientific organizations and cooperated with other state agencies, including our liaison with the Energy and Minerals Department.

Our Annual Reports continue to feature scientific and technical articles that present the results of selected projects.

New Mexico is rich in mineral resources, especially energy materials. Thus, the emphasis of our program will continue to be to aid and encourage 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

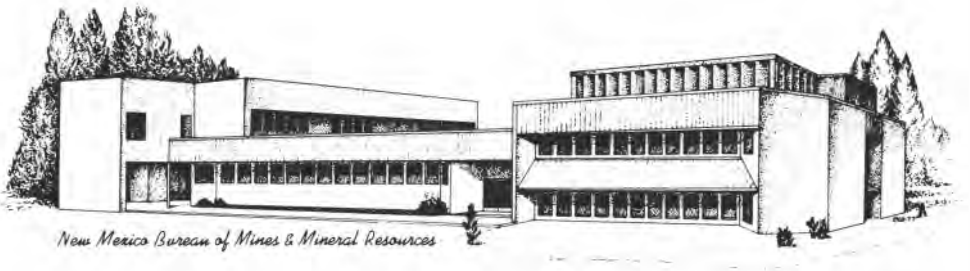
New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

ANNUAL REPORT

for the fiscal year
July 1, 1980, to June 30, 1981

by
Frank E. Kottlowski
and staff



SOCORRO 1982

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63-1-3
Printed by University of New Mexico Printing Plant, June 1982

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 $2.00

Purpose and functions

The New Mexico Bureau of Mines and Mineral Resources is the official state agency responsible by law for original investigations in geology and mineral resources in the state. The Bureau investigates, evaluates, and disseminates information on geology, mineral resources, energy resources, and metallurgy. Our emphasis is on finding and harvesting the nonrenewable resources of the state for the benefit and well-being of the citizens of New Mexico with full consideration of environmental impacts.

For 54 yrs NMBMMR has served New Mexico in this legislatively assigned role. Most of our investigations have been reported in numerous bulletins, memoirs, circulars, groundwater reports, hydrologic reports, geologic maps, scenic-trip guidebooks, progress reports, resource maps, and open-file reports. In addition, hundreds of articles have been published by staff members and by research associates in journals of professional and scientific societies. In addition, staff members have made many scientific and technical presentations to state, national, and international organizations. NMBMMR's program of geologic and mineral-resource studies has contributed significantly to New Mexico's position as a leading producer of energy and mineral materials.

In 1980 the value of minerals extracted in New Mexico totaled $5.95 billion. Payments from the U.S. Bureau of Land Management and compensatory reimbursement in lieu of taxes totaled $152 million. State severance and other taxes collected on minerals extracted in New Mexico during 1980 plus bonuses and royalties were almost $750 million. Thus, New Mexico's mineral industry is one of the major contributors to the state's economy.

The Bureau's operations extend into every corner of the state and cover most of the facets of geology and mineral resources. Examples are John Hawley's and David Love's overseeing of the WIPP project in southeast New Mexico, a cooperative report with the Energy Improvement Division on criteria for hazardous-waste-disposal sites in New Mexico, and a beginning plan to look at the geologic features of the state as related to areas that could accommodate sites for the disposal of low-level radioactive waste.

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

GEOLOGY AND MINERAL RESOURCES

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

The scientific and technical literature generated by the Bureau contributes greatly to mineral exploration. Sales of Bureau publications totaled $49,409 this fiscal year; approximately 8,700 copies of the new publications were issued free to state officials, libraries, and scientific organizations. The 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-bl 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 volcanos and desert playas were formed. The popular guides "Scenic Trips

to the Geologic Past" explain the geology of the local areas and point out scenic and geologic wonders. These books also are designed to keep tourists in the state for that extra day that is 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 297,000 mi logged by Bureau field vehicles during the fiscal year.

BASIC SERVICES

Citizens of New Mexico and elsewhere, including geologists, engineers, landowners, prospectors, legislators, students, industry personnel, and tourists, sought technical advice from Bureau staff this year. Our records show that 11,260 letters and 7,260 telephone inquiries were answered and 9,410 office visitors were counseled. Many adults and schoolchildren toured the Bureau's mineral museum. More than 8,100 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 80,000 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.

LABORATORIES

Analytical

This past year the analytical laboratory performed as many analyses as the past two years combined—a total of 5,144 analyses on 1,544 samples. The types of tests ranged from major, minor, and trace elements in water samples to total analyses on silicate rocks. Included in the total were a large percentage of fire assays for gold and silver which remain a favorite request.

—Lynn Brandvold, Chemist

Chemical Microbiology

The chemical microbiology laboratory of the New Mexico Bureau of Mines and Mineral Resources is an applied-research facility engaged in projects sponsored by federal, state, and industrial contracts and grants. During 1980–81, the sponsored research program supported three graduate students, two technicians, and five undergraduate students. Projects researched during this time included: 1) The use of algae and bacteria for removal of uranium, selenium, and molybdenum from uranium-mine waters; 2) The application of fungi and bacteria in clarification of waste waters generated during the beneficiation of several minerals; 3) The effect of hydrostatic pressure on the biohydrometallurgical extraction of copper and uranium ores; 4) The loss of permeability associated with microbial contamination of well sites during in situ leaching of uranium; 5) The production of acid resulting from oxidation of reduced sulfur species associated with oil-shale retort waters; and 6) The biologically mediated recovery of metals associated with abandoned waste

In 1980–81, the chemical microbiology laboratory personnel responded to approximately 240 telephone and 125 letter inquiries regarding the application of biotechnology to mining. Five advisory trips were made and eight lectures were presented upon request. Nineteen scientists visited the laboratory. Over 17 reports were prepared on the laboratory's research studies. *—Corale L. Brierley, Chemical Microbiologist*

Metallurgy

The metallurgical laboratory at the New Mexico Bureau of Mines and Mineral Resources offers technical assistance to persons and organizations engaged in mineral processing within New Mexico.

The laboratory is equipped with crushing and grinding equipment, sizing and screening devices for ore preparation, and a variety of equipment for metallurgical work. These facilities are intensively used not only in Bureau programs, but are also available for use in instructional programs at the New Mexico Institute of Mining and Technology for students majoring in metallurgy, materials, mining, and petroleum.

Metallurgical work performed at the laboratory includes:

1) Gravity concentration by jigging, tabling, or the use of the Humphrey spiral concentrator.
2) Flotation of metallic and nonmetallic minerals. Most of the flotation work is being done on mixed sulfide-oxide copper ores. Many copper deposits contain both sulfides and oxidized copper minerals in close association. Frequently those deposits of copper-sulfide minerals that occur near the surface are partially converted by weathering effects to mixed sulfide-oxide ores. Also, many orebodies that have been opened and originally mined as sulfide ores have, over the years, become partially oxidized. Sulfide minerals are readily concentrated by froth flotation, but the oxidized minerals are difficult to concentrate. Because sulfide-ore discoveries are decreasing in grade and much of the low-grade oxidized ores found with these sulfides is being wasted, flotation of oxidized ores is becoming of great importance. Many methods have been proposed to recover oxidized minerals but with little success. Intensive research is being conducted in this laboratory to develop a successful method for the recovery of sulfides and copper-oxide minerals. Previous experimental work performed here indicates that controlled sulfidization of the oxide ore with ammonium sulfide and a strong and selective collector such as n-dodecyl mercaptan (fed to the system as an emulsion with kerosene in water) is a suitable method for flotation of sulfides and oxide minerals. Also, flotation testing has been performed in several gold and silver ores of reasonable grade and in complex sulfide ores. Coal flotation testing is also being performed at this laboratory.
3) Cyanide leaching. A surge in gold and silver prospecting has been experienced in recent years primarily as a result of exceptionally high prices, but also in part because of decreasingly low base-metal prices.

   Low-grade ores that are available in large tonnage can be mined profitably by the cyanide process. Bottle-leach testing is required to determine feasibility of cyanide leaching for each orebody. These tests determine the consumption of reagents and the required leaching time. Prior to these tests, a mineralogical inspection of the ore is done by the geologists to detect possible problems such as locking of precious metals so that cyanide solutions cannot penetrate and dissolve the precious metals, formation during leaching of adherent films on the surface of native gold and silver inhibiting or preventing dissolution of the metals, and leach-solution fouling and readsorption or reprecipitation of precious metals from solution. Extensive work is currently being done primarily on flotation and leaching methods to improve extraction of ores from New Mexico. *—Amelia Dondero, Metallurgist*

New Mexico Library of Subsurface Data

The library is an important source of information regarding exploration for petroleum, coal, uranium, and carbon dioxide. It is used by industry and graduate students as well as by Bureau geologists. This year the staff aided 489 visitors and received 654 telephone and 427 letter inquiries.

During the year 571 driller's logs and 1,295 petroleum-exploration maps were distributed, and 266 mechanical logs and 163 well cuttings were loaned. In addition, 11,738 well records were copied.

Data added to the files during the year included 402 driller's logs (10,630 on file), 1,924 mechanical logs-wells (23,219 on file), 3,036 mechanical logs-logs (over 50,000 on file), 255 well cuttings-wells (10,884 on file), 863 well cuttings-boxes (36,772 on file), and 2,292 new well records (over 80,000 on file). Data items on file in the petroleum section include well cuttings, well cores, well records, driller's logs, sample descriptions and logs, mechanical logs, geologic maps, petroleum-exploration maps, production data, petroleum-geologic publications, and field and pool definitions and data.

Items not processed during the year because of lack of space included a U.S. Geological Survey donation of 28,350 mechanical logs and a donation from Robert Cress of 2,741 mechanical logs.

—Robert A. Bieberman, Senior Petroleum Geologist

X-ray

During the past year, the x-ray facilities managed by the Bureau have been substantially upgraded by the purchase of a new x-ray spectrometer and a new x-ray diffractometer. Both instruments are automated with on-board microprocessors and can be controlled simultaneously by a computer that stores and processes their output data.

In 1977 considerable inconvenience was incurred because of aging x-ray equipment that was experiencing more and more down time. The products of various manufacturers were studied and formal quotations were requested from six vendors early in 1978. Three of these were selected as having the equipment most appropriate to the needs of New Mexico Tech and, late in 1978, Jacques Renault visited their applications laboratories as well as three independent laboratories using the equipment on a routine basis.

Initially, the Bureau sought to purchase the equipment but, ultimately, it became clear that the Geoscience Department needed to become more directly involved in the x-ray facility. The department and the Bureau proposed to the Tech administration that the two instruments be purchased through the new equipment bond issue then being considered by the state legislature for all the state schools of higher education.

In April of 1980, bids were requested of the three principal vendors, and a decision was made to purchase the equipment from Risaku/USA. The diffractometer was delivered in September, the spectrometer was delivered in January 1981, and the computer was delivered the following March.

Within a month of installation, both instruments were functioning in semi-automatic mode. Full implementation of the computer has taken longer, with the spectrometer operating under computer control by the end of the summer of 1981, and the diffractometer by the first part of October.

The capabilities of the new equipment are impressive. The spectrometer can analyze for 10 major elements in five samples within about 30 min and deliver final concentrations in weight percent. The diffractometer can provide a routine mineralogical analysis with a printout of all peaks and their intensities and spacings in less than 30 min. The computer's search-match routine enables the pattern of an unidentified mineral to be compared with over 3,000 standard patterns and an identification to be obtained.

—Jacques Renault, Senior Geologist

MINERAL MUSEUM

The New Mexico Bureau of Mines and Mineral Resources 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 study collection, more than 6,000 specimens arranged by mineral groups, is available to the public for study during regular office hours.

During the last year, 11 groups arranged for special museum tours. Both students and geologists took advantage of the study collection. Nineteen new specimens were purchased at a cost of $1,301.50. The museum received 104 donated specimens worth approximately $1,000.00. In addition, a private collection worth in excess of $1,500.00 was donated to the museum.

The "Minerals for sale" case in the museum generated $654.40, which was used to purchase new specimens for the display collection. *—Robert M. North, Mineralogist*

SYMPOSIA AND CONFERENCES

Industrial minerals conference

New Mexico was host state for the 17th Annual Forum on the Geology of Industrial Minerals which was held in Albuquerque, May 12–15, 1981. George S. Austin, Bureau deputy director, served as general chairman, and Frank E. Kottlowski, Bureau director, addressed the forum on the industrial minerals of New Mexico. Papers presented by other Bureau staff members included ones on the mineral domain problem in dealing with New Mexico resources (Robert W. Eveleth, mining engineer), gypsum (Mark Logsdon, industrial minerals geologist), scoria (JoAnne C. Osburn, field geologist), barite (Tom Smith, field geologist), and perlite in New Mexico (Robert Weber, senior geologist, and George S. Austin).

Field trips were made to potash mines in Carlsbad, to the Santa Fe area, and to a perlite deposit of US Gypsum near Grants. The forum included 121 registrants.

Coal-resource development and paleontology conference

A conference workshop on development of coal resources and paleontology was held in Farmington, April 8–11, 1981. Representatives from industry and state and federal agencies and members of the Navajo Nation as well as paleontologists were present. Donald L. Wolberg, paleontologist, NMBMMR, served as moderator. A major objective of the sessions centered upon the effort to formulate guidelines for determination of what is or is not paleontologically significant. Transcripts of the sessions were typed and made available to conference participants. The transcripts of the proceedings were then suitably distributed.

New Mexico minerals symposium

The second New Mexico Minerals Symposium was held October 25–26, 1980, at the New Mexico Institute of Mining and Technology in Socorro. The symposium, jointly sponsored by the New Mexico Bureau of Mines and Mineral Resources, the Albuquerque Gem and Mineral Club, and the Geology Department of the New Mexico Institute of Mining and Technology, was attended by 103 participants from as far away as Columbus, Ohio.

The purpose of the symposium is to bring together amateurs and professionals interested in the mineralogy of the state and to provide them a forum for discussion of mineral occurrences in New Mexico. Two new localities for minerals were reported at the symposium: mangano-pickeringite (a manganese-magnesium-aluminum sulfate) from the Ortiz mine of Santa Fe County, and beryl (beryllium-aluminum silicate) from Iron Mountain, Sierra County.

Additionally, a decision was made to make the symposium biennial instead of annual, giving authors and organizers more time to prepare for the event. Planning for the third symposium, to be held in October 1982, is presently underway.

—Robert M. North, Mineralogist

TABLE OF ORGANIZATION

June 30, 1981

Administration & information
Kottlowski, Director, Sr. Geologist
Austin, Deputy Director, Geologist
Vaiza, Executive Secretary
Chavez, J., Administrative Secretary I
Lindsay, Staff Secretary
Smith, Lab Technician II
Crespin, Mechanic

Business office & publication sales
Devlin, Director, Bus.-Pub. Office
Meeks, Department Secretary
McNeil, Staff Secretary
Ness, Staff Secretary

Publishing group
Kelley, Editor & Geologist
Wooldridge, Chief Sci. Illustrator
Brannan, Drafter
Mueller, Drafter
Vetterman, Drafter
Adkins, Assistant Editor
Blodgett, Assistant Editor
Eden, Editorial Technician
Heljeson, Editorial Technician

Environmental geology
Hawley, Environmental Geologist
Love, Environmental Geologist

Geophysics
Reiter, Senior Geophysicist
Broadwell, Lab Technician I

Hydrogeology & geothermal
Stone, Hydrogeologist
Reiter, Senior Geophysicist (P)
O'Brien, Hydrologist

Industrial minerals & coal
Weber, Senior Geologist
Logsdon, Industrial Minerals Geologist
Vacancy, Coal Geologist
Anderson, Geologist
Campbell, Field Coal Geologist
Osburn, J., Field Coal Geologist
Roybal, Coal Data Geologist
Mauldin, Jr., Driller

Metallic ores
Chapin, Senior Geologist
Renault, Senior Petrologist
Robertson, Mining Geologist
Weber, Senior Geologist (P)
Eveleth, Mining Engineer
Chamberlin, Economic Geologist
Osburn, G., Volcanologist
McLemore, Uranium Geologist
Menzie, CRIB Geologist

Metallurgy & chemistry
Jennings, Metallurgist
Brandvold, Chemist
Brierley, Chemical Microbiologist
Popp, Lab Biotechnologist
Shacklett, Lab Biotechnologist
Archuleta, Lab Technician I
Dondero, Metallurgist

Mineralogy & x-ray
North, Mineralogist
Renault, Geologist (P)
Faris, X-Ray Lab Manager

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

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

Abandoned mines project
Frost, Geologist
Baker, Field Researcher
Lopez, Department Secretary

(P) Secondary assignment

Geology and resource projects

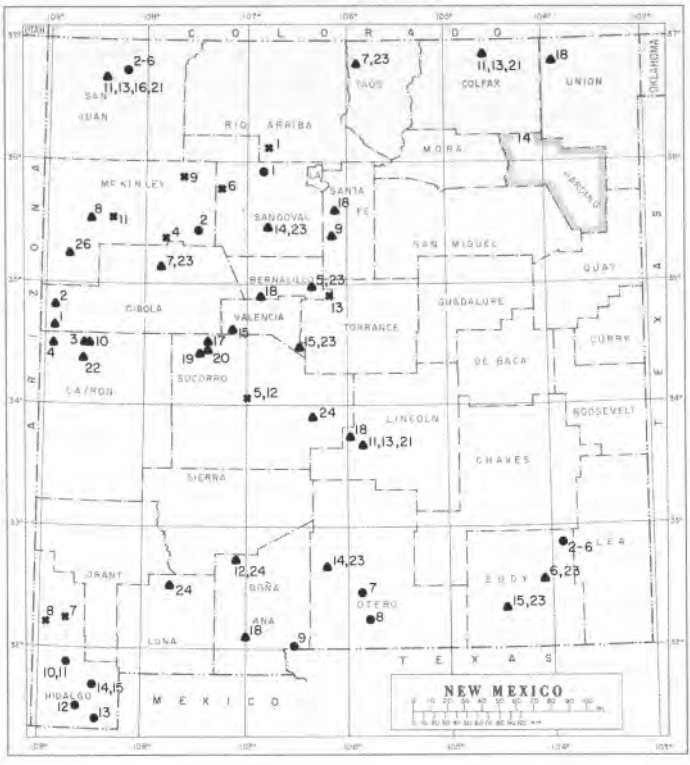
The object of the Bureau's program of investigations is to provide statewide evaluations of mineral resources, to study key areas in detail, and to recommend guidelines for exploration, development, metallurgical extraction, and conservation of New Mexico resources. Completed and continuing projects, wholly or partly funded by the Bureau, are listed in this section. An index map of field projects is shown on pages 10 and 11. A list of part-time research associates on contract to the Bureau appears on page 17. Bureau staff employed during the fiscal year is listed on pages 31–35.

Oil and gas

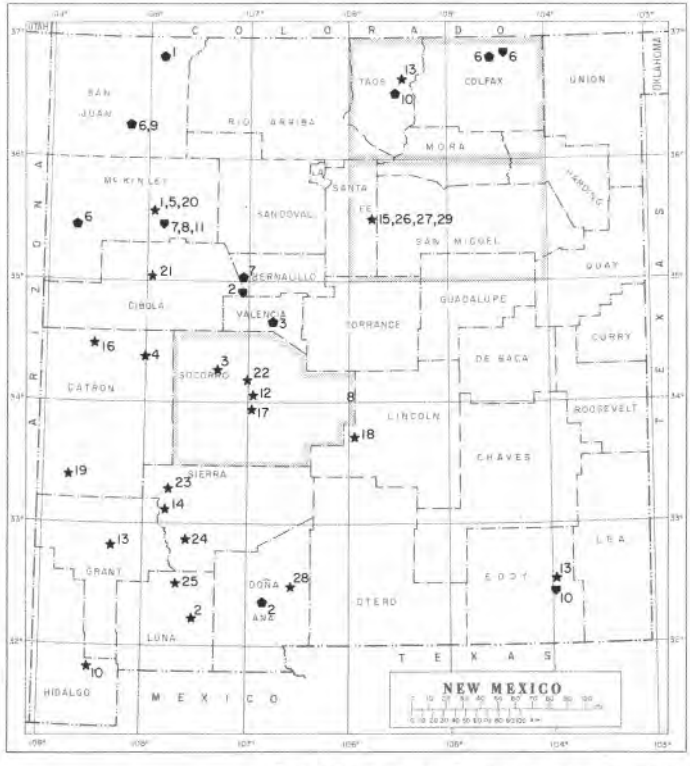
1. Adams (Anderson)—Late Paleozoic tectonic and sedimentologic history of the Peñasco uplift, north-central New Mexico (thesis available)
2. Austin, Myers, Bieberman, Reiter, Siemers, and Frost—Energy-resources map of New Mexico (in cooperation with U.S. Geological Survey)
3. Bieberman—Oil and gas fields, exploration tests, and major-pipelines map of New Mexico
4. Bieberman—Catalog of samples available in New Mexico Library of Subsurface Data (continuing update)
5. Bieberman—Scout-information file, mechanical-log file, lithologic-log file, driller's-log file, and county petroleum-exploration maps (continuing update)
6. Christiansen—History of oil and gas exploration and production in New Mexico
7. Harder (King)—Petroleum potential of Tularosa Basin, south-central New Mexico
8. King—Petroleum potential of Otero Mesa region, south-central New Mexico
9. Potter and Thompson—Paleocurrents in the Bliss Formation of southwestern New Mexico and western Texas (published in 1979–1980 Annual Report)
10. Thompson—Petroleum geology of southwestern New Mexico
11. Thompson—Analyses of petroleum source and reservoir rocks in southwestern New Mexico (in cooperation with New Mexico Energy Institute)
12. Thompson—Subsurface geology of the Cockrell No. 1 Playas well, Hidalgo County
13. Thompson—Subsurface geology of the Humble No. 1 State BA well, Hidalgo County
14. Thompson and Jacka—Pennsylvanian stratigraphy, petrography, and petroleum geology of the Big Hatchet Peak section, Hidalgo County (Circ. 176)
15. Thompson and Jacka—Cambrian-Mississippian stratigraphy, petrography, and petroleum geology of the Mescal Canyon section, Hidalgo County

Industrial minerals and coal

1. Anderson—Geology and coal resources of Cantaralo Spring quadrangle (Open-file Rept. 142)
2. Anderson—Geology and coal resources of Venadito Camp quadrangle
3. Anderson, Campbell, and Hook—Coal resources of the Salt Lake and Zuni coal fields (in cooperation with U.S. Geological Survey)
4. Anderson and Frost—Geology and coal resources of Twentytwo Spring quadrangle (Open-file Rept. 143)
5. Austin—Shale and clay resources of New Mexico
6. Austin, Logsdon, Siemers, and Weber—1981 forum on the geology of industrial minerals
7. Austin and Weber—Perlite deposits of New Mexico
8. Baker—Inventory of abandoned coal mines in New Mexico (in cooperation with New Mexico Bureau of Surface Mining and U.S. Office of Surface Mining)
9. Baker—Madrid AML engineering appraisal
10. Campbell—Coal resources of Cerro Prieto and the Dyke quadrangles (Open-file Rept. 144)
11. Campbell, Roybal, and Osburn, J.—Coal-resources map of New Mexico (ongoing revision of Resource Map 10)

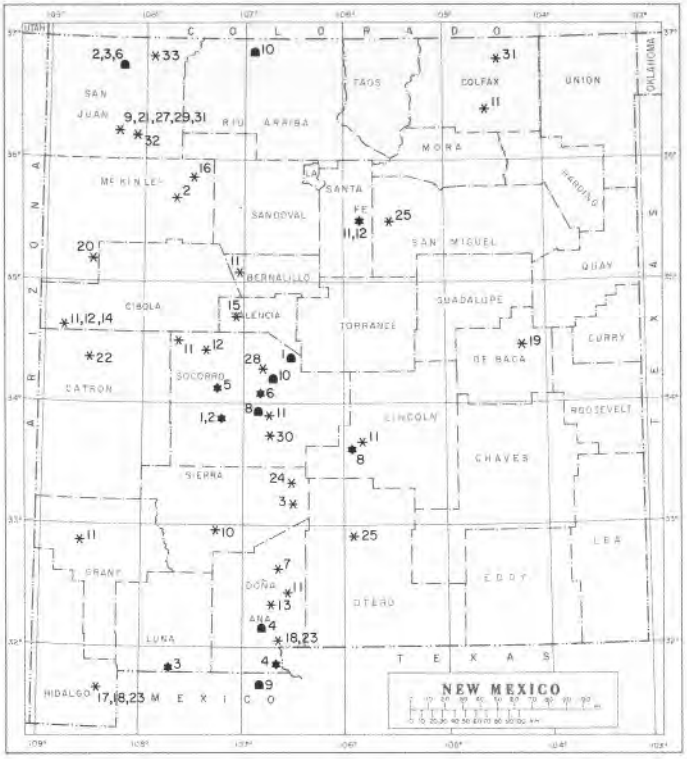


- ▲ Industrial minerals and coal
- ● Oil and gas
- ✱ Water resources and geothermal

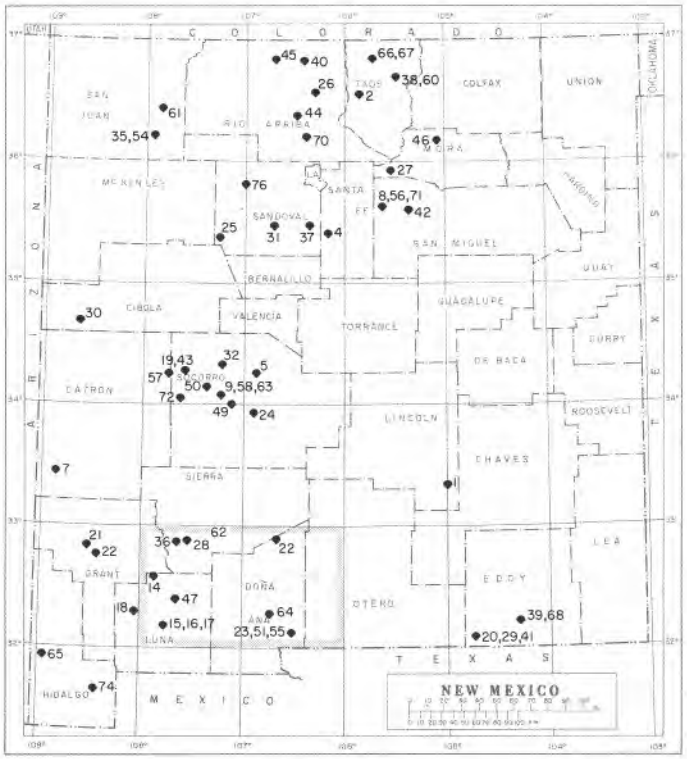


- ● Environmental geology
- ★ Metallic ores and mining districts
- ♥ Metallurgy and chemistry

INDEX MAPS OF BUREAU FIELD PROJECTS.



- Mineralogy, Petrology, and Geochemistry
- Geophysics
- Paleontology



- Geology, geologic mapping, stratigraphy, and special projects

INDEX MAPS OF BUREAU FIELD PROJECTS.

12. Filsinger (Clark and Logsdon)—Barite deposits of Palm Park, Caballo Mountains, Doña Ana County
13. Kottlowski, Campbell, Roybal, and Shomaker—New Mexico coal seams (1981 Keystone Coal Industry Manual)
14. Logsdon—Gypsum resources of New Mexico
15. Logsdon—Geology and industrial potential of limestone in New Mexico
16. Nickelson—History of coal mining in New Mexico
17. Osburn, J.—Geology and coal resources of Pueblo Viejo Mesa quadrangle
18. Osburn, J.—Scoria resources of New Mexico
19. Osburn, J.—Coal geology of Alamo Reservation (Open-file Rept. 160)
20. Osburn, J.—Geology and coal resources of the central Datil Mountains coal field (in cooperation with U.S. Geological Survey; Open-file Rept. 164)
21. Roybal—Computerization of point-source coal data for New Mexico (in cooperation with U.S. Geological Survey)
22. Roybal—Geology and coal resources of Tejana Mesa quadrangle
23. Siemers, Austin, and Kottlowski—Industrial minerals of New Mexico
24. Smith, T. J.—Barite of New Mexico (revision of Circ. 76)
25. Smith, E. W.—Sources of adobe bricks in New Mexico (Circ. 188, at press)
26. Tabet, Massingill, and Campbell—Coal geology of the Pinehaven quadrangle (in cooperation with U.S. Geological Survey; Open-file Rept. 154)

Water and geothermal resources

1. Anderholm (Stone)—Hydrogeology and water resources of Cuba 15-min. quadrangle (Hydrogeologic Sheet 3, in preparation)
2. Brandvold—Water Quality Control Commission projects (continuing update)
3. Brandvold—Water analyses file (continuing update)
4. Brod and Stone—Hydrogeology and water resources of the Ambrosia Lake-San Mateo area (Hydrogeologic Sheet 2)
5. Chapin—Socorro Peak KGRA geology
6. Craigg (Stone)—Hydrogeology and water resources of the Torreon Wash-Chico Arroyo area (Hydrogeologic Sheet 4, at press)
7. Elston, Deal, and Logsdon—Geochemistry of Lightning Dock KGRA
8. Fleischhauer and Stone—Quaternary geology of Lake Animas, Hidalgo County (Circ. 174, at press)
9. Stone—Hydrogeology and water resources of northwestern New Mexico (in cooperation with U.S. Geological Survey and New Mexico State Engineer; Open-file Repts. 90, 91, 105, and 114)
10. Stone—Computerization of New Mexico Bureau of Mines and Mineral Resources well-record data (continuing update)
11. Stone—Hydrogeology of Gallup Sandstone, San Juan Basin
12. Stone—Hydrogeology of Rio Grande valley in Socorro area
13. Titus—Ground water in the Sandia and northern Manzano Mountains (in cooperation with U.S. Geological Survey; Hydrologic Rept. 5)
14. Trauger—Ground-water resources and geologic map of Harding County (in cooperation with U.S. Geological Survey)

Metallic ores and mining districts

1. Anderson—Abandoned or inactive uranium mines in New Mexico (in cooperation with New Mexico Bureau of Surface Mining and U.S. Office of Surface Mining; Open-file Rept. 148)
2. Brown, G. (Clemons)—Mineralization of Mahoney mines and Gym Peak area, Florida Mountains
3. Cather (Chapin)—Sedimentary petrology of the Baca Formation in Alamo Reservation area (in cooperation with University of Texas, Austin; thesis available)
4. Chamberlin—Uranium potential of Datil Mountains-Pie Town area, Catron County (Open-file Rept. 138)
5. Chamberlin—Monitor uranium exploration in New Mexico (continuing update)

6. 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.)
7. Chapin—Geology and mineral resources of the southeast Colorado Plateau margin
8. Chapin and Osburn, G.—Geology and mineral resources of Socorro-Magdalena area
9. Chapin and Osburn, G.—Data bank of radioactive dates, isotopic analyses, and chemical analyses of igneous rocks in New Mexico (continuing update)
10. Edwards (Annis)—Mineralization of Sylvanite-Bager area, Little Hatchet Mountains
11. Eveleth—New Mexico's mining railroads (continuing update)
12. Eveleth—Billing smelter, its role in the territorial mining industry of New Mexico
13. Eveleth, Mardirosian, Weber, and Siemers—Mineral industry location system (MILS) for New Mexico (in cooperation with U.S. Bureau of Mines; completed)
14. Eveleth and North—Reconnaissance report, Brush Heap mine, Kingston mining district, Sierra County (Open-file Rept. 165)
15. Fulp (Woodward, Robertson)—Precambrian geology and mineralization in Dalton Canyon area
16. Guilinger (Chamberlin)—Uranium potential of Tejana Mesa-Hubbell Draw area, Catron County
17. Jahns—Manganese deposits of Luis Lopez district, Lincoln County
18. Jahns—Gold deposits of White Oaks mining district, Lincoln County
19. Kent, G. (Robertson)—Mineralization in the Mogollon mining district
20. McLemore—Radioactive occurrences in New Mexico
21. McLemore—Radioactive occurrences in veins and igneous and metamorphic rocks of New Mexico (Open-file Rept. 155 and U.S. Department of Energy Open-file Rept. GJBX-100 [82])
22. McLemore—Carbonatites in Lemitar Mountains (Open-file Rept. 158)
23. McMillan and Jahns—Structure, petrology, and ore deposits of Chise quadrangle in southern Sierra Cuchillo, Sierra County
24. North and Eveleth—Gold mining and occurrences in New Mexico
25. Proctor—Trace base metals in Cooke's Peak stock
26. Robertson—Wall-rock alteration associated with massive sulfide deposits in Pecos greenstone belt
27. Robertson—Precambrian rocks and mineral deposits of Doctor Creek area, Santa Fe County
28. Seager—Geology and mineral deposits of Organ Mountains (Mem. 36)
29. Wyman (Robertson)—Ultramafic rocks of Pecos greenstone belt in Cow Creek area (thesis available)

Metallurgy and chemistry

1. Brandvold—Directory of commercial analytical laboratories in the southwest (updated; new directory June 1980)
2. Brandvold—Transport mechanisms in sediment-rich streams (in cooperation with Office of Water Research and Technology)
3. Brandvold—Speciation of uranium in organic-rich high-uranium stream sediment from NURE Project
4. Brandvold—Water analyses (continuing update)
5. Brandvold—Rock and ore analyses (continuing)
6. Brandvold, Brandvold, and Popp—Acid rain in New Mexico
7. Brierley and Brierley—Biological methods to remove selected pollutants from uranium-mine waste water (in cooperation with New Mexico Water Resources Research Institute)
8. Brierley and Brierley—Contamination of ground and surface waters by uranium mining and milling (in cooperation with U.S. Bureau of Mines and University of Colorado)
9. Brierley and Brierley—Trace elements in oil shale (in cooperation with U.S. Department of Energy and University of Colorado)
10. Brierley and Lanza—Microbiological flocculation of phosphate and potash slimes (in cooperation with U.S. Bureau of Mines and University of Texas at Dallas)
11. Brierley, Torma, and Brierley—Application of bacterial-leaching technology to deep solution mining of uranium (in cooperation with New Mexico Energy and Minerals Department)
12. Brierley, Torma, and Brierley—Application of bacterial-leaching technology to deep solution mining conditions (in cooperation with National Science Foundation)

Environmental geology

1. Gillan (Hawley, Love)—Age and climatic effects on soil development in lower Animas River valley, San Juan County
2. Hawley, Gile, and Grossman—Soils and geomorphology in a Basin and Range area of southern New Mexico (Memoir 39)
3. Hawley and Love—Lower Hidden Mountain dam site, Late Quaternary stratigraphy, sedimentation, and geomorphology (with Human Systems Research, Inc.)
4. Hawley and Love—Hazardous-waste disposal site selection (with Environmental Improvement Division)
5. Hawley and Love—Overview of geology as related to environmental concern in New Mexico (Open-file Rept. 126; New Mexico Geological Society, Special Pub. 10, p. 1-10)
6. Hawley, Love, and Hobbs—Alluvial valley floors in coal surface-mine areas (in cooperation with New Mexico Bureau of Surface Mining)
7. Hawley, Love, and Popp—Radionuclide and heavy-metal distribution in recent sediments of major streams in Grants mineral belt
8. Hawley and Love—Quaternary geology of New Mexico (in cooperation with U.S. Geological Survey)
9. Hawley, Love, Weber, 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)
10. 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 Office of Civil Emergency Preparedness, and Linda Kehoe, Governor's office)

Mineralogy, petrology, and geochemistry

1. Chapin—Hydrothermal alteration of ash-flow tuffs
2. D'Andrea (Chapin)—Geochemistry of potassium-metasomatized volcanic rocks in Socorro area (in cooperation with Florida State University; thesis available)
3. Frantes (Hoffer)—Palomas basalt field (thesis available)
4. Herrel (Hoffer)—Petrography and geochemistry of Cristo Rey pluton
5. Lindley (Chapin)—Geochemistry of alteration in ash-flow tuffs in Socorro area (in cooperation with University of North Carolina)
6. North—Guide to New Mexico Bureau of Mines and Mineral Resources Mineral Museum
7. North and Renault—Preparation of x-ray diffraction standards (continuing)
8. Renault—Geochemistry of New Mexico basalts (continuing)
9. Renault—Rapid determination of coal chemistry by x-ray fluorescence spectroscopy
10. Renault—X-ray diffraction profile analysis of silica (continuing)
11. Robertson—Petrography and geochemistry of Precambrian volcanic and subvolcanic rocks from Pecos greenstone belt
12. Robertson—Geochronology of volcanism and plutonism in Pecos greenstone belt
13. Robertson and Rose—Major and minor element geochemistry of Precambrian volcanic rocks of Portage Lake volcanics, Michigan

Geophysics

1. Chapin—COCORP seismic reflection profiles
2. Clarkson (Reiter)—Characteristics of thermal anomaly under the San Juan volcanic field
3. Eggleston, R. (Reiter)—Deep temperature-data study in the Colorado Plateau
4. Keller, G. R.—Aeromagnetic mapping of Tortugas Mountain area, Doña Ana County
5. Reiter—Preliminary consideration of geothermal structure in major volcanic fields of New Mexico and adjacent areas
6. Reiter—Geothermal studies in the San Juan Basin: I) terrestrial heat-flow measurements; II) paleotemperatures, coalification, and petroleum genesis; and III) steady-state model of thermal source of heat flow
7. Reiter—Deep-temperature data and preservation of petroleum in basins

8. Reiter and Eggleston, R.—Deep heat-flow data along Rio Grande rift
9. Reiter and Tovar R.—Heat-flow analysis in northern Chihuahua, Mexico
10. Sanford, Olsen, and Jaksha—Earthquakes in New Mexico, 1849-1977 (Circ. 171)

Paleontology

1. Cobban and Hook—Paleontology of the Late Cretaceous "Cephalopod Zone" of Herrick (1900)
2. Cross, Taggart, and Jameossanaie—Paleobotanical study of Menefee Formation in South Hospah area (in cooperation with Chaco Energy Co.)
3. DeKeyser—Conodonts in Lake Valley Formation of San Andres Mountains
4. Flower—Ordovician correlations (in preparation)
5. Flower—Faunas of the New Mexico Devonian
6. Flower—Studies of Endoceratida and Tarphyceratida
7. Flower and LeMone—Faunal and petrographic studies of Bliss Sandstone, El Paso Group and Montoya Group
8. Gutjahr and Hook—A statistical method for analysis of planispiral coiling (Circ. 173)
9. Hartman—Cretaceous-Tertiary freshwater mollusks in San Juan Basin
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, h) Springer area, and i) Trans-Pecos Texas
12. Hook, Cobban, and Molenaar—Stratigraphy, paleontology, sedimentology, and regional relationships of Upper Cretaceous Tres Hermanos Sandstone
13. King—Fusulinids of the Hueco Formation in the Las Cruces area
14. Kelley, K. (Cross)—Palynology of Upper Cretaceous rocks in Fence Lake area (cooperative with U.S. Geological Survey)
15. Kukalova-Peck—Late Paleozoic fossil insects of Carrizo Arroyo region
16. Leipzig (Wolberg)—Stratigraphy and depositional environments of Fruitland Formation and Kirtland Shale in Star Lake area
17. LeMone—Cretaceous faunas in Big Hatchet Mountains
18. LeMone and Simpson—Wolfcampian megafauna and biostratigraphy of Franklin and Big Hatchet Mountains
19. Leonard and Frye—Stratigraphy and paleontology of Ogallala Formation in New Mexico (includes Circ. 160 and Circ. 161)
20. Molenaar, Hook, and Cobban—Stratigraphy, paleontology, and regional correlations of the upper Cenomanian through lower Coniacian (Upper Cretaceous) strata of western New Mexico
21. Robison, Hunt, and Wolberg—Paleobotany and stratigraphy of Late Cretaceous leaf locality in lower Kirtland Shale
22. Schrodt (Schiebout)—Depositional environments, provenance, and vertebrate paleontology of the Eocene-Oligocene Baca Formation, Catron County, New Mexico (thesis available)
23. Simpson—Permian brachiopods of southwest New Mexico and far west Texas
24. Sorauf—Devonian corals from south-central New Mexico
25. Strimple—Pennsylvanian crinoids from Sangre de Cristo and Sacramento Mountains (Circ. 178)
26. Taylor—Late Cenozoic freshwater mollusks of New Mexico: an annotated bibliography (Open-file Rept. 124)
27. Wolberg—Reptiles and elasmobranchs in the Fruitland and Kirtland Formations
28. Wolberg and Baker—Late Cretaceous vertebrates from Atarque Member, Tres Hermanos Sandstone near La Joya
29. Wolberg and Hunt—Paleontology and stratigraphy of Late Cretaceous rocks in the Hunter Wash area
30. Wolberg, Hunt, and Lucas—Eocene titanothere from Baca Formation near Carthage
31. Wolberg, Payne, and Hunt—Paleontology, stratigraphy, and magnetostratigraphy compared with Ir-levels in San Juan and Raton Basins
32. Wolberg, Rigby, Hunt, Robison, and Hartman—Paleontology and stratigraphy of a Late Cretaceous fossil stump field in the San Juan Basin near Split Lip Flats
33. Wolberg, Rigby, and Schiebout—A Torrejonian faunule from Nacimiento Formation in Bohannan Canyon

Geology, geologic mapping, stratigraphy, and special projects

1. Allen, J., Kottlowski, Spence, and Pendleton—Revision of Scenic Trip No. 3, Roswell-Capitan-Ruidoso
2. Anderson (Wells and Hawley)—Cenozoic terrace and pediment deposits in Taos Plateau area
3. 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)
4. Atkinson, Odlund, and Lee—Mineralogy of cores from San Pedro mining district
5. Baker, B. W. (Wolberg)—Geology and depositional environments of Upper Cretaceous rocks in Sevilleta Grant, Socorro County (thesis available)
6. Balk—Stratigraphic nomenclature of New Mexico
7. Bikerman—Age-dating volcanic rocks in Mogollon area
8. Bowring and Robertson—Ages and isotopic geochemistry of Precambrian rocks in northern and central New Mexico
9. Cather (Chapin)—Petrology and volcano-sedimentary evolution of the Oligocene Spears Formation
10. Chapin—Origin and evolution of the Rio Grande rift
11. Chapin—Cenozoic tectonic and magmatic evolution of New Mexico
12. Chapin—Mechanics of transport and deposition of ash-flow tuffs and their hydrothermal alteration
13. Chapin and Cather—Eocene tectonics and sedimentation in southern Cordillera
14. Clemons—Geology and mineral resources of Massacre Peak quadrangle (Geologic Map 51, at press)
15. Clemons—Geology of the Florida Gap region (Geologic Map 52, at press)
16. Clemons—Geology of Capitol Dome quadrangle (Geologic Map 56, in edit)
17. Clemons—Geology of west half of Gym Peak quadrangle
18. Clemons, Thompson, and Stone—Revision of Scenic Trip No. 10, southwestern New Mexico
19. Coffin (Chapin)—Geology of the east half of the Dog Springs quadrangle, Socorro County (thesis available)
20. Crawford (Pray)—Carbonate facies of Goat Seep reef in Guadalupe Mountains (thesis available)
21. Cunningham—Circle Mesa quadrangle
22. Cunningham—Revision of geologic map of Silver City 7½-min quadrangle
23. Danko—Canutillo Formation in Franklin Mountains and Bishop Cap (thesis available)
24. Eggleston (Chapin)—Geology of the central Chupadera Mountains
25. Gawne—Zia sand in Sky Village area (report available)
26. Gibson (Robertson)—Precambrian geology of Burned Mountain-Hopewell Lake area, Rio Arriba County (thesis available)
27. Grambling—Precambrian geology of Gascon area
28. Gutierrez (Seager)—Volcanic stratigraphy of area between Hillsboro and Kingston, Sierra County
29. Harris (Pray)—Geologic study of Cutoff Formation of southern Guadalupe Mountains
30. Hawley, Anderson, and Love—Investigations of "Fence Lake gravels" and Bidahochi Formation in western New Mexico
31. Hawley, Tedford, Galusha, Barghoorn, and Love—Upper Cenozoic biostratigraphy of northern Albuquerque Basin (in cooperation with American Museum of Natural History)
32. Johansen (Chapin)—Petrology of Mesaverde Group in Rio Salado valley
33. Heljeson and Holts—Bibliography of New Mexico geology and mineral technology, 1976 through 1980 (Bull. 109, at press)
34. Heljeson and Holts—Supplement to bibliography of New Mexico geology and mineral technology through 1975 (Bull. 108)
35. Hunt (Wolberg)—Stratigraphy and sedimentology of fossil stump field near Split Lip Flats
36. Ilchik (Clemons)—Geology of eastern edge of Emery cauldron
37. Kautz (Ingersoll)—Sedimentary and petrological study of Espinaso Formation in southeast Sandoval County (thesis available)
38. Kelley, R. E.—Precambrian geology of Cabresto Creek area, Taos County
39. Kelley, Jacka, and Sorensen—Tepee structures in Guadalupian of Carlsbad area compared to buckles in Meramician of Michigan

40. Kent (Robertson)—Precambrian rocks of the Tusas area (thesis available)
41. Kirkby (Pray)—Study of rocks beneath Cutoff Formation in southern Guadalupe Mountains
42. Klich (Robertson)—Precambrian geology of Elk Mountain-Spring Mountain area, San Miguel County
43. LaRoche (Chapin)—Geology of the Gallinas Peak area, Socorro County (Open-file Rept. 128)
44. Logsdon—Basin analysis of El Rito Formation
45. Muehlberger—Scenic Trip No. 13 to Española-Chama-Cumbres Pass-Monero-Tres Piedras region
46. Nielsen—Ocate volcanic field, north-central New Mexico
47. North—Geologic map of Goat Ridge quadrangle
48. North—Small-size geologic map of New Mexico
49. Osburn, G.—Geology of Molino Peak quadrangle (Open-file Rept. 139)
50. Osburn, G.—Geology of Lion Mountain and Gallinas Peaks areas
51. Osleger—La Tuna Formation in Franklin Mountains and Bishop Cap (thesis available)
52. Ottensman—Sedimentation of the Bliss Formation
53. Owen and Siemers, C.—Dakota units in southeast San Juan Basin between Laguna and La Ventana
54. Rains—Upper Cretaceous and Paleocene silcrete beds in the San Juan Basin (thesis available)
55. Rinowski—Helms Formation in Franklin Mountains and Bishop Cap (thesis available)
56. Robertson—Geochronology of volcanism and plutonism in Pecos greenstone belt
57. Robinson (Chapin)—Geology of the D-Cross quadrangle, Catron and Socorro Counties (thesis available)
58. Roth (Chapin)—Geology of the Sawmill Canyon area, Magdalena Mountains (Open-file Rept. 129)
59. Schilling—Isochron/West, a periodic journal of isotopic geochronology
60. Schilling, Taggart, and Pendleton—Revision of Scenic Trip No. 2, Taos-Red River-Eagle Nest
61. Schultz (Hawley and Wells)—Geomorphology, sedimentology, and Quaternary history of the eolian deposits in west-central San Juan Basin (thesis available)
62. Seager, Clemons, Hawley, and Kelley, R. E.—Geology of Las Cruces 1:125,000 quadrangle (Geologic Map 53, northwest quarter, at press)
63. Siemers, T.—Permian rocks in northern Magdalena Mountains
64. Seager, Kottlowski, Hawley, and King—Geology of Robledo Mountains
65. Spencer (Ross)—Lower Pennsylvanian rocks of southwesternmost New Mexico
66. Stoll (Dungan)—Intermediate to silicic volcanic rocks of Taos Plateau
67. Thompson, R. A. (Dungan)—Studies of early rift-age volcanic rocks, Taos Plateau
68. Thompson and Jacka—Guidebook to depositional and diagenetic features in the Guadalupian of New Mexico and Texas
69. Thompson and Slaczka—A revision of the fluxoturbidite concept based on type examples in the Polish Carpathian flysch
70. Vazzana (Ingersoll and Hawley)—Stratigraphy, sedimentary petrology, and basin evolution of the Abiquiu Formation in north-central New Mexico (thesis available)
71. Wakefield (Robertson)—Precambrian geology of Glorieta Baldy-Ruiz Canyon area, Santa Fe County
72. Weber—Geology of Plains of San Agustin
73. Weber—Petrographic and chemical characteristics of seven new meteorites from New Mexico
74. Weise (LeMone)—Carbonate petrology of U-Bar Limestone in Big Hatchet Mountains
75. Wolberg and Kottlowski—Correlation of stratigraphic units in southwest New Mexico and westernmost Texas (COSUNA project)
76. Wright (Anderson)—Facies of Mancos and lower Mesaverde Group near La Ventana

RESEARCH ASSOCIATES

Professional

John Eliot Allen, Portland State University
John B. Anderson, Rice University
Malcolm P. Annis, University of Cincinnati
Augustus K. Armstrong, U.S. Geological Survey, Menlo Park
Don H. Baker, Jr., New Mexico Tech
Christina L. Balk, New Mexico Tech
Michael Bikerman, University of Pittsburgh

James A. Brierley, New Mexico Tech
Paige W. Christiansen, New Mexico Tech
Kenneth F. Clark, University of Texas (El Paso)
Russell E. Clemons, New Mexico State University
William A. Cobban, U.S. Geological Survey, Denver
Kent C. Condie, New Mexico Tech
Aureal T. Cross, Michigan State University
John E. Cunningham, Western New Mexico University
Thomas DeKeyser, Texas Tech University
William R. Dickinson, University of Arizona
Michael A. Dungan, Southern Methodist University
Peter F. Frenzel, U.S. Geological Survey, Albuquerque
John C. Frye, Geological Society of America
Marian Galusha, Chadron, Nebraska
Jeffrey A. Grambling, University of New Mexico
Constance E. Gawne, New Mexico Tech
Leland H. Gile, Las Cruces
George B. Griswold, Albuquerque
Joseph Hartman, University of Minnesota
Jerry M. Hoffer, University of Texas (El Paso)
Raymond V. Ingersoll, University of New Mexico
Alonzo D. Jacka, Texas Tech University
Lynn C. Jacobson, Albuquerque
Richard H. Jahns, Stanford University
David B. Johnson, New Mexico Tech
G. Randy Keller, University of Texas (El Paso)
Vincent C. Kelley, University of New Mexico
William E. King, New Mexico State University
Jarmila Kukalova-Peck, Carleton University
Edwin R. Landis, U.S. Geological Survey, Denver
Guy R. Lanza, University of Texas (Dallas)
David V. LeMone, University of Texas (El Paso)
A. Byron Leonard, University of Kansas
Forest P. Lyford, U.S. Geological Survey, Albuquerque
Charles A. Mardirosian, Laredo, Texas
John R. MacMillan, New Mexico Tech
Niall J. Mateer, Uppsala University
C. M. Molenaar, U.S. Geological Survey, Denver
Donald A. Myers, U.S. Geological Survey, Denver
William R. Muehlberger, University of Texas (Austin)
Howard B. Nickelson, Carlsbad
Donald E. Owen, Cities Service Oil Company
Michael A. Payne, New Mexico Tech
Lloyd C. Pray, University of Wisconsin (Madison)
Paul E. Potter, University of Cincinnati
Christopher A. Rautman, Amoco Minerals Company
Coleman R. Robison, U.S. Bureau of Land Management, Albuquerque
Allan R. Sanford, New Mexico Tech
Judith A. Schiebout, Louisiana State University
John H. Schilling, Nevada Bureau of Mines and Geology
William R. Seager, New Mexico State University
W. Terry Siemers, Phillips Petroleum Company
Edward W. Smith, San Juan Pueblo, New Mexico
James E. Sorauf, State University of New York at Binghamton
Wendell J. Stewart, Texaco Inc.
Ralph E. Taggart, Michigan State University
Dwight W. Taylor, San Francisco State University
Arpad E. Torma, New Mexico Tech
Jorge C. Tovar R., Petroleos Mexicanos, Chihuahua City
James Lee Wilson, Rice University
Lee A. Woodward, University of New Mexico

Graduate students

Roy Adams, Rice University
Phillip Allen, New Mexico Tech
Bruce W. Baker, New Mexico Tech
Glen Brown, New Mexico State University
Sam Bowring, New Mexico Tech
Steve Cather, University of Texas (Austin)
Gerry W. Clarkson, New Mexico Tech
Greg Coffin, New Mexico Tech
G. Allen Crawford, University of Wisconsin (Madison)
Julie F. D'Andrea, Florida State University
Jeffrey H. Danko, University of Texas (El Paso)

Mark A. Edwards, University of Cincinnati
Roberta Eggleston, New Mexico Tech
Ted Eggleston, New Mexico Tech
K. Babette Faris, New Mexico Tech
Bradford E. Filsinger, University of Texas (El Paso)
Thomas J. Frantes, University of Texas (El Paso)
Michael S. Fulp, University of New Mexico
Thomas Gibson, New Mexico Tech
Mary L. Gillam, University of Colorado
David R. Guilinger, New Mexico Tech
Anita Gutierrez, New Mexico State University
Vicki Harder, New Mexico State University
Mark T. Harris, University of Wisconsin (Madison)
David Herrel, University of Texas (El Paso)
Adrian Hunt, New Mexico Tech
Neil F. Hurley, University of Wisconsin (Madison)
Susan E. Ilchik, New Mexico State University
Abolfazl Jameossanaie, Michigan State University
Steven Johansen, University of Texas (Austin)
Paul F. Kautz, University of New Mexico
Kurtis C. Kelley, Michigan State University
Richard E. Kelley, Southern Methodist University
Gretchen R. Kent, Michigan Tech
Susan C. Kent, New Mexico Tech
Kent C. Kirby, University of Wisconsin (Madison)
Ingrid Klich, New Mexico Tech
Matt LaRoche, New Mexico Tech
Martin R. Leipzig, University of Wisconsin (Milwaukee)
Ione Lindley, University of North Carolina
Roger L. Nielsen, Southern Methodist University
David Osleger, University of Texas (El Paso)
Donald C. Ottensman, University of Texas (Dallas)
Borden R. Putnam III, New Mexico Tech
G. Edward Rains, University of Arizona
Robert D. Rinowski, University of Texas (El Paso)
Bob R. Robinson, University of Texas (El Paso)
Sue Roth, New Mexico Tech
Jon J. Sandor, University of California (Berkeley)
A. Kay Schrodt, Louisiana State University
Jerry A. Schultz, University of New Mexico
Ronald O. Simpson, University of Texas (El Paso)
Patrick K. Spencer, Western Washington University
Nancy J. Stole, Southern Methodist University
Ren A. Thompson, Southern Methodist University
Michael E. Vazzana, University of New Mexico
John M. Wakefield, New Mexico Tech
James E. Weise, University of Texas (El Paso)
Robyn Wright, Rice University
William Wyman, New Mexico Tech

Publishing group

Editing and drafting functions were combined under the direction of the editor-geologist on October 1st. Within the editing section, two of the five authorized positions and two of the four temporary/part-time positions had personnel changes. Within the drafting section, all four authorized positions had personnel changes. Despite these changes and the necessity for training of replacements, an all-time high in production was achieved. Part of this achievement is because the University of New Mexico Printing Plant cleared out a substantial backlog of jobs that had begun to pile up at the beginning of the fiscal year.

New Mexico Geology, the Bureau's quarterly journal of science, is in its third year of publication. Toward the close of the fiscal year, the number of paid subscriptions topped 800. Approximately 60 copies are distributed free to Bureau

staff and selected offices, and 172 copies are circulated in the Bureau's publications exchange program.

Through a cooperative arrangement with the Nevada Bureau of Mines and Geology, the bulletin of isotopic geochronology, *Isochron/West,* will continue to be published every four months through issue No. 36, April 1983. This journal is edited and composed by the Nevada Bureau, printed at the New Mexico Tech printshop, and circulated by the New Mexico Bureau.

The Bureau released 27 new publications (including a pricelist, a booklet, and two leaflets), 2 reissued publications, and 11 open-file reports. Seven new large-scale color maps were issued (four in two book reports, three in two map reports); two large-scale color maps were reissued in a map report.

Pages printed in new publications totaled 1,310 (1,244 scientific, 36 pricelist, 22 leaflet pages, and 8 announcement cards). Pages in reissued publications totaled 74 (scientific).

Funds allocated to printing totaled $107,606, or approximately 6 percent of the Bureau's overall budget. In addition, $172,800 was spent on salaries, benefits, supplies, travel, and manuscript preparation for editing and drafting. Almost all composition and printing continued to be handled by the Printing Plant at the University of New Mexico. The only exceptions were: *Isochron/West,* several leaflets composed and printed by the New Mexico Tech printshop, the geologic map in Memoir 36 compiled and printed by Williams & Heintz Map Corporation in Washington, D.C., and the map in Hydrologic Report 5 compiled by the Albuquerque office of the U.S. Geological Survey and printed by Pikes Peak Lithographing Company in Colorado Springs (under contract to UNM Printing Plant). At the close of the fiscal year 34 manuscripts were in review or pending while 32 were in edit and in press.

New publications

Memoir 36—GEOLOGY OF ORGAN MOUNTAINS AND SOUTHERN SAN ANDRES MOUNTAINS, NEW MEXICO, by W. R. Seager, 1981, 96 p., 8 tables, 88 figs., 3 over-size sheets (includes geologic map at scale 1:31,250), 2 appendices $20.00

Integrates results of recent exploration activity, geophysical studies, and radiometric dating into the geologic framework of the Organ and southern San Andres Mountains. Previously unmapped portions of the area that contain features of structural significance were mapped on a greatly improved 7½-min topographic base map.

Memoir 38—GEOLOGY AND MINERAL TECHNOLOGY OF THE GRANTS URANIUM REGION 1979, compiled by C. A. Rautman in cooperation with 83 authors, 1980, 400 p., 66 tables 483 figs. $18.00

The continued expansion of national energy programs has resulted in new growth and exploration in the Grants uranium region. This volume contains 45 papers and expanded papers plus four abstracts, all given at the 1979 Grants Uranium Symposium, Albuquerque, New Mexico.

Bulletin 108—SUPPLEMENTAL BIBLIOGRAPHY OF NEW MEXICO GEOLOGY AND MINERAL TECHNOLOGY THROUGH 1975, by D. M. Heljeson and C. L. Holts, 1981, 136 p. $10.00

Contains over 1,800 references of New Mexico geoscience and mineral technology not included in earlier bibliographies as well as those included in a previous chronologically incorrect volume.

Circular 171—EARTHQUAKES IN NEW MEXICO, 1849–1977, by Allan R. Sanford, Kenneth H. Olsen, and Lawrence H. Jaksha, 1981, 20 p., 3 tables, 3 figs., 1 appendix $3.00

Discusses the seismicity of New Mexico and its relation to major physiographic provinces and local geologic conditions within each province.

Circular 173—STATISTICAL METHOD FOR ANALYSIS OF PLANISPIRAL COILING IN SHELLED INVERTEBRATES, by Allan L. Gutjahr and Stephen C. Hook, 1981, 15 p., 8 tables, 6 figs. $2.50

Discusses a statistical method for evaluating and comparing planispiral growth patterns among invertebrates predicated on simple logarithmic growth and employing simple and multiple linear regression combined with analysis of variance and covariance techniques.

Circular 176—PENNSYLVANIAN STRATIGRAPHY, PETROGRAPHY, AND PETROLEUM GEOLOGY OF BIG HATCHET PEAK SECTION, HIDALGO COUNTY, NEW MEXICO, by Sam Thompson III and Alonzo D. Jacka, 1981, 126 p., 7 tables, 42 figs. $10.00

Describes, analyzes, and evaluates an exposure of the best petroleum objective found to date in Hidalgo County, New Mexico.

Circular 178—PENNSYLVANIAN CRINOIDS FROM SANGRE DE CRISTO AND SACRAMENTO MOUNTAINS OF NEW MEXICO, by Harrell L. Strimple, 1980, 16 p., 2 pls., 2 tables, 2 figs. $3.00

Discusses 12 species representing eight genera of inadunate crinoids reported from Lower and Middle Pennsylvanian strata of New Mexico. Two new species are proposed: *Diphuicrinus santafeensis* n. sp. and *Aglaocrinus sutherlandi* n. sp.

Circular 180—CONTRIBUTIONS TO MID-CRETACEOUS PALEONTOLOGY AND STRATIGRAPHY OF NEW MEXICO, compiled by Stephen C. Hook, 1981, 36 p., 2 tables, 12 figs. $4.00

First in a planned series of short papers on the paleontology and stratigraphy of the mid-Cretaceous (Albian, Cenomanian, and Turonian) of New Mexico.

Circular 181—NEW MEXICO'S ENERGY RESOURCES '80—ANNUAL REPORT OF BUREAU OF GEOLOGY IN THE MINING AND MINERALS DIVISION OF NEW MEXICO ENERGY AND MINERALS DEPARTMENT, by E. C. Arnold, J. M. Hill, and others, 1981, 60 p., 48 tables, 12 figs. $3.00

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

Hydrologic Report 5—GROUND WATER IN THE SANDIA AND NORTHERN MANZANO MOUNTAINS, NEW MEXICO, by Frank B. Titus, 1980, 66 p., 3 tables, 22 figs. $7.00

Shows the relationship between geology and ground-water availability in the Sandia and northern Manzano Mountains; the study is not designed to give quantitative answers but describes availability and quality of ground water in the aquifers.

Isochron/West—Nos. 28, 29, 30, edited by J. H. Schilling, 26 p., 44 p., and 24 p. Available by subscription (6 issues for $12.00)

A serial journal of isotopic geochronology.

Geologic Map 50—PRECAMBRIAN ROCKS OF RED RIVER-WHEELER PEAK AREA, NEW MEXICO, by Kent C. Condie, 1980, 6 sheets, text, scale 1:48,000 $3.00

This map covers an area bounded by Cabresto Creek drainage (north), Lucero Canyon (south), the escarpment of the Sangre de Cristo Mountains (west), and the Moreno Valley (east).

Resource Map 12 (color)—SATELLITE PHOTOMAP OF NEW MEXICO, compiled by the U.S. Agricultural Stabilization and Conservation Service, 1980, scale approximately 1 inch to 56 mi $3.00

Small 8″ × 10″ continuous-tone, full-color print on photographic paper. Suitable for framing or inserting in reports. Can be examined with 2-power magnifier.

Resource Map 12 (color)—SATELLITE PHOTOMAP OF NEW MEXICO, compiled by the U.S. Agricultural Stabilization and Conservation Service, 1980, scale 1:1,000,000. $40.00

Large 28″ × 31″ continuous-tone, full-color print on photographic paper. Rolled. Suitable for mounting and wall display. Order from Aerial Photography Field Office, U.S. Agricultural Stabilization and Conservation Service, P.O. Box 30010, Salt Lake City, UT 84125.

Resource Map 12 (black and white)—SATELLITE PHOTOMAP OF NEW MEXICO, compiled by the U.S. Agricultural Stabilization and Conservation Service, 1980, scale 1:1,000,000. $3.00

Large 26″ × 29″ monochrome lithographic print on map paper. Folded. Principal geographic, geomorphic, and cultural features are labeled.

Resource Map 13—PRECAMBRIAN ROCKS OF THE SOUTHWESTERN UNITED STATES AND ADJACENT AREAS OF MEXICO, by Kent C. Condie, 1981, 3 sheets, scale 1:1,500,000 $4.00

Delineates Precambrian outcrops in all or part of eight states and Mexico; includes reference list.

Pricelist 15—PUBLICATIONS AVAILABLE FROM NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, APRIL 1981, 32 p. 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, 1979, TO JUNE 30, 1980, by F. E. Kottlowski and staff, 1981, 73 p. $2.00

Summarizes Bureau activities and services for the fiscal year. Also includes articles on paleocurrents of Bliss Sandstone, Upper Cretaceous guide fossil, mineral production activities, and Pleistocene *Equus conversidens*.

Magazine—NEW MEXICO GEOLOGY, VOLUME 2, NUMBER 3, August 1980, 16 p.

Available by subscription (4 issues for $3.00)

Articles: geology and paleontology of Tortugas Mountain, Red Rock talc deposit in Sierra County, Kirtland crocodile in San Juan Basin, Dakota Sandstone–Mancos Shale terminology in southern Zuni Basin, Pancho Villa State Park, new publications, open-file reports, abstracts, announcements.

NEW MEXICO GEOLOGY, VOLUME 2, NUMBER 4, November 1980, 16 p.

Articles: carbonatites in Lemitar Mountains, geothermal leasing inventory, New Mexico topographic map index, New Mexico aeromagnetic map index, Rock Hound State Park, new publications, new projects, abstracts, new books.

NEW MEXICO GEOLOGY, VOLUME 3, NUMBER 1, February 1981, 16 p.

Available by subscription (4 issues for $4.00)

Articles: barite in White Sands Missile Range, ground-water head distribution in Pecos River basin, color satellite photomap of New Mexico, new publications, announcements, abstracts.

NEW MEXICO GEOLOGY, VOLUME 3, NUMBER 2, May 1981, 16 p.

Articles: adobe brick production, Cenozoic stratigraphy and structure of Socorro Peak area, Storrie Lake State Park, announcements, abstracts, new publications, open-file reports, new projects, Upper Cretaceous ammonite, nonfuel mineral production.

Program with abstracts—Industrial rocks and minerals of the Southwest, 17th annual forum on the geology of industrial minerals, Albuquerque, May 12-15, 1981, 25 p.

Contains schedule of events and abstracts of papers presented at the 17th annual forum on the geology of industrial minerals.

Leaflet—Mineral Museum, New Mexico Bureau of Mines and Mineral Resources, by Robert North, 1981, 8 p. FREE

A brief introduction to the Mineral Museum, including history, map, floor plan, collections, hours, and services.

Leaflet—Directory of commerical analytical laboratories in the southwest, compiled by Lynn A. Brandvold, 1980, 6 p. FREE

Includes addresses and types of services offered by each laboratory in five states, brief descriptions of types of analysis, and sample prices.

Re-issued publications

Bulletin 104—LAWS AND REGULATIONS GOVERNING MINERAL RIGHTS IN NEW MEXICO, by Victor H. Verity and Robert J. Young, 1973, 70 p. $2.00

Geologic Map 41—SURFACE DEPOSITS OF SOUTHEAST NEW MEXICO, by C. B. Hunt, 1978, text, scale 1:500,000 $4.00

Open-file reports

OF-120—THE GEOLOGY OF THE WEST-CENTRAL MAGDALENA MOUNTAINS, SOCORRO COUNTY, NEW MEXICO, by S. A. Bowring, 1980, 135 p., 1 table, 14 figs., plus map $28.00

OF-121—DOCUMENTATION FOR COMPUTERIZATION OF GEOTHERMAL ACTIVITY IN NEW MEXICO, by N. H. Mizell, 1980, 27 p. $5.40

OF-122—GEOLOGY OF THE PRECAMBRIAN ROCKS OF THE LEMITAR MOUNTAINS, by V. T. McLemore, 1980, 207 p., 19 tables, 15 figs., plus 3 maps $44.40

OF-123—GEOLOGY OF THE SQUAW PEAK AREA, MAGDALENA, by M. A. Donze, 1980, 131 p., 21 figs., plus map $27.20

OF-124—LATE CENOZOIC FRESHWATER MOLLUSCA OF NEW MEXICO—AN ANNOTATED BIBLIOGRAPHY, by D. W. Taylor, 1980, 51 p. $10.20

OF-125—PETROLOGY, DIAGENESIS, AND GENETIC STRATIGRAPHY OF THE EOCENE BACA FORMATION, ALAMO NAVAJO RESERVATION AND VICINITY, SOCORRO COUNTY, NEW MEXICO, by Steven Cather, 1981, 263 p., 7 tables, 75 figs., 2 appendices, plus map $53.60

OF-126—OVERVIEW OF GEOLOGY AS RELATED TO ENVIRONMENTAL CONCERNS IN NEW MEXICO, by J. W. Hawley and D. W. Love, 1981, 39 p. $7.80

OF-128—GEOLOGY OF THE GALLINAS PEAK AREA, SOCORRO COUNTY, NEW MEXICO, by T. M. Laroche, 1981, 152 p., plus 2 maps $32.40

OF-129—GEOLOGY OF THE SAWMILL CANYON AREA OF THE MAGDALENA MOUNTAINS, SOCORRO COUNTY, NEW MEXICO, by Susan Roth, 1981, 96 p., 2 maps $21.20

OF-135—GEOLOGY OF THE WATER CANYON-JORDAN CANYON AREAS, SOCORRO COUNTY, NEW MEXICO, by Ward Sumner, 1981, 151 p., 1 map $32.20

OF-136—GEOLOGY OF THE NORTHEASTERN DATIL MOUNTAINS, SOCORRO AND CATRON COUNTIES, NEW MEXICO, by R. W. Harrison, 1981, 146 p., 2 maps $31.20

Publication	Lead Editor	Lead Drafter	Cover Artist
Memoir 36	Adkins	Vetterman, Arnold	—
Memoir 38	Holts	—	—
Bulletin 108	Holts	—	—
Circular 171	Adkins	Vetterman	Vetterman
Circular 173	Holts	House	House
Circular 176	Adkins	Vetterman, Arnold	Vetterman
Circular 178	Adkins	Vetterman	Vetterman
Circular 180	Holts	House	Vetterman
Circular 181	Pendleton	—	—
Hydrologic Rept. 5	Pendleton	Arnold	Vetterman
Isochron/West	Pendleton	—	—
Geologic Map 50	Pendleton	House	—
Resource Map 12	Blodgett	Vetterman	—
Resource Map 13	Pendleton	Arnold	—
Pricelist 15	Pendleton	Vetterman	—
Annual Report	Pendleton	Vetterman	Vetterman
New Mexico Geology	Adkins	Vetterman, House, Arnold	—

Outside publications sponsored in part by the Bureau

Adams, R. D., 1980, Late Paleozoic tectonic and sedimentologic history of the Peñasco uplift, north-central New Mexico: Unpublished M.S. thesis, Rice University, 79 p.

Armstrong, A. K., Kottlowski, F. E., Stewart, W. J., Mamet, B. L., Baltz, E. H., Jr., Siemers, W. T., and Thompson, S., III, 1979, The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States–New Mexico: U.S. Geological Survey, Prof. Paper 1110-W, p. W1-W27

Austin, G. S., 1981, Agricultural materials—glauconite, nitrogen compounds, and potash: Mining Engineering, v. 33, no. 5, p. 562–563

Austin, G. S., Siemers, W. T., and Kottlowski, F. E., 1981, Industrial minerals of New Mexico (abs.): Program with Abstracts, 17th Annual Forum on the Geology of Industrial Minerals

Baker, B. W., 1981, Upper Cretaceous geology of the Sevilleta Grant, Socorro County, New Mexico (abs.): 2nd Annual Geoscience Research Symposium, New Mexico Institute of Mining and Technology, p. 6

———, 1981, Geology and depositional environments of Upper Cretaceous rocks, Sevilleta Grant, Socorro County, New Mexico: Unpublished M.S. thesis, New Mexico Institute of Mining and Technology, 158 p.

Baker, B., and Wolberg, D. L., 1981, Upper Cretaceous stratigraphy and paleontology, Lower Tres Hermanos Sandstone, Atarque member, Sevilleta Grant near La Joya, Socorro County, New Mex-

ico (abs.): Annual Meetings, Rocky Mountain Section, American Association of Petroleum Geologists-Society of Economic Paleontologists and Mineralogists, Albuquerque, New Mexico

Brandvold, L. A., Brandvold, D. K., and Popp, C. J., 1980, Effects of uranium mining and milling on surface water in New Mexico: Abstracts for the 7th National Conference on Energy and the Environment, Phoenix, Arizona

Brierley, C. L., 1980, Effect of hydrogen peroxide on leach dump bacteria: Society of Mining Engineers (AIME), Trans., v. 266, p. 1,860–1,863

———, 1980, Leaching of chalcopyrite ore using *Sulfolobus* species: Developments in Industrial Microbiology, v. 21, p. 435–444

Brierley, C. L., Brierley, J. A., Norris, P. R., and Kelly, D. P., 1980, Metal-tolerant micro-organisms of hot, acid environments, *in* Microbial growth and survival in extremes of environments, G. W. Gould and J. E. L. Corry, eds.: London, England, Academic Press, Society of Applied Bacteriology, Tech. Series 15, p. 39–51

Brierley, J. A., and Brierley, C. L., 1980, Biological methods to remove selected inorganic pollutants from uranium mine waste water: Biogeochemistry of ancient and modern environments, p. 661–667

Brierley, J. A., Brierley, C. L., and Dreyer, K. T., 1980, Removal of selected pollutants from uranium mine waste water by biological methods, *in* Uranium mine waste disposal: Society of Mining Engineers of AIME, p. 365–376

Brierley, C. L., 1980, Book review of biogeochemistry of mineral-forming elements; Society of Industrial Microbiology News 30, p. 14–15

Brown, L. D., Chapin, C. E., Sanford, A. R., Kaufman, S., and Oliver, J., 1980, Deep structure of the Rio Grande rift from seismic reflection profiling: Journal of Geophysical Research, v. 85, no. B9, p. 4,773–4,800

Brown, L. D., Allmendinger, R. W., Kaufman, S., Oliver, J., Chapin, C. E., and Sanford, A. R., 1980, Magma bodies, transverse faulting, and deep crustal structure from COCORP surveys across a Cenozoic cauldron in central New Mexico: Geological Society of America, Abstracts with Programs, v. 12, no. 7, p. 393

Chamberlin, R. M., Unconformity-related uranium deposits in Upper Cretaceous sandstones, Datil Mountain area, west-central New Mexico (abs.): American Association of Petroleum Geologists, Bull., v. 65/3, p. 557

Chapin, C. E., and Cather, S. M., 1981, Eocene tectonics and sedimentation in the Colorado Plateau–Rocky Mountain area, *in* Relations of tectonics to ore deposits in the southern Cordillera, W. R. Dickinson and W. D. Payne, eds.: Arizona Geological Society Digest, v. 14, p. 173–198

Chapin, C. E., Sanford, A. R., Brown, L. D., 1980, Past and present magmatic and hydrothermal systems at Socorro, New Mexico (abs.): American Geophysical Union, Trans., v. 61, no. 46, p. 1,150

Clarkson, G., and Reiter, M., 1981, Steady-state models of the thermal source of the San Juan volcanic field (abs.): 2nd Annual Geoscience Research Symposium, New Mexico Institute of Mining and Technology, p. 12

Cobban, W. A., and Hook, S. C., 1980, Occurrence of *Ostrea beloiti* Logan in Cenomanian rocks of Trans-Pecos Texas: New Mexico Geological Society, Guidebook 31st field conference, p. 169–172

Coffin, G. C., 1981, Distribution and stratigraphy of the Dog Springs volcanic complex, Socorro and Catron Counties, New Mexico (abs.): 2nd Annual Geoscience Research Symposium, New Mexico Institute of Mining and Technology, p. 1

Danko, J. H., 1981, Stratigraphy and microfacies analysis of the Canutillo Formation (Late Middle Devonian), Franklin Mountains, Texas and New Mexico, and Bishop Cap hills, New Mexico: Unpublished M.S. thesis, University of Texas (El Paso), 138 p.

Eggleston, T. L., 1981, The evolution of the Socorro cauldron, Socorro County, New Mexico (abs.): 2nd Annual Geoscience Research Symposium, New Mexico Institute of Mining and Technology, p. 16

Franks, T. J., 1981, The geology of the Palomas volcanic field, Luna County, New Mexico, and Chihuahua, Mexico: Unpublished M.S. thesis, University of Texas (El Paso), 70 p.

Gibson, T. R., 1981, Precambrian geology of the Burned Mountain–Hopewell Lake area, Rio Arriba County, New Mexico: Unpublished M.S. thesis, New Mexico Institute of Mining and Technology, 105 p. and appendices

Hawley, J. W., 1981, Pleistocene and Pliocene history of the International Boundary area, southern New Mexico, *in* Geology of the border, southern New Mexico–northern Chihuahua: El Paso Geological Society, Field Trip Guidebook, p. 26-32

Hawley, J. W., and Love, D. W., 1981, Overview of geology as related to environmental concerns in New Mexico, *in* Environmental geology and hydrology in New Mexico, S. G. Wells and W. Lambert, eds.: New Mexico Geological Society, Special Pub. No. 10, p. 1-10

Hunt, A., 1981, The geology and paleontology of a Fruitland Formation (Late Cretaceous) "petrified forest" and adjacent areas in the San Juan Basin of northwest New Mexico (abs.): 2nd Annual Geoscience Research Symposium, New Mexico Institute of Mining and Technology, p. 20

Hunt, A., and Wolberg, D. L., 1981, Late Cretaceous stratigraphy in the area of Hunter Wash, San Juan Basin, New Mexico (abs.): Annual Meetings, Rocky Mountain Section, American Association of Petroleum Geologists and Society of Economic Paleontologists and Mineralogists, Bull., v. 65, p. 561

Kottlowski, F. E., 1981, Pancho Villa State Park, *in* Geology of the Border, southern New Mexico–northern Chihuahua: El Paso Geological Society, Guidebook, p. 20-21

Kottlowski, F. E., Tabet, D. E., and Frost, S. J., 1980, coal seams in New Mexico, *in* Keystone coal industry manual: New York, McGraw-Hill Inc., p. 544-553

LaFon, N. A., 1981, Offshore bar deposits of Semilla Sandstone Member of Mancos Shale (Upper Cretaceous), San Juan Basin, New Mexico: American Association of Petroleum Geologists, Bull., v. 65, p. 706-721

Logsdon, M. J., 1981, Preliminary basin analysis of the El Rito Formation (Eocene), north-central New Mexico (abs.): Rocky Mountain Section, American Association of Petroleum Geologists, Program with Abstracts, 29th Annual Convention

———, 1981, Gypsum resources of New Mexico (abs.): 17th Annual Forum on the Geology of Industrial Minerals, Program with Abstracts, Albuquerque, New Mexico

Longmire, P. A., Gallaher, B. M., and Hawley, J. W., 1981, Geologic, geochemical, and hydrological criteria for disposal of hazardous wastes in New Mexico: New Mexico Geological Society, Spec. Pub. 10, p. 93-102

Love, D. W., and Schultz, J., 1980, Surficial geology and geomorphology related to mitigation of archaeological sites of the UII leave, *in* Human adaptations in a marginal environment, J. L. Moore and J. C. Winter, eds.: The UII Mitigation Project, Office of Contract Archaeology, Albuquerque, New Mexico, p. 29-38, 535-539

Love, D. W., and Wolberg, D. L., 1981, Historical geology as a framework for synthesis and management of data from environmental impact studies in New Mexico (abs.): American Association of Petroleum Geologists, Rocky Mountain Section, 29th Annual Meeting, Bull., v. 65, p. 573

Love, D. W., 1981, Geomorphic-sedimentologic behavior of the upper Chaco drainage system—Implications for testing relationships between the Anaazi and their environment (abs.): Society for American Archaeology, 46th Annual Meeting

Lucas, S., Wolberg, D. L., Hunt, A., and Schoch, B., 1982, An Eocene titanothere from the Baca Formation, Carthage, New Mexico: Journal of Paleontology (in press)

Osburn, J. C., 1981, Scoria exploration and utilization in New Mexico (abs.): 17th Annual Forum on the Geology of Industrial Rocks and Minerals, Program with abstracts

Osleger, D. A., 1981, Stratigraphy and microfacies analysis of the La Tuna Formation (Morrowan–Atokan), Franklin Mountains, Texas and New Mexico, and Bishop Cap hills, New Mexico: Unpublished M.S. thesis, University of Texas (El Paso), 138 p.

Popp, C. J., Jensen, C. M., Brandvold, D. K., and Brandvold, L. A., 1980, Precipitation analysis in New Mexico: Las Vegas, Nevada, Abstracts for Division of Environmental Chemistry, American Chemical Society, August 1980

Raines, G. E., 1981, Paleocene silcrete beds in the San Juan Basin: Unpublished M.S. thesis, University of Arizona, 81 p.

Reiter, M. A., and Mansure, A. J., 1980, Precision continuous-temperature logging and comparison with other types of logs: Geophysics, v. 45, p. 1,857-1,868

Renault, J. R., 1980, Variations in the thermoluminescence properties of quartz as applied to the study of uranium migration: Paris, France, 26th International Geological Congress, Abs., v. 1, p. 141

Rigby, J. K., and Wolberg, D. L., 1980, A unique late Cretaceous fossil assemblage from the "fossil forest" of the Fruitland Formation, San Juan Basin, New Mexico (abs.): Geological Society of America, Annual Meetings, Atlanta, Georgia, GSA Abstracts with Programs, v. 12, no. 7, p. 509

Rinowski, R. D., 1981, Stratigraphy and microfacies analysis of the Helms Formation (Chester), Franklin Mountains, El Paso County, Texas, and Bishop Cap hills, Doña Ana County, New Mexico: Unpublished M.S. thesis, University of Texas (El Paso), 133 p.

Robertson, J. M., 1981, Bimodal volcanism in the early Proterozoic Pecos greenstone belt, southern Sangre de Cristo Mountains, New Mexico (abs.): Geological Society of America, Abstracts with Programs, v. 13, no. 2, p. 103

Robinson, B. R., 1981, Geology of the D-Cross Mountain quadrangle, Socorro and Catron Counties, New Mexico: Unpublished Ph.D. thesis, University of Texas (El Paso), 213 p.

Robison, C., Wolberg, D. L., and Hunt, A., 1981, Paleobotany paleoenvironments and stratigraphy of a Lower Kirtland leaf locality near Bisti, San Juan Basin, New Mexico, Annual Meetings, AAPG-SEPM, San Francisco, California, American Association of Petroleum Geologists, Bull., v. 65, p. 980

———, 1981, Stratigraphy and paleobotany of a Lower Kirtland leaf locality near Bisti, San Juan Basin, New Mexico (abs.): Annual Meetings, Rocky Mountain Section AAPG-SEPM, Albuquerque, New Mexico, American Association of Petroleum Geologists, Bull., v. 65, p. 568

Roth, S. J., 1980, Geology of the Sawmill Canyon area of the Magdalena Mountains, Socorro County, New Mexico: Unpublished M.S. thesis, New Mexico Institute of Mining and Technology, 88 p.

Schrodt, A. K., 1980, Depositional environments, provenance, and vertebrate paleontology of the Eocene-Oligocene Baca Formation, Catron County, New Mexico: Unpublished M.S. thesis, Louisiana State University, 174 p.

Shearer, C., and Reiter, M. A., 1981, Terrestrial heat-flow in Arizona: Journal of Geophysical Research 86, p. 6,249–6,260

Stone, W. J., 1981, Hydrogeology of the Gallup Sandstone, San Juan Basin, New Mexico: Ground Water, v. 19, no. 1, p. 4–11

———, 1981, Water for industry in New Mexico's future: Water Resources Research Institute, Proc. for 26th Annual State Water Conference (in press)

Thompson, S., III, 1980, Pedregosa Basin's main exploration target is Pennsylvanian dolostone: Oil and Gas Journal, October 20, 1980, 3 p.

Thompson, S., III, and Jacka, A. D., 1981, Dolostone reservoirs in Horquilla Formation (Pennsylvanian–Permian), Big Hatchet Peak section, Hidalgo County, New Mexico (abs.): American Association of Petroleum Geologists, Bull., v. 65, no. 3

Vazzana, M. E., 1980, Stratigraphy, sedimentary petrology, and basin evolution of the Abiquiu Formation, north-central New Mexico: Unpublished M.S. thesis, University of New Mexico, 115 p.

Weber, R. H., 1980, Geology of the Ake Site, *in* The Ake Site, P. H. Beckett, ed.—Collection and excavation of LA13423, Catron County, New Mexico: New Mexico State University, CRMD Report 357, p. 221–238

Weber, R. H., and Austin, G. S., 1981, Perlite in New Mexico (abs.): Program with Abstracts, 17th Annual Forum on the Geology of Industrial Minerals

Wolberg, D. L., 1981, Review of Evolution of the vertebrates, by Edwin Colbert: American Scientist, v. 69, no. 3, p. 333

Wolberg, D. L., Hunt, A., Rigby, J. K., and Robison, C., 1981, Stratigraphy and paleobiology of a Late Cretaceous "fossil forest," San Juan Basin, New Mexico: Annual Meetings, AAPG-SEPM, San Francisco, California, American Association of Petroleum Geologists, Bull., v. 65, p. 980

Wolberg, D. L., and Rigby, J. K., Jr., 1980, Vertebrate paleontology of the Fruitland Formation, San Juan Basin, New Mexico—recent discoveries (abs.): Gainesville, 40th Annual Meeting, Society of Vertebrate Paleontology

———, 1981, Paleontology of the "fossil forest," an interesting Late Cretaceous fossil assemblage, San Juan Basin, New Mexico (abs.): Annual Meetings, Rocky Mountain Section, AAPG-SEPM, Albuquerque, New Mexico, American Association of Petroleum Geologists, Bull., v. 65, p. 573

Wolberg, D. L., Hunt, A., Rigby, J. K., Jr., and Menack, J.,1981, Geology and stratigraphy of a Late Cretaceous "fossil forest" near Split Lip Flats, San Juan Basin, New Mexico (abs.): Annual Meetings, Rocky Mountain Section, AAPG-SEPM, Albuquerque, New Mexico, American Association of Petroleum Geologists, Bull., v. 65, p. 574

Wyman, W. F., 1980, Precambrian geology of the Cow Creek ultramafic complex, San Miguel Coun-

ty, New Mexico: Unpublished M.S. thesis, New Mexico Institute of Mining and Technology, 125 p. and appendices

Articles in Bureau publications

Brandvold, L. A., 1980, Directory of commercial analytical laboratories in the Southwest

Campbell, F., Osburn, J. C., and Roybal, G., Coal fields of New Mexico: New Mexico Geology (submitted)

Chamberlin, R. M., 1981, Cenozoic stratigraphy and structure of the Socorro Peak volcanic center, central New Mexico—a summary: New Mexico Geology, v. 3, no. 2, p. 22–24

Eveleth, R. W., Bolt, C. T., and Bieberman, R. A., 1981, Mineral and mineral-fuel production activities in New Mexico during 1979: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1979–1980, p. 57–63

Hook, S. C., and Cobban, W. A., 1981, *Lopha sannionis* (White)—Common Upper Cretaceous guide fossil in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1979–1980, p. 52–56

Hunt, A., 1981, The geology and paleontology of a Fruitland Formation (Late Cretaceous) "petrified forest" and adjacent areas in the San Juan Basin of northwest New Mexico (abs.): New Mexico Geology, v. 3, no. 3, p. 45

Kelley, R. W., 1981, Satellite photomap of New Mexico: New Mexico Geology, v. 3, no. 1, p. 10–11

Lyford, F. P., Frenzel, P. F., and Stone, W. J., 1980, Preliminary estimates of effects of uranium-mine dewatering on water levels, San Juan Basin: New Mexico Bureau of Mines and Mineral Resources, Mem. 38, p. 320–333

McLemore, V., 1980, Carbonatites in the Lemitar Mountains, Socorro County, New Mexico: New Mexico Geology, v. 2, no. 4, p. 49–52

———, 1981, Uranium resources in New Mexico—Discussion of the NURE program: New Mexico Geology, v. 3, no. 4, p. 54–58

Thompson, S., III, and Jacka, A. D., 1981, Pennsylvanian stratigraphy, petrography, and petroleum geology of Big Hatchet Peak section, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 176, 125 p.

Thompson, S., III, and Potter, P. E., 1981, Paleocurrents of Bliss Sandstone (Cambrian–Ordovician), southwestern New Mexico and western Texas: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1979–1980, p. 36–51

Weber, R. H., 1980, Rock Hound (State Park): New Mexico Geology, v. 2, no. 4, p. 59–60

Wolberg, D. L., 1980, *Goniopholis kirtlandicus* wiman—forgotten crocodile from the Kirtland Formation, San Juan Basin, New Mexico: New Mexico Geology, v. 2, no. 3, p. 39–41

———, 1981, *Equus conversidens* from the Pleistocene of northwestern Grant County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1979–1980, p. 64–69

Oral presentations

Baker, K., "Legacy of past coal mining," to Mineral Waste and Stabilization Committee, Santa Fe, New Mexico, September

Brandvold, L., "Waste disposal," panel discussion for Sigma Xi, New Mexico Institute of Mining and Technology, Socorro, New Mexico, April

———, "Problems of women in science," panel discussion for Conference on Women in Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico, December

———, "Water quality regulations," to New Mexico Water Well Drillers Association Convention, Albuquerque, New Mexico, January

Brierley, C., "Biotechnology," to Atlantic Richfield Corporation, Chicago, Illinois, September

———, "Microbial processes for removal of suspended clays from selected industrial wastewaters," to the University of Texas at Dallas, Dallas, Texas, September

———, "Bacterial oxidation of thiosulfate in oil shale wastewaters," to Department of Energy, Laramie, Wyoming, November

———, "Microbial processes for wastewater clarification," to ARCO Chemical Company, Philadelphia, Pennsylvania, December

———, "Microbial schemes for uranium extraction from low-grade ore," to Chevron Research Company, Richmond, California, January

———, "Biological methods for removal of selected inorganic contaminants from uranium mine waters," to U.S. Bureau of Mines Twin Cities Research Laboratory, St. Paul, Minnesota, April

———, "Removal of uranium and molybdenum from uranium mine wastewaters by algae," to Engineering Foundation Conference on Advances in Fermentation Recovery Process Technology, Banff, Canada, June

Chamberlin, R., "Uranium in New Mexico," to Legislative Interim Committee on Alternative Energy Sources, Socorro, New Mexico, August

———, "Volcanic features in the Socorro area: a field trip," to New Mexico Institute of Mining and Technology Math/Science Teachers Seminar, Socorro, New Mexico, November

Frost, S., "Coal in New Mexico," to Carrizozo High School, Carrizozo, New Mexico, November

Hawley, J., "Geology of proposed hazardous waste disposal site near Hatch," to Doña Ana County Planning and Zoning Commission, Las Cruces, New Mexico, August

———, "History of the Rio Grande fluvial system in New Mexico," to Geoscience Seminar at New Mexico Institute of Mining and Technology, Socorro, New Mexico, October

———, "Testimony of hazardous waste disposal siting criteria," to New Mexico Legislature Energy and Natural Resources Committee Hearings, Santa Fe, New Mexico, February and March

———, "Geologic and hydrologic criteria for disposal of hazardous wastes," to New Mexico Institute of Mining and Technology Geoscience Seminar, Socorro, New Mexico, March

———, "Approaches to environmental geology in New Mexico," to Navajo Academy class on Campus and Career Exploration, New Mexico Institute of Mining and Technology, Socorro, New Mexico, March

———, "The last three million years of New Mexico history; and approaches to environmental geology in New Mexico," to New Mexico Academy of Science Visiting Scientist Program, Ruidoso, New Mexico, March

———, "Environmental concerns at WIPP site," to Radioactive Waste Consultation Task Force, Santa Fe, New Mexico, April

Hunt, A., "Vertebrate paleontology," two classes for Geology 335 at New Mexico Institute of Mining and Technology, Socorro, New Mexico

Kelley, R., "Publishing challenges of state geological surveys," to 14th Annual Meeting of Association of Earth Science Editors, Halifax, Nova Scotia, October

Logsdon, M., "Geochemistry of the Lightning Dock known geothermal resources area, Hidalgo County, New Mexico," to University of New Mexico Geology Colloquium, Albuquerque, New Mexico, January

Love, D., "Quaternary geology of Chaco Canyon," to Geoscience Seminar, New Mexico Institute of Mining and Technology, Socorro, New Mexico, December

North, R., "Gold in New Mexico," to New Mexico Minerals Symposium, Socorro, New Mexico, October

Osburn, G., "Cauldrons and ash-flow tuffs of the Socorro–Magdalena part of the Datil–Mogollon volcanic field," to Department of Geology, University of Kansas, Lawrence, Kansas, October

———, "General aspects of volcanism," to New Mexico Tech Math and Science Teachers Seminar, Socorro, New Mexico, November

Osburn, J., "Coal research projects for high school students," to Navajo Students visiting NMIMT, Socorro, New Mexico, August

Reiter, M., "Geothermal studies in the southwest United States," to New Mexico Science Teachers Association, New Mexico Institute of Mining and Technology, Socorro, New Mexico

Stone, W., "Geology of ground water," to Hydrology 411 class at New Mexico Institute of Mining and Technology, Socorro, New Mexico

———, "Hydrogeology of the San Juan Basin," to Hydrology 570 class at New Mexico Institute of Mining and Technology, Socorro, New Mexico

Weber, R., "Lithic materials for archeologists and lithic typology," to ASNM–Museum of New Mexico Field School, Gallup, New Mexico, July

———, "Perlite in New Mexico," to Industrial Minerals Forum, Albuquerque, New Mexico, May

Wolberg, D., "Fossils of New Mexico," to Torres Elementary School, Socorro, New Mexico, September

———, "Fossils of New Mexico," to Torres Elementary School, Socorro, New Mexico, April

———, "Fossils of New Mexico," to Socorro Cub Scouts and Brownie Troops, Socorro, New Mexico, May

Other activities

Participation in scientific and professional conferences

American Association of Petroleum Geologists: annual meeting, June
American Association of Petroleum Geologists: Rocky Mountain Section, annual meeting, April
American Association of State Geologists: annual meeting, June
American Chemical Society: New Mexico Section, February
American Geophysical Union: annual meeting, December
American Institute of Mining and Metallurgical Engineers: annual meeting, February
American Institute of Mining and Metallurgical Engineers: fall meeting, October
American Institute of Professional Geologists: 17th annual meeting, September
American Society for Microbiolgoy: Tri-State Meeting, October
Archaeological Society of New Mexico: annual meeting, April
Arizona Geological Society: symposium on tectonics and ore deposits in the southern Cordillera, March
Association of Earth Science Editors: 14th annual meeting, October
Biotechnology in Energy Production and Conservation: Oak Ridge National Laboratory, May
Clay Mineral Society: annual meeting, October
Colorado State University: fluvial systems, March
Department of Energy: Oil Shale Water Management Review, November
Department of Energy: Uranium Industry Seminar, October
El Paso Geological Society: annual field conference, April
Engineering Foundation: Advances in Fermentation Recovery Process Technology, June
Fluvial Processes short course: March
Forum on the Geology of Industrial Minerals: annual meeting, May
Geological Society of America: annual meeting, November
Geological Society of America: Cordilleran Section, March
Geoscience Research Symposium: second annual meeting, April
Gran Quivira Conference: October
International Geological Congress: July
International Quaternary Association: Field Conference on Plio/Pleistocene boundary, March–April
Max-Planck Instit fur Biochemie: Workshop on the Molecular Biology of Archaebacteria, June
Mineral Waste and Stabilization Liaison Committee: July and September
National Water Well Association of Australia: Groundwater 81, June
New Mexico Geological Society: 31st field conference, Trans-Pecos Region, November
New Mexico Mineral Symposium: second annual meeting, September
New Mexico State Water Conference: Water Resources Research Institute, March
New Mexico Water Well Association: annual convention, January
Oklahoma University: coal fundamentals, December
Seventh National Conference on Energy and the Environment: December
Sigma Xi: annual meeting, October
Society for American Archaeology: 46th annual meeting, April
Society for Applied Spectroscopy: New Mexico Section, January
Society for Applied Spectroscopy: Pittsburgh Conference, March
Society for Industrial Microbiology: annual meeting, August
Society for Industrial Microbiology: Board of Directors meeting, April and December
Society for Vertebrate Paleontology: annual meeting, November
United States Geological Survey: state cluster, October
University of Kentucky: symposium on hydrology, sedimentation, reclamation in surface mining, December

Participation in committees and commissions

Austin—Sigma Xi, Local Chapter Secretary; SME, Continuing Education Committee, member; SME, Technical Papers Subcommittee, member; IndMd, Div. of SME-AIME, Technical Commit-

tee, chairman-elect; NMIMT Senate, Vice President 1979–1980 (into fall 1980); NMIMT Financial Aids Committee, member; NMIMT Council of Chairs, member; NMIMT Computer Advisory Committee, member; Graduate Council, member; NMIMT Senate Research Committee, member; Geochemist Search Committee, Geoscience Dept., member; Geoscience Dept., member; Executive Committee, Sigma Xi Chapter at NMIMT, member; Hazardous Waste Committee of Sigma Xi at NMIMT, member; Insurance Committee at NMIMT, member; Forum on the Geology of Industrial Minerals Steering Committee, member; Geoscience Executive Committee, member.

Bieberman—AAPG, member of House of Delegates, representing NMGS; AAPG, member of Committee on Preservation of Samples and Cores; AAPG, member of Membership Committee; NMGS, delegate to Rocky Mountain Section-AAPG; NMIMT Search Committee, member, for Personnel Director; Tenure Committee, member; Petroleum Geologist Search Committee, chairman.

Brandvold—New Mexico Water Conference Advisory Board; New Mexico Water Quality Control Commission, director's representative; Society for Applied Spectroscopy, Rio Grande section, Nominating Committee; NMIMT Sigma Xi, Membership Committee; New Mexico Water Well Drillers Association, Technical Support Group.

Brierley—Society for Industrial Microbiology, Membership Committee, chairman; NMIMT, National Alumni Fund Committee, member; NMIMT, Senate Ombudsman.

Chapin—Geothermal Energy Committee, NMIMT.

Chamberlin—Director of Library Search Committee, member, NMIMT.

Hawley—Geological Society of America; Correlation of Stratigraphic Units of North America Committee; Geological Society of America/Soil Science Society of America Interdisciplinary Committee; NMIMT Chapter of Sigma Xi; Hazardous Waste Commission.

Kelley—Association of Earth Science Editors, member of Board of Directors; New Mexico Geological Society, member of Highway Geologic Map Committee; NMIMT tenure committee.

Kottlowski—American Association of Petroleum Geologists, Stratigraphic Correlations Committee, Publications Committee (Associate Editor), Energy Minerals Division (Publication Councilor); American Commission on Stratigraphic Nomenclature; Association of American State Geologists, AAPG Liaison; Geological Society of America, Councilor; Geological Society of America, Councilor, Coal Geology Division; Cady Award 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; Potential Gas Committee; Regional Coordinator for COSUNA (Correlations of Stratigraphic Units of North America); National Research Council, CODES chairman; COMRE chairman; New Mexico State Land Office, Mining representative on Advisory Council.

Logsdon—Society of Sigma Xi, Committee on Toxic Waste Disposal, member; Petroleum Geologist Search Committee, member.

Love—Albuquerque Gem and Mineral Club, board member.

North—Safety Committee, member.

Reiter—Sabbatical Leave Committee, chairman; V.P.A.A. Search Committee, member; Graduate Council, member; Tenure Committee, member; Thesis Committee.

Renault—New Mexico Energy Institute-NMSU; NMIMT Computer Advisory Commission; NMIMT Performing Arts Series, Secretary; San Miguel School, school board.

Robertson—New Mexico Geological Society, Executive Committee, past president; New Mexico Geological Society, Publications Committee, chairman; Advertising Committee, chairman; Development Committee, chairman; Sigma Xi, Executive Committee, Treasurer; Economic Geologist Search Committee, Geoscience Department; International Union of Geological Sciences Commission on Stratigraphy, Precambrian working group.

Stone—New Mexico Water Well Association, Technical Support Group, chairperson; NMWRRI, State Water Conference, Advisory Committee, member; NMWRRI, Steering Committee for Water Data Management Study, representative; NMIMT Library Committee, member; NMIMT Space Utilization and Planning Committee, member; NMIMT Employee Grievance Committee.

Thompson—Petroleum Geologist Search Committee, member; American Association of Petroleum Geologists, Rocky Mountain Section, Oil and Gas Section, co-chairman.

Weber—New Mexico Natural History Museum, Policy-Advisory Committee, Archaeological Society of New Mexico, Board of Trustees, Certification Council, Vice President; Field Trip, Industrial Minerals Forum, chairman, tenure committees; Economic Geologist Search Committee.

Staff

New employees joining the Bureau were Steve Blodgett, Assistant Editor, 1 January 1981; James Brannan, Drafter, 2 March 1981; Amelia Dondero, Metallurgist (temporary), 18 May 1981; Babette Faris, X-ray Lab. Manager, 1 October 1980; Dana Heljeson, Editorial Technician, 16 November 1980; Barbara Johnson, Staff Secretary, 23 March 1981; Sherry Krukowski, Records and Documents Manager, 21 July 1980; Mark Logsdon, Industrial Minerals Geologist, 1 January 1981; Annabelle Lopez, Clerk Typist, 18 February 1981; David Love, Environmental Geologist, 1 July 1980; Donald McGinnis, Driller's Helper, 20 May 1981; Virginia McLemore, Uranium Geologist, 1 July 1980; David Menzie, CRIB Geologist, 16 December 1980; Teresa Mueller, Drafter, 1 April 1981; Sue Ness, Staff Secretary, 8 August 1980; Keith O'Brien, Hydrologist, 1 January 1981; Dale Straley, Driller's Helper, 15 October 1980.

Resignations during the fiscal year were William Arnold, Scientific Illustrator, 31 March 1981; Steve Cather, Field Geologist, 22 August 1980; Bradley House, Scientific Illustrator, 13 February 1981; Barbara Johnson, Staff Secretary, 15 June 1981; Melvin Jennings, Metallurgist, 30 April 1981; Sue Kent, Field Geologist, 31 July 1980; Sherry Krukowski, Records and Documents Manager, 15 May 1981; Mark Lawson, Technician I, 7 October 1980; Donald McGinnis, Driller's Helper, 26 June 1981; Nancy Mizell, Geologist, 10 October 1980; Connie Oliver, Receptionist, 8 August 1980; Linda Padilla, Staff Secretary, 6 March 1981; Donald Slosar, Technician I, 29 August 1980; Tom Smith, Field Geologist, 19 August 1980; Dale Straley, Driller's Helper, 7 April 1981; Margaret Weber, Assistant Editor, 16 September 1980; William Willis, Driller, 8 October 1980.

Promotions were Wes Mauldin, Jr., to Assistant Driller, 16 November 1980; Michael Wooldridge to Chief Scientific Illustrator, 1 October 1980; Jacques Renault to Senior Geologist, 1 July 1980.

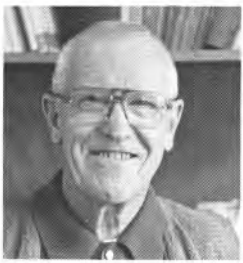
Frank E. Kottlowski
Director,
Senior Geologist 7/2/51

George S. Austin
Deputy Director 9/1/74

Marla Adkins
Assistant Editor 4/21/80

Orin J. Anderson
Field Geologist 7/25/79

Ruben Archuleta
Metallurgical Technician 4/16/79



William E. Arnold
Scientific Illustrator 1/4/54

Kevin Baker
Field Researcher
6/4/79

Robert A. Bieberman
Senior Petrol. Geologist
6/1/50

Steve Blodgett
Assistant Editor
1/1/81

Lynn A. Brandvold
Chemist 11/10/65

James C. Brannan
Drafter
3/21/81

Corale Brierley
Chemical Microbiologist 9/1/71

Brenda R. Broadwell
Assoc. Lab. Geoscientist
4/3/78

Frank Campbell
Coal Geologist 4/1/79

Steve M. Cather
Field Geologist
2/1/80

Richard Chamberlin
Economic Geologist 5/1/79

Charles E. Chapin
Senior Geologist 6/1/70

Jeanette Chavez
Admin. Secretary I 6/14/78

Richard Chavez
Assist. Head, Petrol. Section
2/21/57

Ruben A. Crespin
Technician II 2/24/75

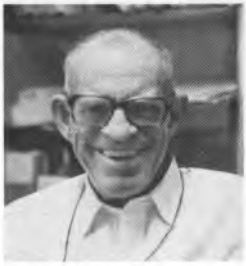
Lois Devlin
Director, Bus.-Pub. Office
1/24/62

Amelia Dondero
Metallurgist
2/1/81

Kathy C. Eden
Editorial Clerk 1/25/79

Robert W. Eveleth
Mining Engineer 12/1/77

K. Babette Faris
X-ray Lab. Manager
10/1/80



Rousseau H. Flower
Sr. Emerit. Paleontologist
9/1/51

Steve Frost
Field Geologist
3/16/77

John W. Hawley
Environmental Geologist
5/22/77

Dana Heljeson
Editorial Technician
11/16/80

Stephen C. Hook
Paleontologist 4/1/76

Bradley House
Scientific Illustrator 8/1/77

Melvin Jennings
Metallurgist 7/9/79

Robert W. Kelley
Editor-Geologist 5/15/71

Mark Lawson
Technician I
2/1/80

Arleen Montoya Lindsey
Staff Secretary
5/22/78

Mark Logsdon
Industrial Minerals Geologist
1/1/81

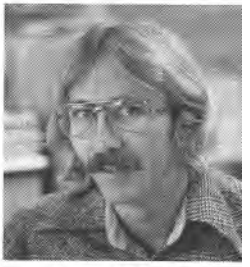
David W. Love
Environmental Geologist
7/1/80

Wes Mauldin
Driller's Helper 6/11/79

Virginia McLemore
Uranium Geologist
7/1/80

Lynn McNeil
Staff Secretary
6/23/80

Norma J. Meeks
Department Secretary
4/21/75



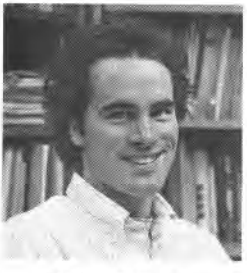
David Menzie
CRIB Geologist
12/16/80

Nancy H. Mizell
Geologist 12/1/76

Teresa Mueller
Drafter
4/1/81

Sue Ness
Staff Secretary
8/8/80

Robert M. North
Mineralogist 9/1/78



Keith O'Brien
Hydrologist
1/1/81

Connie Oliver
Receptionist 6/25/79

Glenn R. Osburn
Volcanologist 5/1/78

JoAnne C. Osburn
Field Geologist 9/16/79

Linda Padilla
Staff Secretary 11/16/78

Joan C. Pendleton
Associate Editor 7/27/76

Barbara R. Popp
Lab. Biotechnologist
7/17/78

Marshall A. Reiter
Senior Geophysicist 4/1/75

Jacques R. Renault
Senior Geologist
9/1/64

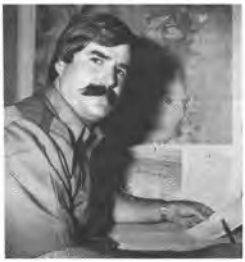
James M. Robertson
Mining Geologist 11/4/74

Gretchen Roybal
Coal Geologist
5/19/80

Amy Shacklett
Asst. Lab. Biotech. 8/1/79

Jackie H. Smith
Technician IV 12/16/63

Tom Smith
Field Geologist
1/1/80

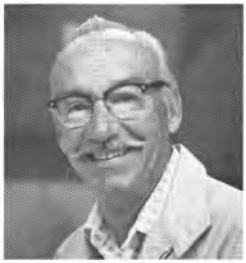


William J. Stone
Hydrogeologist 9/1/74

Sam Thompson III
Petroleum Geologist
10/14/74

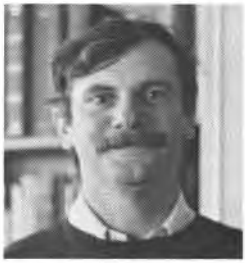
Judy M. Vaiza
Executive Secretary
2/25/74

Debra Vetterman
Drafter
6/2/80



Robert H. Weber
Senior Geologist 5/15/50

William T. Willis
Driller 2/20/78



Donald Wolberg
Vertebrate Paleontologist
12/15/78

Michael W. Wooldridge
Scientific Illustrator 1/25/71

SPATHITES PUERCOENSIS (HERRICK AND JOHNSON)—COMMON UPPER CRETACEOUS GUIDE FOSSIL IN RIO PUERCO VALLEY, NEW MEXICO

by Stephen C. Hook, *Research Associate,* Getty Oil Company, Exploration and Production Research Center, Houston, Texas
and William A. Cobban, *Paleontologist,* U.S. Geological Survey, Denver, Colorado

This is the fifth article in a series documenting biostratigraphically important and easily recognizable fossil mollusks that occur in the Upper Cretaceous rocks of New Mexico. Previous papers described and illustrated the oysters *Pycnodonte newberryi* (Stanton), *P.* aff. *P. kellumi* (Jones), *P.* cf. *P. kellumi* (Jones), *Lopha lugubris* (Conrad), and *L. sannionis* (White); the bivalve *Inoceramus dimidius* White; and the ammonites *Prionocyclus*

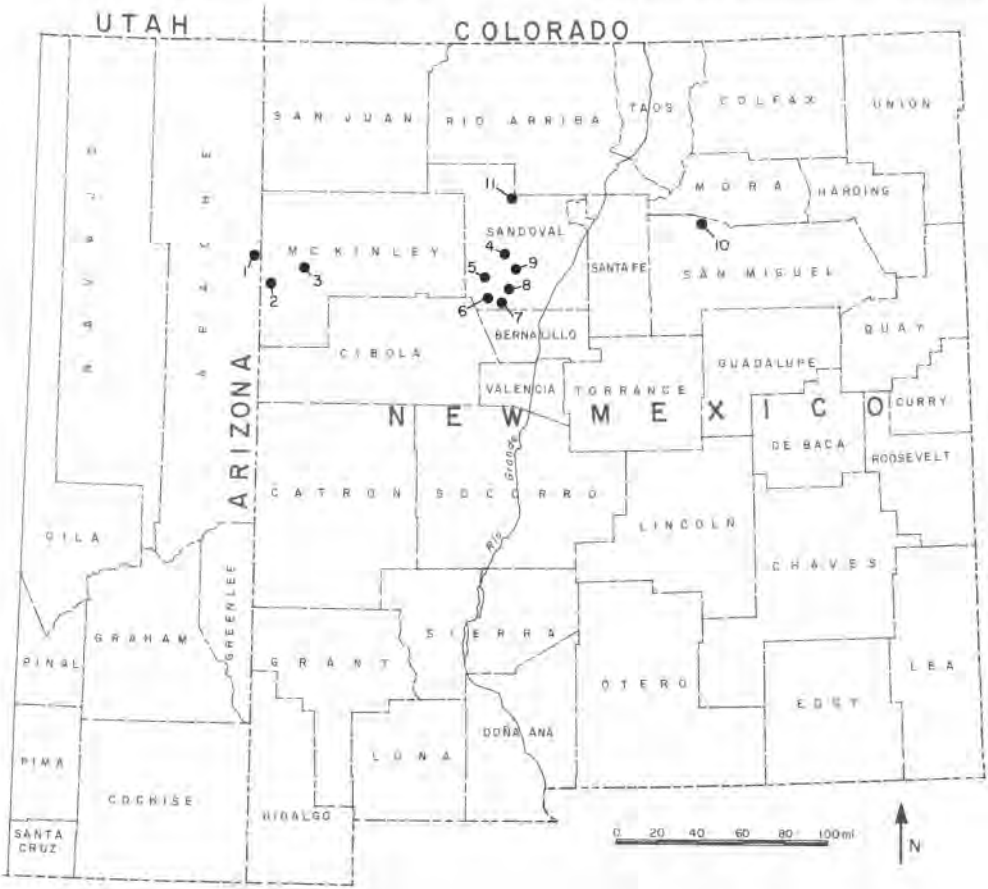


FIGURE 1—Map of New Mexico and part of Arizona showing localities (x) where *Spathites puercoensis* (Herrick and Johnson) has been collected and approximate position of Late Cretaceous shoreline (curved line) during *S. puercoensis* time. USGS Mesozoic localities are 1 (D11144, D11490), 2 (D11143), 3 (D2078), 4 (D4020, D4021), 5 (7992), 6 (15925, 15947, D10508), 7 (3520, 3672, 15797, 15799, D10469, D11476), 8 (7204, 7983, 15792, 15795, 15906, 15909), 9 (10575, 16114), 10 (D10769), and 11 (D10309).

novimexicanus (Marcou), *P. macombi* Meek, and *Scaphites whitfieldi* Cobban (Hook and Cobban, 1977, 1979, 1980, 1981).

Spathites puercoensis (Herrick and Johnson) is one of the most abundant late Cretaceous ammonite species in New Mexico, yet almost all known occurrences of the species are limited to the northern half of the state (fig. 1). The species occurs in the Rio Puerco valley, northwest of Albuquerque, in great abundance in septarian limestone concretions in the Mancos Shale, just below the Juana Lopez Member. Here, *S. puercoensis* is the dominant form in the "Cephalopod zone" of Herrick (1900, p. 338), Herrick and Johnson (1900, p. 15), and Lee (1917, p. 195–198) or the "Cephalopod Shales" of Herrick and Johnson (1900, p. 26, 39, 41).

S. puercoensis (fig. 2) was described by C. L. Herrick and D. W. Johnson (1900) as *Buchiceras swallovi* variety *puercoensis* in their 1900 paper on the geology of the Albuquerque sheet. Clarence Luther Herrick (1858–1904) was the first professor of geology and second president of the University of New Mexico (1897–1901). As Northrop (1966, p. 10) pointed out, "Herrick was versatile and brilliant. In the short span of 28 years from 1877 to 1904, despite ill heatlh, he turned out 156 papers in the fields of geology, zoology, neurology, psychobiology, and philosophy. He was also a remarkably effective teacher."

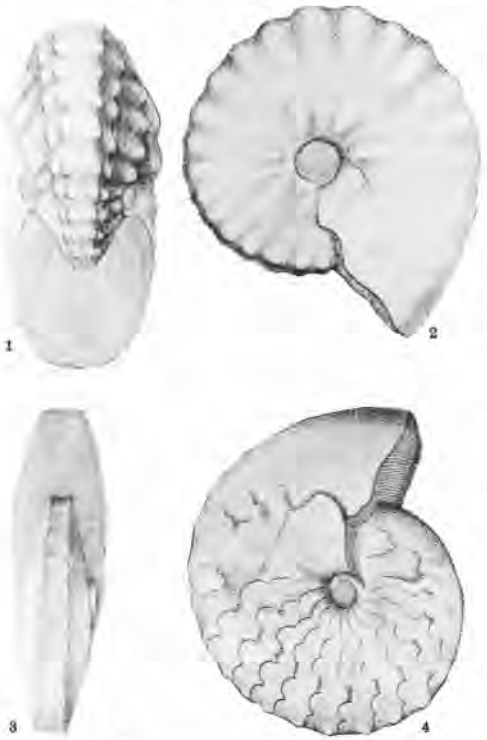


FIGURE 2—Reproduction of original illustration of *Buchiceras swallovi* var. *puercoensis* (*Spathites puercoensis*) from Herrick and Johnson (1900, pl. 1.) Compare suture with that shown in fig. 4.

Although Herrick's contributions to the geology of New Mexico have been generally ignored or overlooked for many years, his pioneering studies on the stratigraphy and paleontology of the Cretaceous in central New Mexico are now being recognized. Cobban and Hook (1980) named a genus of the ammonite family Coilopoceratidae in his honor, and Hook and others (1982) have redefined the Tres Hermanos Sandstone on the basis of his geologic observations. Excellent biographies of Herrick can be found in C. J. Herrick (1955) and Tight (1905).

Douglas Wilson Johnson was a student of Herrick's and received the first Bachelor of Science degree in geology from the University of New Mexico in 1901. The University later (1942) awarded Johnson an honorary L.L.D. degree (Northrop, 1966).

Spathites puercoensis (Herrick and Johnson)

Spathites puercoensis (fig. 3) is a moderate-sized, involute ammonite that has a narrow, sulcate venter on the inner whorls and a broadly rounded venter on the adult body chamber. Ornamentation consists of nodate to bullate umbilical tubercles, clavate inner and outer ventrolateral tubercles, and weak, broad ribs terminating in the inner ventrolateral tubercles. The suture is very simple and consists of broad, little-divided saddles and narrower lobes that have short branches (fig. 4). The species shows the usual range in ammonite variation from slender, weakly ornamented forms (fig. 3I) to stout, strongly ornamented ones (fig. 3D-H).

Spathites puercoensis was originally described by Herrick and Johnson (1900, p. 39, pl. 1, figs. 1–4) as *Buchiceras swallovi* Shumard variety *puercoensis*. The new variety was distinguished from *B. swallovi* by its more slender form, smoother shell, and lack of umbilical tubercles. Stouter forms that had more prominent ornament including umbilical tubercles were collected by Herrick and

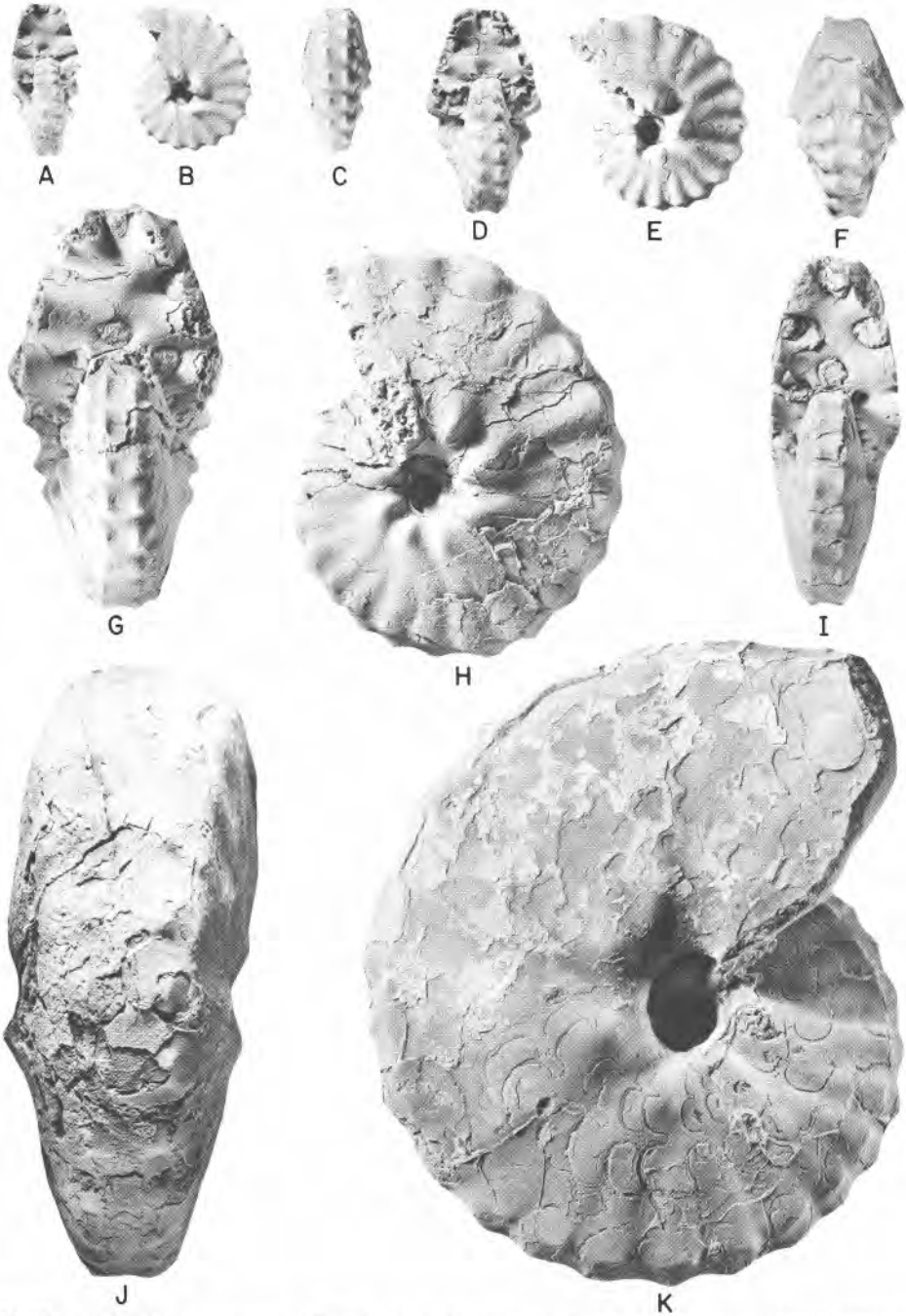


FIGURE 3—*Spathites puercoenesis* (Herrick and Johnson), natural size. A-F, hypotypes USNM 321171, 321172 from Mancos Shale at USGS Mesozoic locality 15947, 1,000 ft north of south line and 5,000 ft west of east line of Agua Salada Grant, Sandoval County, New Mexico. G-K, hypotypes USNM 321173–321175 from Mancos Shale at USGS Mesozoic locality 3672 in Rio Puerco valley 5 mi north of San Ignacio, Sandoval County, New Mexico.

FIGURE 4—Third from last suture of *Spathites puercoensis* (Herrick and Johnson) shown in fig. 3K.

Johnson from the "Cephalopod zone" and assigned to *B. swallovi*. These authors, however, noted the presence of transitional forms in their collection. *Buchiceras swallovi* Shumard (1860, p. 591), first illustrated by White (1883, pl. 18, fig. 1a), is an older ammonite (middle Cenomanian) from the Woodbine Formation of Texas; it is the type species of the genus *Metoicoceras* Hyatt (1903). In this respect, it is of interest to note that T. W. Stanton (in Lee, 1917, p. 195–198) identified *S. puercoensis* as "*Metoicoceras* sp., *M. puercense* (sic), and *M.* sp. related to *M. swallovi*". The species was later assigned to *Spathites* by Cobban (in Dane and others, 1968, p. F7) and more recently illustrated by Kennedy and others (1980, pl. 104, figs. 1–5; pl. 106, fig. 3; text fig. 8C).

Spathites puercoensis lies either in the lower part of the middle Turonian zone of *Prionocyclus hyatti* (Stanton) or just below it. Most collections of ammonites from the Rio Puerco valley consist of an association of *S. puercoensis* and *Hoplitoides sandovalensis* Cobban and Hook without *P. hyatti* (Cobban and Hook, 1980, p. 24). The few collections that include *P. hyatti* may have been made over too large a stratigraphic interval.

Aside from the 21 localities where *S. puercoensis* has been collected from part of the Rio Puerco valley, the species is known in New Mexico by only a few fragments in olive-gray shaly siltstone beds in the Mancos Shale at two localities near Gallup and by a few specimens in the Codell Sandstone Member of the Carlile Shale at one locality near Las Vegas (fig. 1). Outside New Mexico, *S. puercoensis* is known from sparse fragments at two localities northwest of Gallup just over the Arizona border (fig. 1).

ACKNOWLEDGMENTS—Photographs of *Spathites puercoensis* (Herrick and Johnson) were made by R. E. Burkholder, U.S. Geological Survey, Denver, Colorado. The manuscript was critically reviewed by G. R. Scott and C. H. Maxwell, both of the U.S. Geological Survey, Denver.

References

Cobban, W. A., and Hook, S. C., 1980, The Upper Cretaceous (Turonian) ammonite family Coilopoceratidae Hyatt in the Western Interior of the United States: U.S. Geological Survey, Prof. Paper 1192, 28 p., 21 pls.

Dane, C. H., Kauffman, E. G., and Cobban, W. A., 1968, Semilla Sandstone, a new member of the Mancos Shale in the southeastern part of the San Juan Basin, New Mexico: U.S. Geological Survey, Bull. 1254-F, 21 p.

Herrick, C. J., 1955, Clarence Luther Herrick, pioneer naturalist, teacher, and psychobiologist: American Philosophical Society, Transactions, n.s., v. 45, pt. 1, 83 p.

Herrick, C. L., 1900, Report of a geological reconnaissance in western Socorro and Valencia Counties, New Mexico: American Geologist, v. 25, no. 6, p. 331–346; New Mexico University, Bull. 2, 17 p.

Herrick, C. L., and Johnson, D. W., 1900, The geology of the Albuquerque sheet: Denison University Scientific Laboratories, Bull., v. 11, art. 9, p. 175–239, pls. 27–32; New Mexico University, Bull. 2, 67 p., 22 pls.

Hook, S. C., and Cobban, W. A., 1977, *Pycnodonte newberryi* (Stanton)—common guide fossil in Upper Cretaceous of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Rept. 1976–77, p. 48–54, 5 figs.

———, 1979, *Prionocyclus novimexicanus* (Marcou)—common Upper Cretaceous guide fossil in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Rept. 1977–78, p. 34–42, 5 figs.

———, 1980, Some guide fossils in Upper Cretaceous Juana Lopez Member of Mancos and Carlile Shales, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Rept. 1978–79, p. 38–49, 7 figs.

———, 1981, *Lopha sannionis* (White)—common Upper Cretaceous guide fossil in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Rept. 1979–1980, p. 52–56, 3 figs.

Hook, S. C., Molenaar, C. M., and Cobban, W. A., 1982, Redefinition of the Cretaceous Tres Hermanos Sandstone of Herrick (1900), New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circ. 185 (in press)

Hyatt, Alpheus, 1903, Pseudoceratites of the Cretaceous, T. W. Stanton, ed.: U.S. Geological Survey, Mono. 44, 351 p., 47 pls.

Kennedy, W. J., Wright, C. W., and Hancock, J. M., 1980, Origin, evolution and systematics of the Cretaceous ammonoid *Spathites:* Palaeontology, v. 23, pt. 4, p. 821–837, pls. 104–106

Lee, W. T., 1917 [1918], Geology of the Raton Mesa and other regions in Colorado and New Mexico: U.S. Geological Survey, Prof. Paper 101, p. 9–221, illus.

Northrop, S. A., 1966, University of New Mexico contributions in geology, 1898–1964: University of New Mexico, Pubs. in Geology, no. 7, 152 p.

Shumard, B. F., 1860, Descriptions of new Cretaceous fossils from Texas: Academy of Science of St. Louis, Transactions, v. 1, p. 590–610

Tight, W. G., 1905, Clarence Luther Herrick: American Geologist, v. 36, p. 1–26

White, C. A., 1883, Contributions to invertebrate paleontology, no. 2; Cretaceous fossils of the western states and territories: U.S. Geological and Geographical Survey of the Territories (Hayden), Annual Rept. 12, pt. 1, p. 5–39, 19 pls.

FORMER DIRECTOR RECALLS . . .

by Eugene Callaghan, *Consulting Geologist,* Salt Lake City, Utah

The years during which I had the privilege of serving as director of the New Mexico Bureau of Mines and Mineral Resources, from September 1949 to January 1957, were the most exciting and productive of my life. I was offered the position by President E. J. Workman on the recommendation of Professor R. H. Jahns (then with the California Institute of Technology) and was appointed by the Board of Regents, soon to be headed by Thomas Cramer of Carlsbad. At the time President Workman interviewed me I was professor of economic geology at Indiana University and, from 1930 to 1946, I had been a geologist in the U.S. Geological Survey in various assignments and capacities. Dr. Workman said, "I want you to build the best state geological survey in the country"—a challenge for which I felt I was, through breadth of experience in federal and state work, ready.

This was an opportunity to build, to expand the knowledge of the geology of New Mexico, especially as it applied to the development of mineral resources and the growth of the state's economy. The spirit of building had already been generated by President Workman who founded the Research and Development Division at the University of New Mexico during the war years and had moved that division to the campus of the New Mexico School of Mines at Socorro when he became president in 1946. A new building had just been completed for the Research and Development Division to carry on contract research in weaponry. I lived in my house trailer which Mr. and Mrs. Abe Baca kindly permitted me to park in their backyard on School of Mines Road. My family remained in Washington, D.C., until housing became available in Socorro.

When I arrived, Bureau personnel, consisting of E. C. Anderson who had been the prior director and who was a trained mining engineer; Donn M. Clippinger, materials engineer; Philip F. McKinley, economic geologist; and Richard C. Northrop, petroleum geologist, were in the basement of Brown Hall, the college's administration building. Richard A. Matuszeski was assayer and Marian Burks was office manager. The petroleum engineer was Edward E. Kinney stationed in the Bureau's Artesia office. The legislative appropriation was $90,000.

However, in October 1949 the Bureau was moved into the southeast corner of the new Research and Development Laboratory, with sufficient space for establishing a business office, publications room, petroleum sample library, drafting room, mineralogical laboratory, two geological laboratories, and two offices for engineers. Space for assaying was made available in another building. Surveying equipment, laboratory and drafting equipment, and field vehicles were added as funds permitted. This program was most encouraging and made possible the addition of three staff members, Robert H. Weber as economic geologist, Robert A. Bieberman as petroleum geologist (both still employed by the Bureau), and Hans H. Adler as mineralogist. In 1951 the name of the school was changed to New Mexico Institute of Mining and Technology; the Bureau was designated a division along with the College Division and the Research and Development Division.

The legislative appropriation rose from $90,000 in fiscal year 1950–51 to $170,000 in fiscal year 1951–52. These totals seem miniscule now but at that time much could be accomplished. One of the principal objectives of the Bureau was to provide geologic maps and accompanying reports as a basis for effective exploration for mineral occurrences of all types. To obtain the maximum amount of mapping coverage at the least cost we set up what I called the Field Assistance Fellowship program for Ph.D. candidates at major universities. The Bureau agreed to provide base maps and aerial photos plus a modest stipend to cover field expenses and field direction for mapping specified areas. Laboratory work at the candidate's university was their responsibility as well as the preparation of the report. The Bureau had the first right to publish. Also the candidate's major professor was required to visit them in the field. Because I generally went along, the Bureau received the advantage of free consultation from distinguished geologists. The response to this offer was excellent and resulted in many publications and maps as the availability of base maps permitted. Im-

portant to my personal life was the fact that faculty housing was provided and in 1951 my family joined me in Socorro.

The rise in the legislative appropriation permitted a notable increase in the Bureau's permanent staff. From July 1950 to July 1952, seven economic geologists, a hydrologic engineer, a stratigraphic geologist, a mineralogical petrographer, four geological technologists, an illustrator, and a stenographer were added. Robert Balk was induced to leave his professorship at the University of Chicago and come to the Bureau. He had a worldwide reputation in the field of igneous structure. Brewster Baldwin came to the Bureau from the University of South Dakota where he was instructor. Frank E. Kottlowski, the present director, had been a student and field assistant of mine at Indiana University where he had specialized in coal geology. Max Willard was an experienced field geologist who had worked with me in Utah. John Eliot Allen transferred from the College Division to the Bureau. He had long field experience in Oregon and had taught at Pennsylvania State University. Frederick J. Kuellmer, University of Chicago, Henry L. Jicha, Jr., Columbia University, and Robert A. Zeller, Jr., UCLA, had been Field Assistance Fellows with the Bureau. Rousseau H. Flower was a well-known paleontologist and stratigrapher at the New York State Museum. Francis X. Bushman came to the Bureau as hydrologic engineer from the State Water Survey Division at Urbana, Illinois. Ming-Shan Sun joined the Bureau as mineralogist-petrographer from post-doctoral studies at Columbia University. W. Dean Pennington was a petroleum geologist from Indiana University. Wright W. Putney joined the Bureau as illustrator after receiving training in art education at New Mexico Highlands University. Charles E. Stearns of Harvard and Tufts Universities, Richard H. Jahns of California Institute of Technology, and Clay T. Smith of the College Division were employed part-time for quadrangle mapping. Ten new candidates were added to the Field Assistance Fellowship program. The excellent support staff was selected by Marian Burks; she remained as office manager until 1955. From July 1950 to July 1952, 48 field projects and 6 groundwater studies were undertaken; 7 maps and book reports were published and 12 others were in preparation.

As a means of expanding the work of Bureau personnel beyond the limitation of the legislative appropriation, a contract (approved by the Regents) was negotiated with the U.S. Bureau of Indian Affairs to make an intensive geological and mineral survey of 450 mi^2 of the Navajo Reservation. Robert Balk and John Allen were assigned to this project, and the results were published in 1954. Authorities in special fields were enlisted. A report on the pegmatite deposits in the Picuris Range by Arthur Montgomery (who had operated the principal mine) was published in 1953.

Not only was the staff engaged in scientific and engineering studies but many direct services were provided to citizens. From July 1952 to July 1954, more than a thousand visitors were logged, more than 8,500 letters sent, over 10,000 maps and book reports sold, and 2,800 publications distributed without cost. Some 1,200 publications were distributed to libraries on an exchange basis; small mineral collections were distributed to schools. The oil well sample library made available to private industry samples representing 3,502 wells, 725 strip logs, and 6,912 driller's logs. Staff members served many organizations by presenting papers and serving as officers and members of committees. The Bureau cooperated with and served universities, schools, and state and federal agencies. Roy W. Foster, Ohio State University, joined the staff as a petroleum geologist in 1953, and John H. Schilling, Harvard University, began as a mining geologist in 1954. William E. Arnold started many years of service to the Bureau as Scientific Illustrator in 1954.

In February 1955 the Bureau lost its most distinguished staff member, Robert Balk, in the crash of a commercial airliner on the face of the Sandia Mountains during a snowstorm. He was on his way east on Bureau business. My own loss in this tragic event was tremendous for Robert was my closest friend going back to the time I was a student at Columbia University in 1927. He had come to Socorro in part through deep personal friendship to help me. His three years with the Bureau were very productive. His widow, Christina Lochman Balk, was appointed to the Bureau staff as stratigraphic geologist until she transferred to the College Division in 1957.

The legislative appropriation advanced to $200,000 in fiscal year 1954–55, then $224,091 in fiscal year 1955–56. During these two years the range of production by the permanent and temporary staffs was expanded; 108 field and

special projects and 11 ground-water studies were undertaken. A contract study on the stratigraphy of the San Andres Mountains within the White Sands Missile Range was financed by the petroleum industry and carried out under the field direction of Frank E. Kottlowski. Its publication in 1956 initiated the Memoir series featuring a larger format than the Bulletin series for more favorable presentation of illustrations. A series of popular guidebooks to localities of public interest was initiated. Completion of a new wing at the south side of the Research and Development Laboratory provided the Bureau with much needed additional space.

A fine compliment to the Bureau was its selection by the Association of American State Geologists to host the Association's annual meeting in 1955, bringing many state geologists and federal officials to Socorro. Also, the Governor appointed me to serve on the Western Governors Mining Advisory Council and attend a meeting in 1955 in Sacramento, California.

In 1956 the Board of Regents indicated that while geologic investigations should continue at a high rate, additional effort should be made in mining and metallurgy. I felt that in developing the Bureau as a mainly geological organization I was fulfilling President Workman's request to build one of the most productive state geological surveys. When opportunity came for a significant position in private industry, I resigned from the Bureau as of January 1957. This was not easy for I had greatly enjoyed the administrative and investigative work and especially my friendships with the many fine and thoroughly competent staff members.

I look back with pride to those formative years and to the accomplishments of the scientists, engineers, and support staff I recruited. I am proud, too, of the productive organization the Bureau has become, with a legislative appropriation of nearly $1.5 million, excellent facilities, and a large staff competent in a wide range of endeavors. During my encumbancy the value of New Mexico mineral production (which included the beginning of the uranium boom) climbed from approximately $190 million to $560 million. In 1979 the value was almost $5.5 billion. I hope that I participated in developing the momentum the Bureau has enjoyed, especially under the direction of Frank Kottlowski whom I brought to New Mexico more than 30 yrs ago.

Shortly before moving out of Socorro in 1957, I had a conversation with Harrison Schmitt (the father of present U.S. Senator "Jack" Schmitt), the noted consulting geologist based in Silver City. "You know, Callaghan, it is great to be able to reach into my file of Bureau publications and find a useful geologic map covering an area in which I may be interested. That was not possible a few years ago."

NEW MEXICO URANIUM SEVERANCE TAXES

by Lynn C. Jacobsen, *Consultant,* Albuquerque, New Mexico

Nuclear power and the uranium industry—overview

For nearly 3 yrs nuclear power in the United States has been a stagnant industry. Nuclear power in 1981 comprised about 11% of the domestic electricity generation; this compares with 12.5% in 1978. No reactors have been ordered since 1978, and 67 reactor units, representing a design capacity of 73 million kilowatts, have been cancelled. Many other units have been delayed.

Although a significant proportion of the population has reservations in regard to nuclear power, modest growth in the amount of nuclear power generated is anticipated. As of the summer of 1981, 74 reactors were licensed for commercial operations, and construction permits for another 80 had been granted. The Nuclear Regulatory Commission has announced that it expects to license five or six units for commercial operation for each of the next several years. Continuation at that pace would require an approximate doubling of uranium requirements over the next decade.

Three Mile Island is, of course, a major contributor to the slowdown, but a lower rate of growth in power consumption, inflation, and the politicization of nuclear power have also played their parts.

The contraction of nuclear power has inevitably had an impact on the uranium industry. With slower growth in power consumption, growing confidence that foreign supplies of uranium would be available, extraordinarily high interest rates, and utility commissions reluctant to grant rate increases, utilities that had purchased uranium beyond their immediate needs began to reduce their inventories. This selling by the utilities has driven the price below the production costs of most producers, and several producers found purchasing uranium from utility inventories to fulfill delivery commitments to be more attractive than producing.

This upside-down market cannot persist for long, but the utilities still have large inventories and the uranium industry has productive capacity well above current requirements. However, approximately 50% of the generating capacity now under construction is nuclear, and requirements for these plants, in combination with the closing of mines and the delay of new development, will bring a better balance between supply and demand and presumably an increase in prices. Views as to when the industry will return to a state of health vary widely. Optimists look forward to gradual improvement over the next three years; pessimists see the abundance of low-cost foreign uranium dooming the United States to forever being a marginal producer. No one in the industry foresees the magnitude of expansion that was being projected and publicized a year ago by federal government agencies.

The growth of nuclear power also has slowed in the remainder of the industrialized world but not to the extent it has in the United States. Led by aggressive programs in France, Britain, Japan, and Russia, 43 nations now have nuclear plants, and the number of plants and proportion of power generated by nuclear reactors has increased steadily. France, in particular, has made a major commitment to nuclear power. Currently, the French are commissioning a new nuclear power plant every two months. They lead the world in breeder technology with a 250-MW unit considered a technical success, and a 1,200-MW unit nearing completion. France also is expanding its capacity to reprocess spent fuel; it does not consider waste disposal to be a technical problem.

Foreign uranium producers also have been expanding their capacity. Additions to existing facilities have been made in Canada, South Africa, and Niger; major new production centers are in every stage from early planning to approaching start up in Canada, Australia, Niger, and Namibia. The United States is still the world's large producer, but it is expected to lose that position in the latter half of this decade. Much of the new foreign capacity will be based on large reserves of high-grade ore and consequently is expected to have low production costs. Growth of nuclear power in foreign nations will absorb much of this new capacity, but shortages are not now foreseen. Probably the most widely held view of the outlook for uranium is a period of gradual recovery, followed by growth of a mature,

relatively stable, competitive industry having market characteristics similar to the copper industry.

Trends in New Mexico uranium industry

The slower-than-expected growth and other problems of the nuclear power industry have inevitably resulted in sharply decreased demand for uranium and a precipitous drop in price from over $40/lb in 1979 to less than $25/lb in the summer of 1981. Prices dropped below costs for most operators, and the result has been that only those producers with contracts entered into before 1980 have been able to continue operations. Of the 54 mines operating in 1979, 25 either have been permanently closed or placed on standby. Most of these were smaller operations, but among them were the Anaconda Jackpile-Paguate open-pit mine, the Sohio-Reserve JJ #1, the Kerr-McGee Rio Puerco mine, and several medium-size mines in the Ambrosia Lake district. Work on new major production centers by Phillips, Conoco, and Bokum has been halted indefinitely.

Six processing mills are licensed to operate in the state. The Bokum Marquez mill has never been opened, the Sohio-Reserve L-Bar mill was closed in July 1981, the Anaconda Bluewater mill has been scheduled for closure in March 1982, and the Homestake Ambrosia Lake mill and the United Nuclear Churchrock mill are operating at reduced rates. Only the Kerr-McGee mill is operating in a nearly normal fashion.

The gloomy outlook has affected exploration. The large exploration staffs of major oil and mining companies mostly have been disbanded, acquisition of leases and mining claims has come to a halt, and the number of active surface drilling rigs is about one-tenth the number active in 1979. Several contractors have gone out of business, others have sold or stacked rigs, and still others have shifted most of their operations out of state.

The number of jobs lost from the industry has now approached 3,000, or more than one-third of the total employment in the industry 2 yrs ago. These positions had an annual aggregate wage of approximately $60 million. The reduction in purchases of supplies and services has been at least equal to the reduction in wages.

The decline has, of course, rippled through the economy. The boom created by the actual and expected growth of uranium production has collapsed; in Grants and Milan, houses and apartments stand vacant and real estate values have plummeted. All aspects of the local economy from banks to fast-food restaurants have been affected, and tax collections have failed to keep pace with inflation while the demand for governmental services has increased.

Clearly a number of factors have contributed to the decline of the industry. Among them are Three Mile Island, the lack of a national commitment to nuclear power, the rise of foreign productive capacity, lower prices, higher costs (including severance taxes), and a ratcheting regulatory policy. Most of these factors have worked industry-wide; hence, it is of interest to see how New Mexico has fared relative to the rest of the United States. In table 1, uranium-concentrate production (yellowcake) is shown for the United States and for New Mexico for the years 1974–1980 (DOE, 1981), as well as the projected 1981 production for New Mexico.

As can be seen in table 1, New Mexico's share of United States' production rose through 1976 when it reached a peak of 48%. The amount of concentrates produced, as contrasted with the share of production, continued to increase until 1978, when it reached a peak of 8,560 tons. Since then the production has dropped to an estimated 7,750 tons in 1980, and an estimated share of production of 35%. The lower production in 1979 is exaggerated because of the problems at the UNC Churchrock mill, but even if that mill had operated in normal fashion, the trend would have been the same. Because of the lag between mine production and mill production,

TABLE 1—URANIUM CONCENTRATE PRODUCTION; a) estimated by Department of Energy based on July 1981 information.

Calendar year	United States (tons)	New Mexico	
		tons	percent
1974	11,528	4,951	43
1975	11,600	5,191	45
1976	12,747	6,059	48
1977	14,940	6,780	45
1978	18,490	8,560	46
1979	18,730	7,420	40
1980	21,850	7,750	35
1981	17,800[a]	5,200[a]	29

most of the impact of reduced operations will not be seen in mill output until 1981, when the expected production is 5,200 tons—a reduction of nearly 40% from the peak of 1978.

Much of the same story is told by the statistics of surface drilling, as shown in table 2 (DOE, 1981). New Mexico's share of total United States drilling increased until 1976 when it comprised over 32%; however, since 1976 the New Mexico share has dropped to below 15%. The relative decline in New Mexico is not the result of depletion of its resource base. In fact, the proportion of known uranium resources with an average grade of 0.10% in New Mexico has increased from approximately 52% in 1976 to about 56% in 1980. New Mexico has 56% of the known uranium resources of the United States but less than one-third of the production and less than 15% of the surface drilling—and these shares have been dropping from 1976. The data indicate that producers have found development and production of uranium to be less attractive in New Mexico than in other areas; thus, relative decline began in 1977. It is hardly a coincidence that in 1977 New Mexico put into effect the highest severance tax in the country.

Role of the severance tax

Since 1977 New Mexico has had by far the highest nominal severance-tax rates on uranium of any of the major producing states. As used here, the term "severance tax" also includes the natural-resource excise tax and the continued-care fund tax in New Mexico and equivalent taxes in other states. Effective January 1, 1977, severance taxes in New Mexico became $2.25 to $2.50 per lb higher than severance taxes in other producing states, and this differential remained until 1980, when it was increased. In table 3, the amount of severance tax at the rate in effect at the end of 1980 for a lb of uranium sold for $30 and for $40 is shown for the major producing states (New Mexico, Texas, Utah, and Wyoming revenue and taxation departments, personal communication, 1981).

In 1981 the Legislature reduced the uranium severance tax (but not the resource excise tax) for a 3-yr period commencing July 1, 1981. The reduction was accomplished by redefining "taxable value" to mean 60% of sales realization. This reduction was welcomed by those producers with existing contracts, but because the large differential with other states exists for prospective sales the temporary relief is of minimum assistance to existing or potential producers in competition for new sales contracts. Although the intent of the temporary tax reduction was to help the industry through a period of distress, the relief was not structured to accomplish its purpose.

Most uranium is sold in multi-year contracts with deliveries starting one or more years after the contract is negotiated. Thus, the uranium currently being delivered by New Mexico producers is the result of sales made before 1980, and the greater decline of production in New Mexico than in other states indicates that New Mexico producers were not as successful as the producers in other states in getting the high-price sales contracts that were available from 1977 through 1979. The imposition of high severance taxes was not the sole cause of the relative decline of uranium pro-

TABLE 2—SURFACE DRILLING FOR URANIUM; a) estimated by Department of Energy, and b) estimated by author based on drilling activity through September 1981.

Calendar year	Total United States (millions of feet)	New Mexico	
		millions of feet	percent
1974	22.0	4.9	22.1
1975	25.4	5.7	22.4
1976	34.0	11.0	32.4
1977	41.0	9.1	22.2
1978	47.0	9.9	21.1
1979	40.8	6.3	15.4
1980	27.8[a]	4.1[b]	14.7

TABLE 3—COMPARISON OF SEVERANCE TAXES IN EFFECT AT END OF 1980 FOR A LB OF URANIUM SOLD FOR $30 AND FOR $40; a) temporary credit of 50% of tax due on the first 100,000 lbs is available in FY 1980–1981, on 75,000 lbs in FY 1980–1982, and on 50,000 lbs in FY 1982–1983; b) varies with grade of ore; and c) varies with transportation and milling costs and has a $50,000 exemption.

State	Severance tax	
	$30/lb	$40/lb
New Mexico[a]	$2.375	$3.55
Wyoming[b]	0.30–0.45	0.40–0.60
Utah[c]	0.20–0.30	0.25–0.35
Texas	–0–	–0–

duction in New Mexico, but it was a major factor.

Severance taxes are, of course, not the only tax on uranium producers; ad valorem taxes are also significant, and apparently Wyoming has a modestly higher rate of taxation than New Mexico. Comparisons are not readily made because of differences in assessment procedures and the cost and age of facilities but, on the average, in 1979 Wyoming collected ad valorem taxes of about $.20 more per lb of uranium concentrates produced than New Mexico did. Thus, the net disadvantage of a New Mexico producer is about $2.00 for contracts in the range of current prices; this disadvantage increases to more than $2.75 if the prices increases to $40.

The point at which the tax is applied is of critical importance. For example, the Wyoming severance-tax rate is 5.5% and the New Mexico rate, at recent price levels, is approximately 7-9%. The difference seems small but, because Wyoming applies its tax at the mine mouth and New Mexico applies its tax after processing, the Wyoming severance tax on an average lb sold for $30 is about $.40, whereas the New Mexico tax is about $2.37. Clearly this is not an insignificant differential in an industry that has shown losses more commonly than it has shown profits, and which even in good years has profits of only a few dollars per lb. Further, the difference increases as the price increases and, as the market improves, Wyoming producers will be able to enter the market at prices from $2.00 to $2.75 per lb lower than can New Mexico producers.

The New Mexico tax is a simple excise tax on uranium concentrates; it is similar to the tax on various luxury goods and imports for which the government seeks to discourage consumption. Like most excise taxes, it is regressive; that is, the ratio of tax to net income increases as net income decreases. Two producers selling at the same price and mining the same grade ore will have the same severance tax, although one may have production costs of $75 per ton and the other $50 per ton. Taxes continue even when production is at a loss, as is the current situation for most uranium producers.

For uranium, the regressiveness is compounded as a result of the escalation of tax rates with price. For a price of $30 per lb, the tax rate is 7.9% of gross sales, but for each $1 increase in price, the tax rate is increasing 11% up to $40, where the tax rate is 8.9%. For each additional $1 increase in price above $40, the tax rate is increasing 12.57%. An increase in price from $30 to $40, or 33⅓%, results in an increase of 50% in tax; hence, as inflation moves prices and costs upward, the producers become progressively worse off.

Still another negative feature of the tax is that it discourages the production of low-grade ore and leads to premature abandonment of properties. Consider an operator producing ore with a grade of 0.12%, or 2.4 lbs per ton, and having direct mining and milling costs of $60 per ton. Neglecting processing losses, he will have, at a $30 sales price, revenue of $72 for each ton of ore. On the 2.4 lbs of uranium, he will pay a total severance tax of $5.70; after the severance tax, he will have an operating income of $6.30 per ton of ore. His severance tax will be 47.5% of his before-tax operating income. If his grade should drop to 0.11%, or 2.2 lbs per ton, his revenue will decrease from $72 to $66 for each ton of ore, but his severance tax will drop only from $5.70 to $5.22, and his operating income will be $.78 per ton of ore ($66-$60-$5.22). Severance tax is now 87% of his before-tax operating income. At a grade of 0.10%, his revenue would exactly equal his mining and milling costs, but he would be subject to a tax of $4.75 for each ton of ore produced and would not likely stay in business very long.

Wyoming has recognized the value of these low-grade resources and, using sales price and a formula developed by the Atomic Energy Commission, values uranium recovered from low-grade ores lower than that recovered from high-grade ores. Utah, to some degree, accomplishes the same result with an allowance for transportation and milling costs and a $50,000 exemption.

When the 1977 severance-tax legislation was being considered, equity among the energy fuels—uranium, coal, and oil and gas—was of concern. The objective of equity is admirable but, because of vastly different structures of the three industries, is extremely difficult to define. Oil and gas are characterized by a small labor input and production costs that are a small proportion of net income. Oil and gas have steady prices and markets and, when the costs for a producing well equal revenue, the well is simply abandoned. Extremely rarely is an oil or gas well operated at a loss.

Severance taxes impact only at the margin and on a very small share of production.

Uranium and coal, in contrast, have large inputs of labor and supplies, create proportionately more secondary economic activity, and have production costs that are a high proportion of revenue. Markets are uncertain and mines are not readily shut down; hence it is not uncommon for mines to be operated at a loss. The principle of equity would seem to require consideration of the relation between direct taxes and net income and of the taxes generated indirectly by the industries.

Uranium is a totally fungible product. The consumer has no reason to find New Mexico uranium more desirable than that from Wyoming or Australia, and transportation costs are insignificant. It has no locality or quality premium to be captured by taxes, and a tax on New Mexico uranium that is not matched by all other producing areas simply puts New Mexico at a competitive disadvantage. Among minerals, uranium has some distinctive characteristics, particularly the wide range in grades of ores that are mined; however, the uranium industry is much more like the other major mineral industries of the state (copper, potash, and molybdenum) than it is like oil and gas or coal. All the former have large labor inputs, face uncertain markets, require some degree of processing before marketing, and face major competition from producers outside the state.

New Mexico uranium-severance-tax collections amounted to $21.1 million in 1978, $16.2 million in 1979, and $20.2 million in 1980. These are not insignificant amounts, but they are small relative to the total economic impact of the industry on the state. The direct impact, that is, personal income, purchase of supplies and services, and governmental revenue, amounts to $250–$300 million per year (Leaming, 1980). The effect of these dollars circulating and recirculating is to add another two to three times that amount to the state's economy. Thus, the uranium contribution to the state is on the order of $1 billion.

Not all features of the severance tax are bad. The tax is simple to compute, simple to collect and administer, and the revenue it will produce is relatively predictable. These are not inconsequential advantages, but it is also a tax of diminishing returns; the jobs not created; the construction contracts not let; the supplies not bought; the income, gross receipts, and ad valorem taxes not paid are not so readily measured.

Summary and recommendations

The New Mexico uranium industry is in a major and serious depression. The decline has been more severe than for the economy as a whole and greater in New Mexico than in other states. The situation for uranium is in many ways like that of the potash industry in the 1960's—rising costs, weak markets, and low-cost foreign competition. No quick turnaround can be anticipated, and although most observers expect an eventual recovery, the recovery will likely be to a mature competitive industry with modest rates of growth.

Taxes are an instrument of economic policy as well as a means of raising revenue, and the current uranium severance tax does not serve the New Mexico economy well. It places New Mexico producers at a major disadvantage relative to those of other states, discriminates relative to other minerals, and is structured to bring about inefficient production of the state's resources.

No member of the industry believes the problems associated with uranium production will disappear if relief is granted on the rate of taxation. However, the tax is a burden—a burden not fully shared by producers in other states, and its magnitude will have much to do with the rate at which the industry recovers. As existing delivery contracts expire, producers will scramble for the new contracts that become available, and inevitably New Mexico producers will be the last who will be able to enter the market. With the overhang of foreign supplies, that entry could be delayed a long time.

When the severance taxes were raised in 1977 and 1980, the widely held belief was that uranium production would be expanding dramatically, that producers were likely to be reaping bonanza profits, that New Mexico uranium had an economic advantage over that of other states, and that severance taxes could be passed through to consumers. All of these assumptions have proved false, and because the industry can now be perceived more realistically, the level and structure of the tax should be reviewed.

Two primary considerations should guide this review. The first, obviously, is the inequitable difference between the taxes in New Mexico and those in other states. The extra

burden in New Mexico for future sales contracts in the $30 price range is now $2.00 per lb over Wyoming and still higher relative to other major producing states; the burden will increase as the price recovers. As in any other industry, such a differential cannot persist for long without strangling the industry.

The second consideration is the disparity between the treatment of uranium and that of other minerals. A possible rational approach to severance taxes would be to have three categories—oil and gas, coal, and other major minerals. Each of these have distinctive characteristics that justify different treatment. Uranium is somewhat different from copper, molybdenum, and potash, but the differences are small relative to the differences between the four of them and oil and gas or coal. In scale, structure, and markets, uranium is much more like the other minerals than it is like oil and gas or coal. In particular, uranium, copper, potash, and molybdenum all require processing before marketing. Processing of minerals is not significantly different from other manufacturing, and the value added by processing should not be taxed in the same manner as is the extraction of minerals.

References

Leaming, George F., 1980, The economic impact of the New Mexico uranium industry: Marana, Arizona, Southwest Economic Information Center, p. 71–75

U.S. Department of Energy, 1981, Statistical data of the uranium industry: Grand Junction, Colorado, Department of Energy Rept. GJO-100

DEVELOPMENT OF COAL RESOURCES AND PALEONTOLOGY—SUMMARY OF A CONFERENCE WORKSHOP

(Held in Farmington, New Mexico, April 8–11, 1981)

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

The sedimentary rocks of New Mexico contain an abundant and diverse record of fossil organisms that spans hundreds of millions of years of the earth's history. New Mexico's sedimentary rocks contain fossil invertebrates, vertebrates, and plants and have long held the attention of scientists and the interested public. This paleontologic record helps to document the history of life and depositional environments of this planet and has been investigated by paleontologists and geologists for about 120 yrs.

The Upper Cretaceous parts of the state's rock and fossil record are intimately associated with coal, a major economic and energy resource, especially in the San Juan and Raton Basins of northwest and northeast New Mexico. Coal and fossil resources occur on Federal, State, Indian, and private lands. Most of the coal resources of the Raton Basin are privately owned, while in the San Juan Basin, the preponderance of coal and fossil resources occur within the boundaries of the Navajo Nation or on lands managed by the U.S. Bureau of Land Management under a multiple-land-use concept. Within both basins, New Mexico State lands contribute a comparatively minor but important part of total land area.

Significantly, most of the coal resources, especially strippable coal resources, of the San Juan Basin occur within the Fruitland Formation of Late Cretaceous age. The Fruitland Formation also has long been known for its contained fossils and for its development of badland topography.

Much discussion has centered on the development of the coal resources of the San Juan Basin in general and the Fruitland Formation in particular. The development of Fruitland coal resources, considered vital to national energy needs by many, and the impacts this development would have upon scientifically and culturally valuable paleontologic materials have been points of contention for several years. The lead agencies of the Federal government, the Bureau of Land Management and the Office of Surface Mining, are committed to policies and programs of multiple use with adequate mitigation and reclamation. The State of New Mexico, through its various agencies, is committed to much the same philosophy. The Navajo Nation is committed to a program of economic development of its energy resources but within the context, once again, of adequate mitigation and reclamation. Most importantly, the avowed goal of national energy policy is to lessen our national dependence upon uncertain foreign energy sources.

Despite the apparent concordance of objectives and views regarding the development of New Mexico's coal resources, major problems have existed regarding matters of definition and procedure. Private industry, responsible for the orderly development of coal resources, has been confronted with a confusion of contradictory requirements, regulations, or no guidelines at all, especially regarding the asessment, mitigation, and salvage of paleontological materials likely to be impacted by expanded coal-resource development. General agreement was that energy-resource development was vital to the interests of the state and the nation and that the scientific values of paleontological resources should be adequately addressed within any development scheme. Unfortunately, little clear direction seemed to exist as to how to best approach the matter of orderly development and paleontological resource assessment, mitigation, and salvage.

Formulating an approach

In an effort to determine what sort of solutions could be formulated to satisfactorily deal with these problems, informal discussions were held by New Mexico Bureau of Mines and Mineral Resources staff with interested and experienced paleontologists across the nation, personnel of state and federal agencies, and representatives from industry. Soon the need for a more formal and organized effort became apparent and, to this end, the New Mexico Bureau of Mines and Mineral Resources organized a conference workshop to consider the problems of paleontology and coal in New Mexico, with the hope and intention of generating guidelines for an adequate

and orderly program of coal-resource development and scientific mitigation of paleontologic materials. The New Mexico Bureau of Mines and Mineral Resources viewed its function as organizer, moderator, and facilitator in an effort to provide a communication channel not previously available.

Farmington was selected as the most appropriate site to hold the sessions because of its proximity to areas of interest for field excursions that were contemplated. Industry was canvassed for financial support via grants to the New Mexico Bureau of Mines and Mineral Resources to meet the travel expenses and maintenance costs of participants who ordinarily would have been unable to attend, given current economic difficulties experienced by most academic and research institutions.

The paleontologists invited included scientists of national and international reputation, it is true, but invited participants were also professionals familiar with paleontologic materials in the San Juan Basin. The scientists included paleontologists from the Carnegie Museum of Natural History, Michigan State University, University of Minnesota, University of Colorado, American Museum of Natural History, University of California at Berkeley, University of Texas at Austin; the U.S. Geological Survey, Branch of Paleontology and Stratigraphy; and the U.S. Bureau of Land Management including representatives from Albuquerque, Farmington, and Washington, D.C. Additionally, representatives of various state agencies directly involved with energy-related matters or the management of state lands were in attendance and included the New Mexico State Land Office, the Mining and Minerals Division, and the Energy Resources and Development Division of EMD. Significantly, an invited participant was Dr. Robert Chenhall, Director of the New Mexico Museum of Natural History. The Navajo Nation Cultural Resource Management Program was represented by Laurel K. Grove. Representatives from coal companies active in New Mexico rounded out the participating group. A list of participants and their affiliations is included below. We sincerely appreciate the time and effort spent by all of the participants.

Conference workshop program

The program and agenda, conducted from April 8-11, 1981, attempted to cover a broad range of topics, problems, suggested solutions, and guidelines and also included field tours. Field excursions included views of operating surface mines and mine leases and the very large Navajo mine, operated by Utah International on lands of the Navajo Nation, as well as the much smaller De-Na-Zin mine, operated by Sunbelt Mining on New Mexico State lands. Visits of these mines provided opportunities to see and discuss the contrasting scales of operation, differences in stratigraphy, reclamation methods, access to spoils piles, and what can or cannot be seen from the control center of an operating dragline.

Additional field tours included areas that have been heavily "picked over" for fossils contrasted with areas that have been relatively untouched by fossil collectors. Fossil localities inspected during the field tour included areas producing invertebrates (both brackish and freshwater), vertebrates, and plants. A proposed Wilderness Study Area was also toured and included an interesting presentation by Angela Berger, a BLM wilderness specialist. The generally informal nature of geologic field trips and the mixing of participants in field vehicles and on outcrops is always conducive to breaking down communication barriers. This proved to be very much the case in this instance as well.

More formal discussion sessions were conducted at the Farmington Holiday Inn. Following an introduction of program staff and participants, Dr. Frank Kottlowski, Director of the New Mexico Bureau of Mines and Mineral Resources, set the tone and pace of the discussions with a presentation of the purpose and scope of the meetings, an overview of San Juan Basin coal resources, history of development, and functions of various state agencies. Following this introductory phase, Dr. Donald L. Wolberg, New Mexico Bureau of Mines and Mineral Resources, served as moderator. Brief presentations were made by industry, the Navajo Nation representative, the USGS, and the BLM. Paleontologic overviews included vertebrates by Dr. William Clemens, invertebrates by Joseph Hartman, and paleobotany by Dr. Aureal Cross.

In the discussions that followed, the premining "phase" of inventory, mitigation, and salvage was apparently where greatest effort should be concentrated. Criteria for determining significance were generally agreed upon as was a possible mechanism for evaluat-

ing research designs and the selection of investigators.

A major objective of the sessions centered upon the effort to formulate guidelines for the determination of what is or is not paleontologically significant. Although vertebrate fossils have gained the most attention in the public's mind, considerable effort was made to include invertebrate and paleobotanical materials in any significance-determination scheme.

Significance is intended to mean an estimation of the scientific or educational importance of paleontological materials. The following criteria were generated by conference participants of fossil material to be in the inventory, or listing, process and the functional analysis process. Thus, the combination of these criteria determines significance. If the fossil material meets these criteria, it is significant, and appropriate mitigation should be undertaken.

Materials Inventoried

1) Vertebrate material
   a) Complete skull and/or jaw
   b) Articulated or complete skeleton
   c) Concentration of vertebrate material
   d) Unique or rare occurrence
   e) Intimate association with the paleoenvironment
2) Invertebrate material
   a) Good to excellent preservation of shell material
   b) Concentrations of diverse material
   c) Intimate association with the paleoenvironment
   d) Stratigraphic sequence
3) Plant material
   a) Well preserved plant material of any kind
   b) Petrified wood
   c) Fossil stumps
   d) Intimate association of fossil plant and animal materials

Functional Analysis

1) Does the material contribute to faunal or floral lists?
2) Does the material significantly contribute to the systematics of the group or groups collected?
3) Does the material contribute to our knowledge of the functional anatomy of the organism?
4) Does the material contribute to our knowledge of the biostratigraphy, paleoecology, or taphonomy of the occurring organisms?
5) Does the material possibly contribute to a potential museum exhibit?

Adequate mitigation might involve sampling and/or salvage of those materials that can be included within the criteria listed above under significant occurrences. Adequate mitigation is meant to indicate a scientifically designed sampling program. Thus, an entire mollusk bed need not be salvaged nor all ancient stumps in a stump field. A sample of the mollusk bed or adequate wood samples will suffice for these occurrences.

Serving as chairperson, Dr. Chenhall moderated a discussion between representatives of the New Mexico State Land Office and various paleontologists regarding the issuance of paleontology permits for New Mexico State Lands and the mechanism for handling such permits. This discussion generated additional efforts to resolve paleontological issues related to New Mexico State lands.

The discussions were recorded through the efforts of Kathy Eden, of the editorial staff of the New Mexico Bureau of Mines and Mineral Resources. In all, some 25 hrs of discussion were recorded. The tapes have been transcribed and resulted in a document more than 300 pages in length. Copies of the transcription have been circulated to conference participants for clarification and revision. From these transcriptions, nonessential material has been deleted and a more compact document reflecting the proceedings has been arrived at. Our intention is to suitably distribute these proceedings.

Conclusion

To our knowledge, this conference workshop provided the first opportunity for representatives of the professional paleontological community, state and federal agencies, industry, and the Navajo Nation to meet at one time and place and discuss issues of mutual concern. This forum provided an opportunity to generate realistic approaches and programs that could ensure adequate mitigation of paleontologic materials within the context of coal-resource development. This forum also provided the opportunity for communication channels to develop between participants scarcely aware of each other's existence beyond just names or titles. The "bone diggers," "clam people," "fossil-plant people," "regulators," and "miners," we hope and are firmly convinced, came away from the sessions with a better perspective and respect for each other's positions. We are sincerely

grateful for the time, energy, and effort that all the participants expended. We feel that the participants have demonstrated that reasonable solutions are possible for very difficult and complex problems.

NOTE—At the annual business meeting of the Society of Vertebrate Paleontology on October 30, 1981, the following criteria were agreed upon as being valuable for determination for mitigation after survey:

1) Complete (>75%) skeleton(s),
2) Skulls and/or articulated material,
3) Whole isolated bones, and
4) Significant concentration of fragmentary but identifiable elements. In general, significant would be 40–50 elements/ton of matrix or 10 fragments/m^2 of surface.

Specific assessments made by a professional vertebrate paleontologist were also recommended. Farish Jenkins, Harvard University, added a preamble to the criteria above and the entire statement will be published in the newsletter of the Society of Vertebrate Paleontology.

List of participants

1) Emery Arnold
Director, Mining and Minerals Division
New Mexico Energy and Minerals Department
Santa Fe, New Mexico

2) Dr. Craig C. Black
Director, Carnegie Museum of Natural History
Pittsburgh, Pennsylvania

3) John Bokich
Sunbelt Mining Company, Inc.
Albuquerque, New Mexico

4) George Byers
Santa Fe Industries, Inc.
Albuquerque, New Mexico

5) Dr. Robert Chenhall
Director, New Mexico Museum of Natural History
Albuquerque, New Mexico

6) Dr. William A. Clemens
Department of Paleontology
University of California
Berkeley, California

7) Dr. Aureal T. Cross
Department of Geology
Michigan State University
East Lansing, Michigan

8) Dr. Theodore Delevoryas
Department of Botany
University of Texas
Austin, Texas

9) Kathy Eden
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico

10) Lucy Fox
New Mexico Department of Energy and Minerals
Energy Resources and Development Division
Santa Fe, New Mexico

11) William R. Garcia
New Mexico State Land Office, Legal Division
Santa Fe, New Mexico

12) Sterling Grogan
Utah International, Inc.
San Francisco, California

13) Laurel K. Grove
Navajo Nation Cultural Resource Management Program
Window Rock, Arizona

14) Joseph H. Hartman
Department of Geology and Geophysics
University of Minnesota
Minneapolis, Minnesota

15) Adrian Hunt
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico

16) Dr. Frank E. Kottlowski
Director, New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico

17) Dr. Leonard Krishtalka
Carnegie Museum of Natural History
Pittsburgh, Pennsylvania

18) Robert McCallum
Arch Mineral Corporation
Santa Fe, New Mexico

19) Dr. Malcolm C. McKenna
American Museum of Natural History
New York, New York

20) Donald Moseley
Utah International, Inc.
Fruitland, New Mexico

21) Michael O'Neill
U.S. Bureau of Land Management
Farmington, New Mexico

22) Wayne R. Pilz
Public Service Company of New Mexico
Albuquerque, New Mexico

23) Dr. John Pojeta, Jr.
U.S. Geological Survey
Smithsonian Institution
Washington, D.C.

24) Dr. J. Keith Rigby, Jr.
U.S. Bureau of Land Management
Albuquerque, New Mexico

25) Dr. Coleman Robison
U.S. Bureau of Land Management
Albuquerque, New Mexico

26) Dr. Peter Robinson
Director, University of Colorado Museum
Boulder, Colorado

27) Daniel A. Sanchez
New Mexico State Land Office
Santa Fe, New Mexico

28) Dr. William Sliter
Director, Branch of Paleontology and Stratigraphy
U.S. Geological Survey
Reston, Virginia

29) Robert Sulenski
U.S. Bureau of Land Management
Washington, D.C.

30) Dr. Ralph E. Taggert
Department of Botany and Plant Pathology
Michigan State University
East Lansing, Michigan

31) John R. Taylor
Chaco Energy Company
Albuquerque, New Mexico

32) John E. Tilton
Chaco Energy Company
Albuquerque, New Mexico

33) Dr. Donald L. Wolberg
New Mexico Bureau of Mines and Mineral Resources
Socorro, New Mexico

PRELIMINARY REPORT ON SEDIMENTOLOGY AND GAS PRODUCTION OF TIGHT ABO FORMATION SANDSTONES, CHAVES COUNTY, NEW MEXICO

by R. F. Broadhead, *Petroleum Geologist,* New Mexico Bureau of Mines and Mineral Resources

Introduction

Red beds correlated with the Abo Formation (Permian) are currently the most sought after targets for natural gas drilling in New Mexico. Most of the drilling activity and all of the production from these red beds is confined to north-central Chaves County (figs. 1, 2). First production was obtained in 1977 by the Yates Petroleum Corp. No. 1 McConkey well located in sec. 10, T. 9 S., R. 26 E., Chaves County (table 1). This well was a workover of the Honolulu Oil Corp. No. 1 McConkey Estate well originally abandoned as a dry hole in 1951. After the Ellenburger Group (Ordovician) and the Devonian and Pennsylvanian Systems were tested by Yates without success,

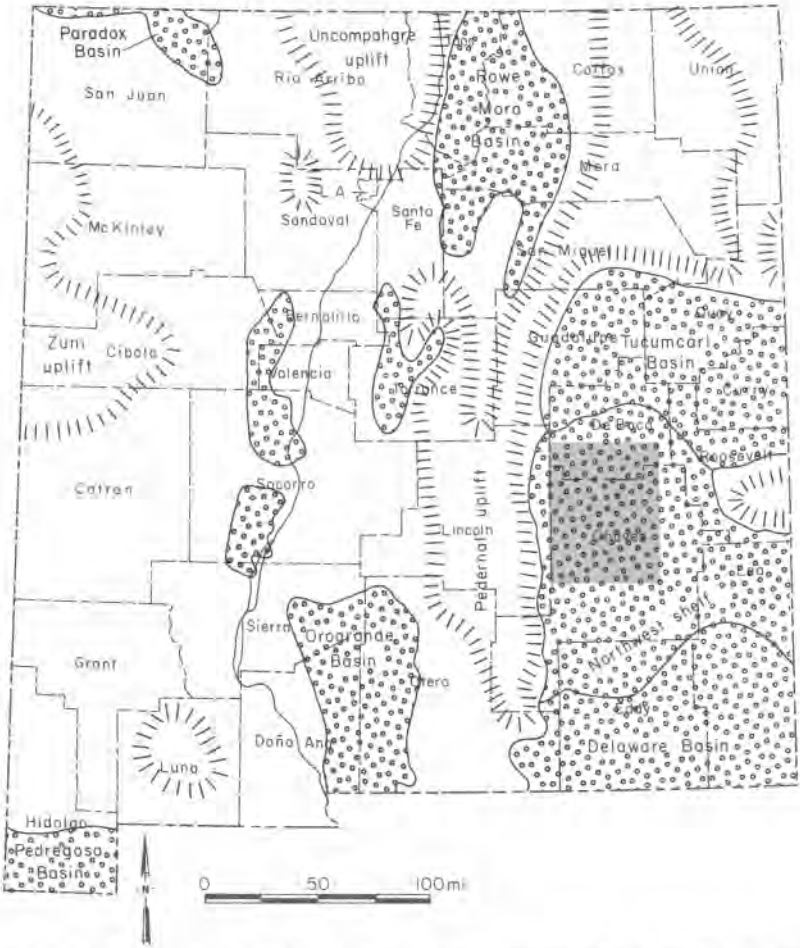


FIGURE 1—AREA OF ABO GAS PRODUCTION (shaded) and major Wolfcampian-age uplifts (hachured) and basins (stippled).

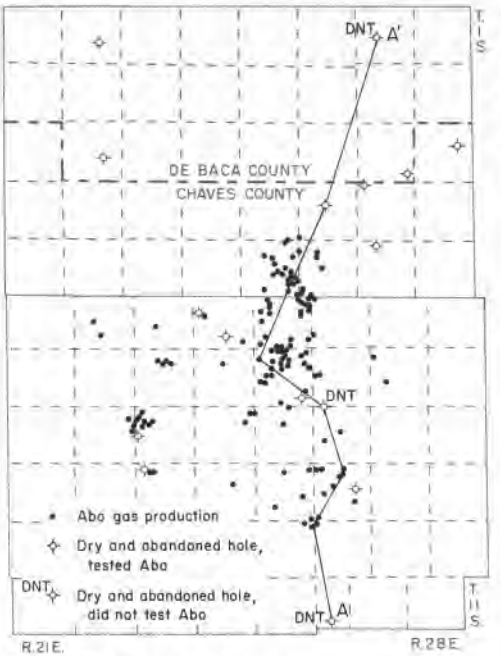


FIGURE 2—AREA OF ABO GAS PRODUCTION. Shown are wells that produce gas from the Abo, wells that unsuccessfully tested the Abo for gas and were subsequently abandoned, and three wells that did not test the Abo but were used in cross section A–A'.

the Permian red beds were tested. After acidizing and artificial fracturing, the red beds produced 2,550 MCFGPD (thousand ft^3 of gas per day) and 1 BCPD (bbl of gas condensate per day) upon initial completion. This discovery prompted operators to drill a few more wells in the area to specifically test the red beds. These additional wells confirmed the discovery. Drilling continued at a slow pace until 1980 when the Abo received federal designation as a "tight gas sand." This designation raises the ceiling price that producers can sell gas for from \$2.81 to \$4.92 per thousand ft^3 of gas. Since that time, over 120 wells have been drilled on 160 acre spacing with the Abo as their primary objective. More than 150 wells have been drilled in search of Abo gas since the initial discovery in 1977. The higher gas prices now make it economic to drill and produce gas from these wells.

This report is preliminary and applies only to the area where the Abo currently produces gas. Stratigraphy and sedimentology are related to the distribution of gas reservoirs. The investigation of the Abo continues; stratigraphic and sedimentologic analyses are being extended into Lincoln, northern De Baca, and Guadalupe Counties with more detailed petrography. A comprehensive report is expected to be published next year.

Regional setting

The area of current Abo gas production lies on the northwestern part of the northwest shelf of the Delaware Basin (fig. 1). Both of these geomorphic features are of Permian age. Although many small-scale structures are present in the producing area, two major structural features have a dominating influence. These structural features are the Pecos slope and the Pedernal uplift (fig. 1).

The Pecos slope (Kelley and Thompson, 1964, p. 110–111; Kelley, 1971, p. 38) is the gently eastward-dipping homocline which occurs over the entire producing area. The Pecos slope originates west of the producing area on the Mescalero arch in Lincoln County. From there, rocks that range in age from Precambrian to Triassic dip eastward into the Delaware Basin at an overall angle of about one-half degree to one degree. Numerous smaller scale structures, including wrench faults and folds, are superimposed on the Pecos slope (Kelley, 1971, p. 37–57).

The other major structural feature that influences rocks in the producing area is the Pedernal uplift. This is a north-northeast-trending structural high which occurs in Lincoln County, just west of the producing area. The uplift extends as far north as southeastern Colorado and as far south as the Texas–New Mexico border. The Pedernal uplift is present as a modern high of Precambrian and Paleozoic rocks but originated in early Pennsylvanian time as a faulted mountain range of Precambrian rocks which rose out of the Paleozoic seas (Thompson, 1942, p. 12–13; Meyer, 1966, p. 69–74, 93; Kottlowski, 1969). Uplift continued into Wolfcampian (early Permian) time. The Pedernal uplift had a marked effect on sedimentation during the late Pennsylvanian and early Permian. The dominantly granitic terrain of the uplift was eroded and provided vast quantities of arkosic sands and muds to the Paleozoic seas present to the east and west of the uplift. The Pedernal uplift also was a major barrier to these seas and exhibited a strong control on depositional facies. Uplift

TABLE 1—IMPORTANT ABO WELLS. Initial discovery well, three wells with high production rates, most northerly, easterly, southerly, and westerly producing wells, and wells with significant show are listed. MCFGPD = thousand ft^3 of gas per day; BCPD = bbls of gas condensate per day; BWPD = bbls of water per day; IPCAOF = initial potential calculated open flow; IPF = initial potential flow; IPP = initial production pumping; and TD = total depth.

Location (section-township-range, county)	Operator, well no., lease	Completion date (mo/yr)	TD (ft)	Rock unit at TD	Remarks
10-9S-26E, Chaves	Yates Petroleum Corp. No. 1 McConkey (owwo)	9/77	6,371	granite (Precambrian)	First well with Abo production. Initial production 2,550 MCFGPD + 1 BCPD through perforations from 4,764 to 4,782 ft
6-10S-26E, Chaves	McClellan Oil Corp. No. 1 Penjack	2/79	5,570	granite (Precambrian)	Most southerly Abo production. IPCAOF = 1,703 MCFGPD. Produces through perforations from 4,314 to 4,334 ft
4-7S-25E, Chaves	Mesa Petroleum Co. No. 1 Savage Federal	8/80	5,102	Pennsylvanian	Large volume of gas from Abo. IPCAOF = 11,986 MCFGPD. Produces through perforations from 3,600 to 3,954 ft
31-4S-25E, Chaves	Yates Petroleum Corp. No. 2 Willow Creek Unit	11/80	5,500	Pennsylvanian	Mostly northerly Abo production. IPF = 576 MCFGPD. Produces through perforations from 3,626 to 3,796 ft
5-6S-25E, Chaves	Mesa Petroleum Co. No. 1 Jess Federal	5/81	4,350	Hueco (Permian)	Largest calculated open flow gas volume from Abo. IPCAOF = 15,500 MCFGPD. Produces through perforations from 3,710 to 3,745 ft
17-6S-25E, Chaves	Mesa Petroleum Co. No. 1 Foreman Federal	5/81	5,080	Pennsylvanian	Large volume of gas from Abo. IPCAOF = 11,500 MCFGPD. Produces through perforations from 3,706 to 4,021 ft
20-6S-22E, Chaves	Fred Pool Operating Co. No. 3 McKnight	6/81	3,101	Hueco ? (Permian)	Westernmost well with Abo production. IPCAOF = 2,485 MCFGPD. Produces through perforations from 2,734 to 2,759 ft
20-7S-27E, Chaves	Gaelic Petroleum Co. No. 1 Rua	8/81	6,810	Mississippian	Easternmost well with Abo production. IPP = 18 MCFGPD + 82 BWPD. Produces through perforations from 5,015 to 5,098 ft
23-3S-21E, De Baca	Mesa Petroleum Corp. No. 1 Devils Federal	8/81	3,800	Abo (Permian)	Noncommercial show of gas in Abo from perforations from 3,134 to 3,155 ft and from 3,292 to 3,312 ft. This is good show of gas 19 mi northwest of nearest Abo production

of the Pedernal mountains culminated in Wolfcampian time. By the late Wolfcampian, the Pedernal uplift was almost completely buried in its own debris. This burial resulted in onlap of Lower Permian strata onto the eastern and western flanks of the uplift.

Stratigraphy

REGIONAL—Red beds of the Abo are present over a large part of New Mexico from McKinley County in the northwest part of the state to Sierra County in the southwest part of the state to the Rio Grande valley in central New Mexico. These rocks have been extensively studied in outcrops west of the Pedernal uplift in the Rio Grande valley. The Abo Formation was first named by Lee (Lee and Girty, 1909, p. 20–21) for the interbedded red to purple sandstones, conglomeratic sandstones, and mudstones that crop out in Abo Canyon at the southern end of the Manzano Mountains, Socorro and Torrance Counties, New Mexico. The type section was moved a few miles to better exposures and described in more detail by Needham and Bates (1943, p. 1,654–1,657). According to Needham and Bates, the Abo is composed of about 40% arkosic sandstone and 60% mudstone at its type section. Characteristic features of Abo outcrops in and adjacent to the Rio Grande valley include crossbedding, symmetric and asymmetric ripple marks, dessication cracks (mud cracks), casts of halite crystals, plant fossils, and bones and tracks of land-dwelling reptiles and amphibians (Needham and Bates, 1943, p. 1,657; Kottlowski, 1963, p. 50; Kelley and Northrop, 1975, p. 50). Many of the sandstones are lense-shaped channel fills. In south-central New Mexico in the San Andres Mountains, conglomerates of the Abo are generally thin, sheetlike deposits and are not channel fills (Kottlowski and others, 1956, p. 52). The northern parts of the Abo seem to have been deposited in a continental environment; in the southern part of the state the Abo intertongues with the marine limestones and shales of the Hueco Formation and was probably, at least in part, deposited in a marine environment (Kottlowski and others, 1956, p. 49–53; Pray, 1961, p. 96–106; Kelley and Northrop, 1975, p. 49).

At the type section, the Abo Formation conformably overlies the limestones and shales of the Bursum Formation (Permian). This conformable contact with the Bursum has been documented in many places (Kottlowski, 1963, p. 45, 46, 47; Kottlowski and Stewart, 1970, p. 23). Locally, the contact of the Abo with the Bursum may be erosional and unconformable (Bachman, 1968, p. 29). The Bursum is a northern equivalent of the marine deposits of the Hueco Formation (Kottlowski and Stewart, 1970, p. 23). On higher parts of the west flank of the southern part of the Pedernal uplift, the Bursum is absent in many places and the Abo rests unconformably on folded and faulted pre-Permian Paleozoic sedimentary rocks (Pray 1949; Pray, 1954, p. 101; Pray, 1961, p. 97). Along higher parts of the Pedernal uplift, the Abo rests unconformably on Precambrian rocks (Kottlowski, 1963, p. 51; Perhac, 1964, p. 87; Kottlowski and Stewart, 1970, p. 23, 27, 31).

The Yeso Formation (Permian) conformably overlies the Abo (Needham and Bates, 1943, p. 1,657; Kottlowski, 1963, p. 56; Kelley and Northrop, 1975, p. 50) in most places but unconformably onlaps Precambrian rocks on the highest points of the Pedernal uplift where the Abo either was never deposited or was deposited and then later eroded (Kelley, 1971, p. 7). The Yeso is composed primarily of orange fine-grained sandstone, anhydrite (gypsum in outcrop), limestone, and dolostone. The percentage of each of these lithologies varies vertically within the Yeso and this variation is the basis on which the Yeso Formation is subdivided into four members (Hunter and Ingersoll, 1981). A basal sandstone-rich and anhydrite-poor interval has been named the Meseta Blanca Member (Wood and Northrop, 1946).

The age of the Abo Formation on the western side of the Pedernal uplift has been the subject of much debate. The Abo primarily seems to be of Wolfcampian age (Kottlowski, 1963, p. 51), but in western and northern New Mexico the Abo may be of late Pennsylvanian age (Wood and Northrop, 1946; Kottlowski, 1963, p. 47); the upper part of the Abo may be of early Leonardian age (Kottlowski, 1963, p. 50–51, 54).

LOCAL—Lower Permian red beds are the gas reservoirs in the producing area situated on the east side of the Pedernal uplift. Known only in the subsurface, these red beds do not crop out because the eastward dip of the Pecos slope has not permitted exhumation of them or the core of the Pedernal uplift from under younger Permian strata. The age of these red beds and the exact correlative relation of them with the Abo Formation on the western side of the uplift is uncertain. The Roswell Geological

Society (1956) correlated these red beds entirely with the Abo Formation, therefore considering them mostly Wolfcampian with the upper part possibly Leonardian. Kottlowski (1963, fig. 14) tentatively correlated a lower interval of red beds with the Abo Formation and an upper interval of red beds with the Meseta Blanca Member of the Yeso Formation; this correlation could give a Wolfcampian age to the lower red-bed interval and a Leonardian age to the upper red-bed interval. This relationship is applicable in Eddy County approximately 40 mi south of the producing area. The relationship of the productive red beds in northern Chaves County to the two intervals of red beds described by Kottlowski is uncertain. In yet a third correlation, Meyer (1966, p. 71) correlated the red beds east of the uplift with the Wichita Formation (Leonardian) of Texas. According to Meyer, the Wichita Formation separates the Hueco Formation (Meyer's "Wolfcampian") from the Yeso Formation. For this report, the red beds on the east side of the Pedernal uplift are tentatively correlated as the Abo Formation and are assigned the same ages as the Abo on the west side of the uplift; that is, the bulk of the Abo is of Wolfcampian age, but near the top it may be of Leonardian age. This tentative correlation is based on lithologic similarity to the Abo Formation, as well as the similar way that the Abo Formation and the red beds on the east side of the uplift onlap the Precambrian core of the uplift and the similar way that both units intertongue with the Hueco limestones to the south. Future lithic correlations with better known rocks in Eddy County south of the producing area will establish a more certain correlation as will correlations made with more closely spaced well control across the buried core of the Pedernal uplift.

Cuttings from two wells were logged in detail with a binocular microscope and are the basis for the following subsurface description of the Abo in the producing area. The two wells are the Yates Petroleum Corp. No. 1 Willow Creek Unit located in sec. 16, T. 4 S., R. 25 E. and the Honolulu Oil Corp. No. 1 McConkey Estate located in sec. 10, T. 9 S., R. 26 E., both in Chaves County. Cuttings were logged from the Abo, the lower part of the Yeso, and the upper part of the Hueco. The term mudstone is used for rocks that are composed of more than 50% detrital clay and silt-size grains. Sandstones are detrital rocks composed of more than 50% sand-size grains. Anhydrite rock contains more than 50% mineral anhydrite, although in some cases this may be gypsum or hemihydrite; distinguishing these minerals from each other in well cuttings is difficult. Rock colors are of the wet rock and were described with the Geological Society of America Rock-color chart (Goddard and others, 1980). Percentages of lithologies in a sample, grain size, roundness, and sorting were made with standard visual comparator charts (Compton, 1962, p. 214; Swanson, 1981). Gamma-ray logs, conventional resistivity logs, and laterologs were used in characterizing and correlating the Abo, Yeso, and Hueco Formations. Neutron-porosity logs were also used but only in conjunction with one of the other three types of logs.

Depths to the top of the Abo range from approximately 2,700 ft in the western part of the producing area to approximately 4,700 ft in the eastern part. Thickness of the Abo ranges from approximately 400 ft in the western and southern parts of the producing area to approximately 800 ft in the northern part. The westward thinning of the Abo is the result of onlap onto the Pedernal uplift; southerly thinning results from intertonguing with the Hueco Formation.

In Chaves and De Baca Counties, the Abo Formation (fig. 3) is composed principally of interbedded red mudstone, a subordinate amount of red arkosic sandstone, and minor amounts of gray to black mudstone and white to light-gray anhydrite rock. Sandstone beds are as thick as 20 ft. The top of the Abo is selected at the base of the thick anhydrite and sandstone section which is correlated with the Yeso in the subsurface; on wireline logs (fig. 4) the Abo top is marked by a dramatic increase of radioactivity on the gamma-ray log and a slight decrease in resistivity measurement. The base of the Abo is picked at the highest limestone bed in the red-bed sequence; this limestone marks the top of the Hueco Formation (Wolfcamp of drillers' terminology) and is represented on wireline logs by a sharp decrease in radioactivity and an accompanying sharp increase in resistivity (fig. 4).

The Abo sandstones are arkosic to subarkosic arenites (Dott, 1964). They are rich in pink and white feldspars and quartz and are moderate reddish orange (10R6/6) to dark reddish brown (10R3/4) in color. Quartz and feldspar are angular to very angular, very fine to fine and rarely medium sand-size grains. Most sandstones are well to moderately

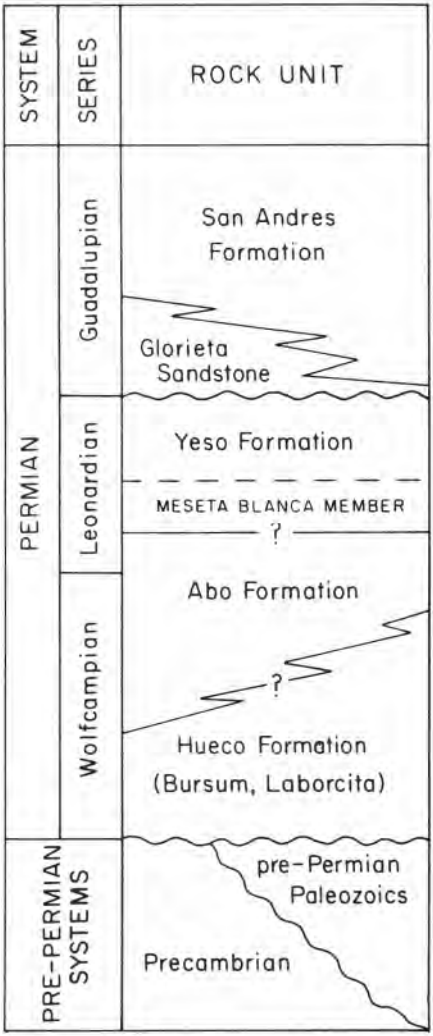


FIGURE 3—GENERALIZED STRATIGRAPHIC COLUMN OF PERMIAN AND OLDER ROCKS IN CHAVES COUNTY.

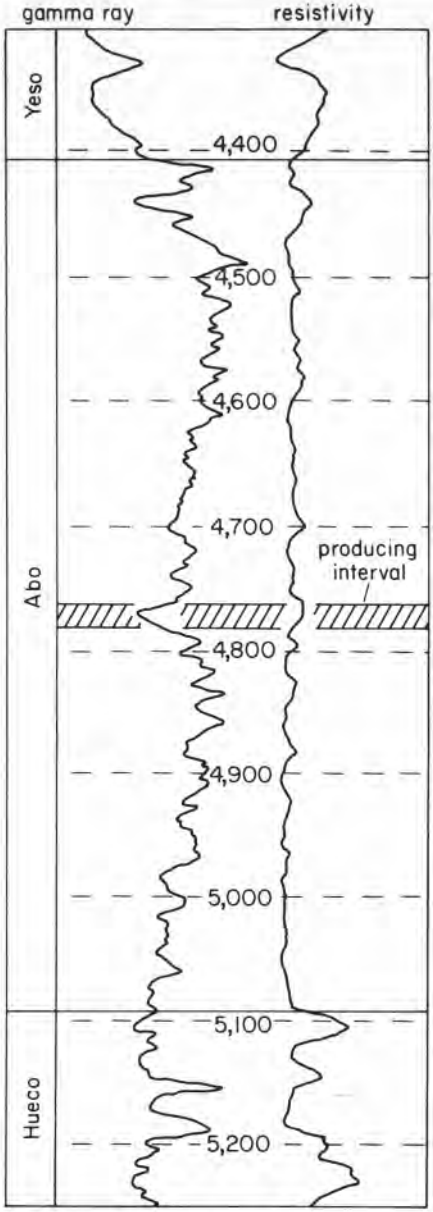


FIGURE 4—WIRELINE LOGS OF HONOLULU OIL CORP. NO. 1 MCCONKEY ESTATE, SEC. 10, T. 9 S., R. 26 E., CHAVES COUNTY. Well was reworked in 1977 by Yates Petroleum Corp. to become first Abo producer in Chaves County.

sorted. Most contain small amounts of (<10%) red clay matrix although a few sandstones contain as much as 20% red clay matrix; these latter sandstones are arkosic wackes. Calcite and anhydrite are common as cements and reduce permeability and porosity. Only a trace of visible porosity is present. Permeability is also low; the New Mexico Oil Conservation Division has estimated from measurements on cores that Abo sandstones have an average in situ permeability of only 0.0067 millidarcies. The sandstones are friable to well indurated; this property varies with the amount of cement present. Calcite and anhydrite occur as microcrystalline intergranular cement and anhydrite also occurs as macroscopic acicular crystals of poikilotopic cement. Some sandstones are cemented by anhydrite, some by calcite, and some by both. Stratigraphic control of the relative abundances of these cements in the sandstones does not seem to be present.

The most abundant types of mudstones in the Abo Formation are moderate reddish orange (10R6/6) to moderate reddish brown (10R4/6) to dark reddish brown (10R3/4) in color. They are composed mostly of clay with very little silt-size debris. Near the top of the Abo, the mudstones are generally anhydritic and become less anhydritic and more calcareous toward the base. In addition to this regular vertical stratigraphic variability, an irregular lateral stratigraphic variability of the distribution of calcite and anhydrite in the mudstones also exists. The anhydrite occurs as birdseye lenses up to 3 mm long, which are elongate parallel to lamination. Anhydrite also occurs as fillings of fractures which are perpendicular to lamination, as irregularly shaped patches and streaks, and as acicular crystals with poikilotopic texture that cut across lamination. The red mudstones of the lower part of the Abo are calcareous and the amount of calcite in these mudstones increases with depth. Unlike the anhydrite, the calcite is disseminated throughout the rock and with rare exception does not occur as discrete patches or bodies.

Anhydrite rock in the Abo is generally white (N9) to medium light gray (N6). This rock is composed dominantly of microcrystalline to macrocrystalline anhydrite and usually also contains subordinate to trace amounts of clay minerals, microcrystalline calcite, and detrital fine sand-size quartz. Rarely, as much as 30% detrital quartz is present; this appears to have been replaced by the anhydrite.

Trace amounts of medium-gray (N5) to black (N1) mudstone also occur in the Abo. This lithology is characteristically fissile and slightly pyritic. Lighter colored varieties are anhydritic.

The Hueco Formation is composed of interbedded limestones and shales and underlies the Abo Formation in Chaves and De Baca Counties. In its upper part, the Hueco is composed of approximately equal amounts of interbedded limestone and red mudstone. The Hueco intertongues with the Abo, thickening to the south at the expense of a concurrently thinning Abo (fig. 5). The limestones are laterally extensive sheets as thick as 40 ft which can be correlated for several miles in the subsurface. Dark-gray (N3) to grayish-black (N2) in color, the limestones are fusulinid mudstones, wackestones, and packstones (see Dunham, 1962, for classification). Mudstones and wackestones are abundant; packstones are rare. Fusulinids are present in amounts ranging from a trace to 50% of the rock. They are embedded in a dark, slightly pyritic, microcrystalline calcite matrix. Some wackestones and packstones are pelletal. Fossils other than fusulinids are rare; present are brachiopods and articulated and disarticulated crinoid columnals.

The interbedded mudstones are grayish red (5R5/2) and calcareous. They appear virtually identical to mudstones in the lower part of the Abo except that rarely they contain poorly preserved fragments of brachiopods. These mudstones are actually tongues of the Abo that extend into the Hueco Formation.

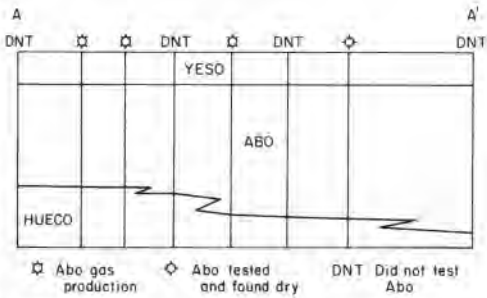


FIGURE 5—SOUTH-NORTH STRATIGRAPHIC CROSS SECTION. Datum is top of the Abo; see fig. 2 for location.

Sedimentology and gas production

Production from the Abo is currently confined to north-central Chaves County (fig. 2). The sandstones of the Abo Formation are the gas reservoirs (fig. 4). Stratigraphic control within the Abo of reservoir sandstones seems present within the productive area; almost all of the production comes from the upper two-thirds of the Abo. Because of low permeability, the sandstones must be artificially stimulated before economic levels of production can be obtained. The stimulation is a two-step process; the sandstones are first acidized and then are hydraulically fractured. Productivity jumps from a few tens of thousands of ft^3 of gas per day before stimulation to millions of ft^3 of gas per day after stimulation. An average Abo well will obtain initial production tests of 1,000 MCFGPD (thousand ft^3 of gas per day) to 3,000 MCFGPD after stimulation. Although a very few wells have tested to 100 MCFGPD or less on completion, several have tested more than the average amount. Some have even tested over 10,000 MCFGPD; these are listed in table 1 along with other important Abo wells. Wells that test over 2,000 MCFGPD are present in all parts of the producing area.

Sedimentology is important to understanding reservoir distribution because the Abo traps are stratigraphic. The Abo and Hueco Formations of Chaves and De Baca Counties form a regressive sequence; the transition from the Abo to the overlying Yeso Formation is the result of a rapid marine transgression. The limestones of the Hueco are characteristic of a flat-lying marine shelf that had open marine or perhaps slightly restricted circulation (Wilson, 1975, p. 209). The upper part of the Abo was deposited in an arid continental environment; this is shown by the resemblance of the mudstones to muds found forming in modern subaerial to intertidal parts of deltas (Thompson, 1968; Reineck and Singh, 1975, p. 57–58). Additional evidence that the upper part of the Abo is of continental origin is the overall lithologic similarity to the Abo west of the Pedernal uplift where outcrops exhibit depositional features that are clearly of continental origin. The downward transition of anhydritic mudstones to calcareous mudstones suggests that the lower part of the Abo was deposited in a marine environment. The intertonguing of the calcareous mudstones with the marine Hueco limestones supports this idea. The Abo is envisioned as having been deposited as a delta that prograded out over the shelf on which occurred Hueco carbonate sedimentation. The upper anhydritic part of the Abo was deposited in the subaerial portion of the delta, and the lower calcareous part was deposited as submarine muds and sands on the delta front and prodelta. An arid or semiarid environment is suggested by the abundance of anhydrite in the mudstones and the paucity of plant remains. The source of the Abo sands and muds was the exposed Precambrian granitic terrain of the Pedernal uplift located to the west and north of Chaves County. The overlying sandstones and anhydrites of the Yeso Formation have been interpreted as shallow marine deposits (Hunter and Ingersoll, 1981, p. 51–52). If so, the sudden transition from Abo red beds to Yeso marine deposits probably records a sudden Leonardian-age transgression.

The depositional interpretation is important to the understanding of reservoir distribution. The production of most of the gas from the upper two-thirds of the Abo indicates that most reservoir-quality sandstones were deposited in nonmarine environments. The presence of good producing wells in all parts of the Abo field suggests that many depositional subenvironments of the delta system contain adequate reservoirs. Because of the progradational nature of the Abo, reservoir sandstones should then be present over a larger geographic area than that which currently produces. The occurrence of a noncommercial show of gas in the Mesa Petroleum No. 1 Devils Federal well located in southwestern De Baca County (table 1) supports this hypothesis.

ACKNOWLEDGMENTS—Frank E. Kottlowski, Director of the New Mexico Bureau of Mines and Mineral Resources suggested this study. Larry Brooks of the New Mexico Oil Conservation Division provided information on drilling statistics and permeability measurements.

References

Bachman, G. O., 1968, Geology of the Mockingbird Gap quadrangle, Lincoln and Socorro Counties, New Mexico: U.S. Geological Survey, Prof. Paper 594-J, 43 p.

Compton, R. R., 1962, Manual of field geology: New York, Wiley, 378 p.

Dott, R. L., 1964, Wacke, graywacke, and matrix—what approach to immature sandstone classification?: Journal of Sedimentary Petrology, v. 34, p. 625–632

Dunham, R. G., 1962, Classification of carbonate rocks according to depositional texture, *in* Classification of carbonate rocks, W. E. Ham, ed.: American Association of Petroleum Geologists, Mem. 1, p. 108–121

Goddard, E. N., Trask, P. D., DeFord, R. K., Rove, O. N., Singewald, J. T., Jr., and Overbeck, R. M., 1980, Rock-color chart: Boulder, Geological Society of America, 11 p.

Hunter, J. C., and Ingersoll, R. V., 1981, Canas Gypsum Member of Yeso Formation (Permian) in New Mexico: New Mexico Geology, v. 3, no. 4, p. 49–53

Kelley, V. C., 1971, Geology of the Pecos country, southeastern New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 24, 75 p.

Kelley, V. C., and Northrop, S. A., 1975, Geology of Sandia Mountains and vicinity, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 29, 136 p.

Kelley, V. C., and Thompson, T. B., 1964, Tectonics and general geology of the Ruidoso–Carrizozo region, central New Mexico: New Mexico Geological Society, Guidebook 15th field conference, p. 110–121

Kottlowski, F. E., 1960, Summary of Pennsylvanian sections in southwestern New Mexico and southeastern Arizona: New Mexico Bureau of Mines and Mineral Resources, Bull. 66, 187 p.

———, 1963, Paleozoic and Mesozoic strata of southwestern and south-central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 79, 100 p.

———, 1969, Summary of late Paleozoic in El Paso border region, *in* Border stratigraphy symposium, F. E. Kottlowski and D. V. LeMone, eds.: New Mexico Bureau of Mines and Mineral Resources, Circ. 104, p. 38–51

Kottlowski, F. E., Flower, R. H., Thompson, M. L., and Foster, R. W., 1956, Stratigraphic studies of the San Andres Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 1, 132 p.

Kottlowski, F. E., and Stewart, W. J., 1970, The Wolfcampian Joyita uplift in central New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 23, pt. I, p. 1–31

Lee, W. T., and Girty, G. H., 1909, The Manzano Group of the Rio Grande valley, New Mexico: U.S. Geological Survey, Bull. 389, 141 p.

Meyer, R. F., 1966, Geology of Pennsylvanian and Wolfcampian rocks in southeast New Mexico: New Mexico Bureau of Mines and Mineral Resources, Mem. 17, 123 p.

Needham, C. E., and Bates, R. L., 1943, Permian type sections in central New Mexico: Geological Society of America, Bull., v. 54, p. 1,653–1,667

Perhac, R. M., 1964, Resume of the geology of the Gallinas Mountains: New Mexico Geological Society, Guidebook 15th field conference, p. 87–91

Pray, L. C., 1949, Pre-Abo deformation in the Sacramento Mountains, New Mexico (abs.): Geological Society of America, Bull., v. 60, p. 1,914–1,915

———, 1954, Outline of the stratigraphy and structure of the Sacramento Mountains escarpment: New Mexico Geological Society, Guidebook 5th field conference, p. 92–107

———, 1961, Geology of the Sacramento Mountains escarpment, Otero County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 35, 144 p.

Reineck, H. E., and Singh, I. B., 1975, Depositional sedimentary environments: Berlin, Springer-Verlag, 439 p.

Roswell Geological Society, 1956, West-east correlation section, San Andres Mountains to New Mexico–Texas line, southeastern New Mexico

Swanson, R. G., 1981, Sample examination manual: Tulsa, American Association of Petroleum Geologists, 128 p.

Thompson, M. L., 1942, Pennsylvanian System in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bull. 17, 90 p.

Thompson, R. W., 1968, Tidal flat sedimentation on the Colorado River delta, northwestern Gulf of California: Geological Society of America, Mem. 107, 133 p.

Wheatley, R., 1981, 'Tight' designation sparks Abo play: Oil and Gas Journal, v. 79, no. 25, p. 26–27

Wilson, J. L., 1975, Carbonate facies in geologic history: Berlin, Heidelberg, Springer-Verlag, 471 p.

Wood, G. H., and Northrop, S. A., 1946, Geology of the Nacimiento Mountains, San Pedro Mountain, and adjacent plateaus in parts of Sandoval and Rio Arriba Counties, New Mexico: U.S. Geological Survey, Oil and Gas Investigations Map OM–57

MINERAL AND MINERAL-FUEL PRODUCTION ACTIVITIES IN NEW MEXICO DURING 1980

by Robert W. Eveleth, *Mining Engineer,*
Robert A. Bieberman, *Senior Petroleum Geologist*
Frank Campbell, *Coal Geologist,* and Gretchen Roybal, *Coal Geologist,*
New Mexico Bureau of Mines and Mineral Resources

The overall value of mineral and mineral-fuel production totaled $5.95 billion for 1980, representing a 32% increase over that for 1979 (table 1). Typically, as for the past several years, fossil fuels excepting coal accounted for the greater proportion (76.5%) of the total. While production of natural gas and crude petroleum continued its steady decline, dollar values again jumped substantially—25% for natural gas and 60% for crude petroleum. Increases in both coal and uranium production were also recorded (Department of Energy, 1981).

Production decreases were recorded in the nonfuel sector for such commodities as copper, perlite, potash, pumice, and gypsum, among others. Nevertheless, New Mexico again ranked first nationwide in the production of uranium, perlite, and potash and third in copper. The state advanced to third place in pumice production while molybdenum remained fourth (table 2).

TABLE 1—MINERAL AND MINERAL-FUEL PRODUCTION IN NEW MEXICO. Short tons unless noted; **NA**, not available; **XX**, not applicable; **W**, withheld to avoid disclosing individual company data; *, revised (adjusted from preliminary 1979 figures. Data sources: U.S. Bureau of Mines; U.S. Department of Energy; Oil Conservation Division, New Mexico Department of Energy and Minerals; Oil and Gas Accounting Division, New Mexico Department of Taxation and Revenue (all unpublished data, personal communications, 1981-82); and Keystone Coal Industry Manual (1981).

	1979		1980	
	Quantity	Value (thousand dollars)	Quantity	Value (thousand dollars)
Clays, excluding fireclay (thousand tons)	74	124	60	114
Coal (thousand tons)	14,635	176,466	19,481	260,037
Copper (tons)	181,088	336,934	164,679	337,328
Gem stones	NA	180	NA	150
Gold (troy oz)	22,988	7,065	15,787	9,670
Gypsum (thousand tons)	251	3,244	182	1,688
Manganiferous ore, 5-35% Mn (tons)	33,152	W	31,427	W
Mica (tons)	17,000	W	W	W
Natural gas (million ft^3)	1,162,714	1,616,172	1,132,316	2,026,846
Natural gas liquids (thousand bbls)	42,857*	646,280*	43,003	733,948
Peat (tons)	2,000	40	2,000	40
Perlite (thousand tons)	588	14,874	539	14,404
Petroleum, crude (thousand bbls)	79,649	1,119,861	75,324	1,794,210
Potash (thousand tons)	2,210	228,716	2,060	289,011
Pumice, including cinder (thousand tons)	604	3,550	448	3,028
Salt (tons)	W	W	W	W
Sand and gravel (thousand tons)	7,141	18,245	7,050	17,676
Stone, crushed (thousand tons)	2,589	6,743	2,217	7,259
Stone, dimension (thousand tons)	20	117	18	91
Uranium, recoverable U_3O_8 (thousand lbs)	14,118	310,603	15,500	371,018
Combined barite, CO_2, cement, fireclay, iron ore, lead, lime, molybdenum, silver, sulfur, vanadium, zinc, and W	XX	77,521	XX	87,845
Totals	XX	4,566,735*	XX	5,954,363

TABLE 2—NEW MEXICO PRODUCTION AND NATIONAL RANKING BY COMMODITY. *, percent of total quantity produced, all others percent of total value produced; W, withheld to avoid disclosing individual company data. Sources: U.S. Bureau of Mines (personal communication, 1981) and U.S. Department of Energy (personal communication, 1981).

Mineral commodity	1979 rank	1979 Number of states producing	1979 Percent of total	1980 rank	1980 Number of states producing	1980 Percent of total
Uranium	1	7	40	1	9	35
Perlite	1	7	91	1	7	87
Potash	1	3	82	1	3	82
Natural carbon dioxide	2	4	W	2	4	W
Manganese ores	2	3	14*	2	3	20*
Copper	3	13	11	3	10	13
Molybdenum	4	6	W	4	5	W
Natural gas	4	31	5.7*	4	31	5.8*
Natural gas liquids	4	21	7.7*	4	21	7.9*
Pumice	5	11	23	3	5	20
Vanadium	5	5	W	5	5	W
Silver	6	17	W	7	13	W
Gold	7	12	2	7	11	2
Crude petroleum	7	32	2.6*	7	31	2.3*

TABLE 3—OIL AND GAS PRODUCTION, 1980; source: Oil Conservation Division, New Mexico Department of Energy and Minerals (personal communication, 1981).

County and area	Crude oil (bbls) Production	Crude oil (bbls) Gain (+) or decline (-) from 1979	Natural gas (thousands ft³) Production	Natural gas (thousands ft³) Gain (+) or decline (-) from 1979
Chaves	2,158,238	+ 253,695	11,580,939	+ 1,371,011
Eddy	15,996,147	-4,036,576	214,522,121	-17,486,327
Lea	49,535,060	-270,449	335,829,143	-16,765,998
Roosevelt	1,522,787	-188,883	4,020,463	+ 339,818
Southeast totals	69,212,232	-4,242,213	565,952,666	-32,541,496
McKinley	912,053	-162,275	81,835	-53,276
Rio Arriba	2,090,343	+ 29,544	183,193,022	+ 3,349,909
Sandoval	368,999	+ 10,724	2,228,888	-242,154
San Juan	2,740,038	-39,172	380,859,833	-900,020
Northwest totals	6,111,433	-82,835	566,363,578	+ 2,154,459
Mora	0	0	0	-10,404
Northeast totals	0	0	0	-10,404
State totals	75,323,665	-4,325,048	1,132,316,244	-30,397,441

Several significant events occurred during the year that had and will continue to have far-reaching effects on the future of New Mexico's minerals industry. Highlights include Kennecott's massive modernization and expansion project at Chino and the firm's subsequent joint venture with Mitsubishi Corporation of Japan; the startup of mining operations at the Ortiz mine near Cerrillos by Gold Fields, Ltd.; and ground-breaking at Gold Dust camp near Hillsboro for Quintana's new open-pit copper mine and concentrator.

Adversely affecting the copper industry were a lengthy nationwide strike and the tense political and environmental reverberations emanating from the closure of Anaconda's Butte smelter.

Mineral fuels

OIL AND GAS—New Mexico oil production for 1980 decreased by 5.4% (4.3 million bbls) from 1979 (table 3). The southeast produced 5.8% or 4.2 million bbls less oil than in 1979, while the northwest produced 1.3% or 0.08 million bbls less oil than in 1979. Natural-gas production in New Mexico decreased by 2.6% or 30.4 billion ft^3. A decline of 5.43% or 32.5 billion ft^3 in natural-gas production was posted in the southeast, which was offset by a 2.1-billion-ft^3 or 0.38% increase in natural-gas production in the northwest. The state ranked seventh in the nation in crude-oil production and fourth in natural-gas production.

In 1980 exploratory drilling and the rates of success in New Mexico increased over 1979 levels (table 4). The 292 wildcats drilled in 1980 with a success rate of 48.6% compare with 201 wildcats and a success rate of 41.3% in 1979. Higher activity was reported in both the southeast and northwest areas of the state.

New-field wildcats, the best indicators of the level of exploration activity, also posted increases in the number of wells drilled and the percentage of discoveries. In 1980, 255 new-field wildcats were drilled with a success rate of 39.1% compared to 155 drilled in 1979 with 32.3% discoveries.

TABLE 4—DRILLING STATISTICS, 1979 AND 1980; source: American Petroleum Institute (personal communications, 1980-81).

	1979	1980
Wildcats drilled	201	292
southeast	141	207
northwest	60	85
Oil	22	44
southeast	17	35
northwest	5	9
Gas	61	98
southeast	49	73
northwest	12	25
Success rate (percent)	41.3	48.6
southeast	46.8	52.2
northwest	28.3	40.0
New-field wildcats drilled	155	225
southeast	113	172
northwest	42	53
Oil	16	24
southeast	12	22
northwest	4	2
Gas	34	64
southeast	33	58
northwest	1	6
Success rate (percent)	32.3	39.1
southeast	39.8	46.5
northwest	11.9	15.1
Development wells drilled	1,358	1,643
southeast	650	821
northwest	708	822
Oil	474	627
southeast	391	501
northwest	83	126
Gas	759	898
southeast	176	228
northwest	583	670
Success rate (percent)	90.8	92.8
southeast	87.2	88.8
northwest	94.1	96.8

Primary exploration targets in northwest New Mexico were sandstone reservoirs of Cretaceous age. In southeast New Mexico, exploration for gas continued at a high rate in the Morrow in southern Eddy and Lea Counties and for Abo dry gas in the shallow back reef area of northern Chaves County. Eighteen discoveries from sandstone stratigraphic traps in the Abo were reported.

The total number of development wells drilled in 1980 was 1,643 with 627 producing oil and 898 producing natural gas. The overall success rate was 92.8%. The 821 development wells drilled in the southeast area represent a 26.3% increase over 1979, and the 822 drilled in the northwest area represent an increase of

16.1%. Development-well success rates were 88.8% in the southeast and 96.8% in the northwest. Development continued at a rapid rate in the Morrow trend of Eddy and Lea Counties and in the Abo trend of northern Chaves County. Infill, development, and step-out drilling in the natural-gas fields of northwest New Mexico helped make this area the third most active province in the Rocky Mountains.

The Bravo dome carbon-dioxide unit was approved in November 1980 and development began. This unit encompasses some 1,835 mi^2 in Union, Harding, and Quay Counties. The carbon dioxide will be transported by pipeline to oil fields in west Texas and southeast New Mexico and injected into oil reservoirs during enhanced (tertiary oil) recovery operations.

The addition to proved oil reserves in New Mexico from new field discoveries was approximately 2 million bbls, 1 million bbls above the 1979 contribution (table 5). Extensions of and new reservoirs in old fields added an additional 16 million bbls to proved oil reserves, an increase of 14.3% over 1979.

Contributions to proved natural-gas reserves from new-field discoveries decreased 29% from the 1979 level to 68 billion ft^3. Extensions of and new reservoirs in old fields added 712 billion ft^3, a slight increase of 0.84% over 1979.

The net effect of crude-oil production's exceeding discoveries in 1980 was an approximate 2.8% drop in New Mexico's proved reserves to about 547 million bbls. Natural-gas reserves decreased 3.2% to 13.29 trillion ft^3.

TABLE 5—CONTRIBUTIONS TO PROVED RESERVES FROM DISCOVERIES, 1979 AND 1980 (U.S. Department of Energy, personal communication, 1981).

	1979	1980
Added new-field proved oil reserves (million 42-gal bbls)	1	2
Added old-field extensions and new reservoirs proved oil reserves (million 42-gal bbls)	14	16
Added new-field proved natural-gas reserves (billion ft^3)	96	68
Added old-field extensions and new reservoirs proved natural-gas reserves (billion ft^3)	706	712
Total proved oil reserves (million 42-gal bbls)	563	547
Total proved natural-gas reserves (billion ft^3)	13,724	13,287

COAL—New Mexico's coal production has increased rapidly over the last two decades, reaching a total of 19,480,820 tons in 1980, a 33% increase over that for 1979. Value increased 47% to $260 million.

Since the first records by the State Mine Inspector in 1882, coal production in New Mexico has fluctuated between a low of 116,656 tons in 1958 to an all-time high in 1980. Historically, the Spanish used small amounts of coal several centuries ago, and anthracite was mined in the Cerrillos field as early as 1835. Mining on a significant scale began in 1861, when U.S. Army troops at Fort Craig opened a mine in the Carthage field. Production first exceeded a million tons in 1889, for use by the railroads and lead and copper smelters. In 1918, early peak production exceeded 4 million tons. Coal production was stimulated by World War I; coal was used primarily in the smelting, manufacturing, and railroading industries. Dieselization and the use of natural gas caused a reduction in the state's coal production to under the million-ton mark in 1950; this reduction continued down to the aforementioned low of 1958.

Development of the Kaiser Steel Corporation coking-coal mines in the Raton field signaled the upswing in production in 1960. The big boom for coal production came with the introduction of large-scale strip mining in McKinley and San Juan Counties. The combination of inexpensive strippable coal and the increasing demand for electric power in Arizona, New Mexico, and California led to the opening of the McKinley strip mine near Gallup and the Navajo mine near Fruitland. The San Juan mine north of the Navajo mine began stripping operations in late 1972.

The Con Paso mine of Consolidated Coal Company began strip mining coal in 1980 in the southwest corner of the Navajo field. Permits to strip mine coal have been obtained from the State of New Mexico for the Gallo Wash mine in the eastern part of the Bisti area

by Alamito Coal Company, a subsidiary of Tucson Electric Power Company; for the Gateway project in the western part of the Bisti area by Sunbelt Mining; for the La Plata mine in northernmost Fruitland area by Utah International, to be mined by San Juan Coal Company; for the South Hospah mine in the eastern Standing Rock area in central McKinley County by Chaco Energy Company; and for the De-Na-Zin mine in the southwest Bisti area by Sunbelt Mining Company. Kaiser Steel Corporation is operating a small exploratory mine at Potato Canyon, 10 mi west of Raton.

Permits in progress are for the San Juan mine underground extension by Public Service Company of New Mexico; La Ventana mine (underground) in the La Ventana field by Ideal Basic Industries; Star Lake mine in the Star Lake area by Chaco Energy Company; the Black Diamond mines in the northwest Fruitland area by Black Diamond Coal Company; and the Lee Ranch mine in the Star Lake area by Santa Fe Mining.

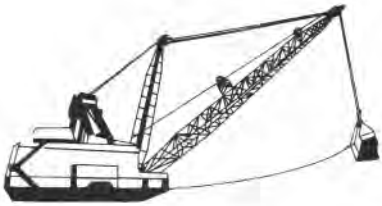
Applications for permits are expected from Arch Minerals for units 1 and 2 in the San Juan Basin, San Juan County. The Cerrillos Coal Company near Madrid and the Old Abe mine owned by the Great American Coal Company at White Oaks are new developments outside the San Juan Basin. Kaiser Steel is looking at Cottonwoods Canyon, east of York Canyon, for further mining in the Raton Basin.

In 1980, slightly over 900,000 tons of coal were produced by Kaiser Steel's York Canyon and Potato Canyon underground mines in the Raton field. Of the state's total production, over 18 million tons were produced by strip mining. The contributing mines and their production figures are listed in table 6. Additionally, a number of unregistered strip mines and small drift mines were operated by the Navajo Indians on their lands in the San Juan Basin.

Most of the coking coal from the York Canyon mine was shipped by unit train to Kaiser Steel Corporation's steel mills in Fontana, California, although at times some tonnage was shipped to the Colorado Fuel and Iron Steel Company's steel plant in Pueblo, Colorado, and to the steel mills of Cia. Fundidora de Fierro y Acero e Monterrey, in Monterrey, Mexico. Steam coal from the McKinley mine is shipped to the Cholla powerplant of Arizona Public Service Company near Joseph City, Arizona. Production from the Navajo mine is used at the Four Corners powerplant near Fruitland, New Mexico. Coal stripped from the San Juan mine in the southern part of the Fruitland field is supplied to the San Juan powerplant by San Juan Coal Company generating electricity for Public Service Company of New Mexico and Tucson Electric Power Company. Coal from the Mentmore mine is shipped by unit train to the Benson powerplant of Arizona Electric Power Cooperative at Cochise, Arizona.

TABLE 6—NEW MEXICO INDIVIDUAL COAL-MINE PRODUCTION; **S**, surface; **U**, underground; source: Keystone coal industry manual, 1981.

Mine	Owner	Production (short tons) 1979	1980
Potato Canyon (u)	Kaiser Steel Corp.	—	5,202
York Canyon (u)	Kaiser Steel Corp.	577,517	900,000
West York Canyon (s)	Kaiser Steel Corp.	766,459	600,000
Amcoal (s)	Amcoal, Inc.	94,296	93,907
McKinley (s)	Pittsburg & Midway Coal Mining Co.	3,365,916	4,568,154
Mentmore (s)	Carbon Coal Co.	628,250	973,980
Arroyo No. 1 (s)	A.J. Firchau	4,466	15,748
Navajo (s)	Utah International, Inc.	5,203,000	7,733,000
San Juan (s)	San Juan Coal Co.	4,000,534	4,538,000
Burnham (s)	Consolidation Coal Co.	—	39,652
De-na-zin (s)	Sunbelt Mining Co., Inc.	—	13,177
	Total	14,640,438	19,480,820



Metallic minerals

COPPER—Copper production was down 9% from last year's 181,000 tons. Value increased slightly to $337 million, reflecting higher average price received during 1980 when the Comex average for the year was $0.97 per lb compared to $0.88 per lb in 1979. Copper prices attained record highs during the first quarter, reaching an all-time record of $1.45 per lb on February 13. Prices quickly dropped back to the $1.00-per-lb level in late March, however, and generally decreased thereafter to below $0.90 at years' end. The poor performance is the result of a general recession and subsequent weak demand for the metal. By mid-1980, some 138,000 metric tons (mt) were held in surplus stocks. Domestic production and operating costs were adversely affected by an industry-wide strike which began July 1 and lasted through mid-September for Kennecott and early October for Phelps Dodge.

In the face of such adversities, lowering unit costs is the only way to stay in business. Toward this end, Kennecott announced a major modernization and expansion project at Chino. The project will include the construction of a new concentrator along with larger crushing and grinding facilities. The company also plans to eliminate rail haulage of ore from Santa Rita to Hurley and to increase the rate of production from the mine by as much as 70%. A reduction in production costs by as much as $0.25 per lb may make Chino one of the lowest cost producers in the United States.

The new facilities and improvements are expected to be essentially completed during 1983 at a cost of approximately $365 million. To help finance this major undertaking, Kennecott announced in June it was considering a joint venture with Mitsubishi Corporation of Japan. An agreement was reached in December whereby the latter would provide funds for expansion and operating costs and would receive in exchange a proportional share of Chino's production.

Phelps Dodge Corporation experienced both record-high earnings during the first quarter because of high copper prices and losses during the third quarter, the latter primarily a result of the copper strike. Further complications arose at the Tyrone mine when, on October 13, the no. 3 tailings dam failed and spilled several hundred thousand tons of tailings into Mangas Creek. Quick action on the part of Phelps Dodge's crews, who rapidly threw up check dams downstream, prevented a real disaster—that of the tailings spilling into the Gila River 12 mi downstream. The Tyrone mill was closed for approximately two weeks as a result of the accident.

FIGURE 1—CONSTRUCTION OF CHINO MINES COMPANY KENNECOTT-MITSUBISHI PARTNERSHIP NEW CONCENTRATOR. View shows conveyor and coarse ore storage area, early 1981. Photo courtesy of Chino Mines Company, Santa Rita, New Mexico.

The company's Hidalgo smelter attained record production for total annual tonnage smelted and copper produced. Success is partly due to the addition of crushed coal in the feed which has improved overall furnace performance and reduced fuel-oil consumption.

Sharon Steel Corporation, successor to UV Industries at the Continental mine, Fierro, is the state's third largest copper producer. Production was not, apparently, adversely affected by the strike—concentrates were stockpiled for the duration. Near-record sales and earnings were, in fact, reported and production proceeded at rated capacity (Sharon Steel Corporation, 1981). Sharon operates both an underground and an open-pit mine. Higher grade ore from the former feeds a mill of 3,000 tons/day capacity while lower grade pit material is processed in a newer mill of 5,000 tons/day capacity.

Quintana Minerals Corporation of Tucson announced final plans for the development of

their open-pit copper mine at Gold Dust camp east of Hillsboro. The $98 million project is a joint venture between Quintana and Philbro Minerals Enterprises, Inc., of New York.

Construction on the 15,000 tons/day concentrator, which is slated to be operable in early 1982, began in August. Mine life is projected at 12–15 yrs and it will produce approximately 40 million lbs of copper and 1 million lbs of molybdenum in concentrates annually. Byproduct gold and silver will also be recovered. When in full production, Quintana may become New Mexico's third largest copper producer.

Exxon Minerals has reached a point with evaluation of its Pino Altos property whereby the company is considering a "test mine" by late 1980. This would include the excavation of some 4,000 ft of decline and tunneling and the mining of several thousand tons of ore for metallurgical testing. A final decision on whether to go ahead with phase two, that is, development of the deposit, would hinge upon the success of phase one.

Exploration for the red metal, while certainly not frantic, was carried on by Anaconda on Copper Hill in the Picuris district of Taos County.

LEAD AND ZINC—New Mexico's one-time leading lead and zinc producer, Asarco's Groundhog mine at Vanadium and mill at Deming, remained closed. Activity was restricted to exploratory diamond drilling and a small amount of development drifting. Otherwise, only routine maintenance was conducted. One company, Sharon Steel Corportion, produced zinc but only as a byproduct of copper mining at Fierro.

Lead and zinc markets remained depressed throughout most of the year primarily because of lessening demand for both metals. The outlook for increased production from domestic mines is poor. While substantial reserves are known to exist in such camps as Hanover, Central, and Magdalena, along with new finds at Pinos Altos and Terrero, these reserves, in view of today's market conditions, appear to be only marginally economic and greatly dependent upon the value of associated metals such as copper, gold, and silver.

GOLD AND SILVER—As far as precious metals are concerned, 1980 may well be remembered as the year of the great gold and silver rush. Values of both metals, because of inflation and world instability, rose precipitously beginning in August of 1979 and went on to attain all-time historic highs on January 21, 1980, when silver and gold reached a daily average of $48.00 and $850.00 per oz, respectively. Although this high was short lived, both metals performed well throughout most of the year. Results were twofold: 1) Many people rushed to cash in on high markets—gold and silver jewelry, coins, and tableware were sold to scrap dealers at a frantic pace, doubtless helping to lower prices, and 2) New Mexico's older precious-metal camps experienced high levels of exploration activity.

New Cinch Uranium, Ltd., a Canadian firm, and Triple S Development, an Albuquerque company, conducted extensive drilling in the Orogrande area with more than 20 holes completed during the year. Although reported values are low (0.04–0.05 oz gold per ton and 0.03–0.04 oz silver per ton), the disclosure of a 3–4 million-ton orebody amenable to cyanidation might prove economical. Additionally, Triple S drilled in the Hermosa district of Sierra County and was considering drilling, pending approval, in the Hopewell district, Rio Arriba County.

Elsewhere, Newmont Exploration Ltd. of Tucson completed some exploration drilling in the Georgetown district, Grant County, and Goldfield Corporation conducted diamond drilling and geophysical studies at their St. Cloud property in Sierra County. Goldfield announced that, as a result of exploration activities at the St. Cloud mine, the reserve figure previously disclosed (276,900 tons containing approximately 2.5 million oz of silver) could be significantly increased (Goldfield Corporation, 1981). The situation looks promising enough that the firm is considering utilizing the existing 250 tons/day flotation mill at their San Pedro mine near Santa Fe; the mill would likely be moved to the Winston-Chloride area sometime in the future.

Again, as in years past, most of New Mexico's gold and silver production derived from byproduct recovery as a result of copper mining. This situation will change, however, when Gold Fields Ltd. Ortiz mine in Santa Fe County goes into full production in 1981 (fig. 2). Goldfield Corporation and Gold Fields, Ltd. are different, nonrelated companies.

Platinum is a precious metal that increasingly finds its way into print. Once again in the headlines because of a reported 4,899-oz theft from Inspiration Consolidated Copper Company in Arizona (which turned out to be 48.99 oz stolen from the firm's chemistry

FIGURE 2—VIEW OF LEACH PAD, YARD CONVEYOR, GANTRY, AND SPRAY SYSTEM, ORTIZ MINE, NEAR CERRILLOS, NEW MEXICO. Photo courtesy Gold Field Mining Corporation.

lab—probably in the form of crucibles), several would-be entrepreneurs are claiming that a "platinum cartel" exists among our larger domestic mining companies who deny the existence of the metal in their ores and thus keep the small miner out of a supposedly lucrative market. Unfortunately, some of these entrepreneurs claim to have developed secret chemical methods to recover platinum and platinum-group metals from domestic ores. Deposits with ludicrously fantastic platinum values are said to be concentrated in the Caballo Mountains area near Truth or Consequences and in certain other locations in Lincoln County.

The New Mexico Bureau of Mines and Mineral Resources has analyzed numerous samples which purportedly contained anomalously high platinum values. Significantly, although the Bureau would very much like to confirm the existence of even a small domestic platinum deposit, no platinum down to the limits of detection (≤ 0.03 oz/ton) has ever been found in any New Mexico ore sample. (Platinum has been readily detected by the Bureau in samples from other areas—the Stillwater Complex of Montana, for example.)

The message is clear—the investor should beware of any "ore" that purportedly contains fantastic gold and silver values or *any* platinum values.

MOLYBDENUM—Molybdenum concentrates were produced at three New Mexico localities; again, the larger producer was Molycorp. Production from the Questa property has declined steadily, however, since 1976. This decline reflects depletion of open-pit reserves and subsequent increasing stripping ratios. The company is now in the midpoint of transition to underground mining. According to the firm's annual report, ". . . most of the 1980 production came from previously stockpiled low grade ores" (Molycorp, 1981).

The general worldwide recession has hurt the molybdenum industry as it has the copper industry. Because of the recessionary industrial slowdown, more molybdenum was on hand in 1980 than required by demand. This surplus resulted in precipitous drops in the spot-market (noncontract) price—a price that reached over $30 per lb in 1979—to below $7.00 per lb in 1980, a level that doubtless hurts all domestic producers. Molycorp's operation, for example, requires a price of about $9.70 per lb to remain economically sound.

Underground development at Questa proceeded on schedule—the conveyor tunnel and vent shaft were completed during the year. Daily capacity of the new $200 million mine and facility is projected at 18,000 tons. Anticipated annual production is 20 million lbs MoS_2. Part of the improvements will include a relocation of the tailing line to the north side of the highway, further away from Red River. The relocation may ease or eliminate future tailing spills.

Additional molybdenum production, up to one million lbs MoS_2 per year in concentrates, is anticipated from Quintana's project at Hillsboro.

Elsewhere, Superior Oil Company Minerals Division of Tucson drilled for molybdenum in the White Mountain wilderness in the Lincoln National Forest.

URANIUM—Uranium production increased by a surprising 10% to 15,500,000 lbs (7,750 tons) according to the Department of Energy (1980), but only by 5% to 14,814,000 lbs according to the State Energy and Minerals Division (EMD, 1980) and by 3% to 14,482,995 lbs according to the State Department of Taxation and Revenue (STR, 1980). The DOE figure is presented in table 1.

Assigned values are equally divergent—from $218.5 million (EMD) to $371 million (STR). Historically, sales and production data were carefully tabulated by the U.S. Bureau of Mines; however, this function ceased in 1979, and DOE does not collect total sales data. According to a uranium-price survey conducted by DOE in mid-1980 (DOE NEWS, 10/20/80) the average price of U_3O_8 advanced from $25.40 to $26.00 per lb during the first

half-year. These prices include older, lower priced contracts as well as newer, higher priced contracts. The sales value assigned by EMD yields an average per-lb price of $14.75 upon that agencies' reported production and $14.10 upon DOE's reported production, clearly too low in view of the above survey.

The most acceptable assigned value seems to be that of STR and is given in table 1. This value, with DOE's production, yields an average per-lb price of $23.94 and with EMD's production an average of $25.04, either of which is "in the ball park."

While uranium production did increase during 1980, little doubt exists that it will drop considerably during 1981. Combined public concern and growing opposition over the possible effects of uranium mining and milling (enhanced considerably by the Three Mile Island incident) increased costs because of government regulations and taxes (for example, the 1980 state severance-tax increase), and weakening demand have all had a profound negative effect on the industry. Spot prices have dropped to the point where some producers have found themselves in the curious (and uncomfortable) position in which uranium can be bought cheaper on the spot market than they themselves can produce it (Wall Street Journal, 8/26/80).

Indeed, 15 producing uranium mines closed in New Mexico during 1980 (Hatchell and Wertz, 1981) and Anaconda announced plans to phase out operations at the Jackpile, the world's largest uranium mine which has been in continuous operation for 28 yrs. Another indicator is the amount of exploratory drilling completed which is also affected, one way or the other, by market conditions. DOE reports (DOE NEWS, 3/30/81) a total of 4.4 million ft of drilling in New Mexico during 1980 down from 6.3 million ft drilled in 1979.

Other uranium exploration was understandably slow. A uranium anomaly was discovered southwest of Costilla Peak in Taos County as a result of geochemical and aerial surveys conducted by NMBMMR as part of the National Uranium Resource Evaluation study (NURE; DOE, 1980). Exxon stepped up exploration activities at its uranium prospect near Cerrillos. Mobil Oil Corporation, currently operating an in situ leaching facility northwest of Crownpoint, announced plans for a second test facility east of town. Other leaching operations are planned in the area by Exxon, Phillips, and UNC–Teton Exploration. Rapid expansion of solution mining, if proven environmentally acceptable, is expected in the future.

Nonmetallics

MICA—Expansion and improvement of existing facilities are planned by Mineral Industrial Commodities of America (MICA), the state's only mica producer. Included is the construction of a new mill near the firm's Tojo mine in Taos County. Mica has been trucked some 45 mi to the company's existing mill at Pojoaque for the last 20 yrs; the lengthy haul has taken its toll on operating costs. The new mill is anticipated to double present capacity and substantially reduce overall costs. Other improvements will include a new paved access road.

Taos County commissioners have provided financial assistance in the form of a $2 million revenue bond. In an effort to strengthen their financial position, the company has applied for patent on 195 acres of mining claims it holds in the Carson National Forest.

BARITE—Barite was produced by a single small company during 1980, Ranger Industries, at two sites north of Socorro—the Ranger East and Elaine prospects. Ores were processed in a small gravity plant at Pueblito prior to shipment to Midland, Texas.

Barite of America (BOA) completed renovation of their plant north of Deming (previously the American-Peru concentrator). Although some barite ore was mined from deposits east of Rincon, metallurgical problems at the mill prevented finished-product shipments. The company expended considerable effort on tunneling and other development at a prospect on the east side of the Florida Mountains southeast of Deming, but no barite was produced.

Ground was broken for Minopco's new mill at Hansonburg. This plant, projected at 400-tons-per-day capacity, will utilize a radically new hydraulic-pulse jig to recover lead, barite, and some fluorspar, instead of depending on more traditional gravity and/or flotation recovery methods.

PERLITE—New Mexico was again the nation's leading perlite producer, although production dropped slightly to 539,000 tons. Perlite is produced in the state by four companies at five locations in Socorro, Taos, and Valencia Counties.

Additionally, the Lieden Oil Company of Oklahoma City is considering installing a

perlite plant near Gage, west of Deming. The company has made application for an air-quality permit.

POTASH—Production of potash, produced by seven companies in the Eddy-Lea County area of southeast New Mexico, declined to 2,060,000 tons although value increased to $289 million. The price increase reflects the healthy worldwide demand for the commodity for use in both chemicals and fertilizers.

Most, if not all, of the potash companies have applied for additional leases. The Bureau of Land Management opened up over 2 million acres of federal land in the area during 1980. No potash leases or prospecting permits had been issued since 1974.

References

American Petroleum Institute, 1980, Quarterly review of drilling statistics: American Petroleum Institute, v. 13, no. 4, p. 14–22

———, 1981, Quarterly review of drilling statistics: American Petroleum Institute, v. 14, no. 4, p. 14–24

Arnold, E. C., and Hill, J. M., compilers, 1981, New Mexico's energy resources, annual report of Bureau of Geology in the Mining and Mineral Division of New Mexico Energy and Minerals Department: New Mexico Bureau of Mines and Mineral Resources, Circ. 181, 59 p.

Engineering and Mining Journal, 1980, Metals week quotations: Engineering and Mining Journal, v. 181, nos. 2–12

———, 1981, Metals week quotations: Engineering and Mining Journal, v. 182, no. 1

Goldfield Corporation, 1981, 75th annual report 1980, 20 p.

Gold Fields Consolidated Ltd., 1980, Annual report and accounts, 51 p.

Hatchell, B., and Wentz, C., compilers, 1981, Uranium resources and technology, a review of the New Mexico uranium industry, 1980: New Mexico Energy and Minerals Department, Bureau of Geology, Mining and Minerals Division

Kennecott Corporation, 1981, 1980 annual report, 52 p.

Keystone Coal Industry Manual, 1981.

Molycorp, 1981, 1980 annual report

Phelps Dodge Corporation, 1981, 1980 annual report, 40 p.

Sharon Steel Corporation, 1981, 1980 annual report, 48 p.

U.S. Department of Energy, 1980, National uranium resource evaluation, Raton quadrangle, New Mexico and Colorado: U.S. Department of Energy, Proj. GJQ-005 (80)

———, 1980–81, DOE news: Grand Junction

———, 1981, Principal findings of the U.S. crude oil, natural gas, and natural gas liquids reserves 1980 annual report: Washington, D.C., Energy Information Administration, U.S. Dept. of Energy, Office of Oil and Gas, DOE/EIA-0216 (80) Ex. p. 1–7

Wall Street Journal, 1980, 8/26/80 issue

Type faces: Text in 8, 9-pt. English Times
References in 7-pt. English Times, leaded one point
Display heads in 12, 18-pt. English Times

Presswork: Miehle Single Color Offset
Harris Single Color Offset

Binding: Smyth sewn with softbound cover

Paper: Cover on 10-pt CIS
Text on 70-lb. white Matte

Ink: Cover—PMS 470
Text—Black

Press Run: 750

Financial statement

New Mexico Bureau of Mines and Mineral Resources
July 1, 1980, to June 30, 1981

Funds available			
Beginning balance July 1, 1980		$ 22,596*	
State appropriation		1,594,100	
Publication receipts		55,926	
New Mexico Geology		6,000	
Reimbursements		31,410	$1,710,032
Expenditures			
Salaries:			
Scientists and engineers	$680,684		
Support staff	220,457		
Part-time staff (students)	109,447	$1,010,588	
Employee benefits		154,876	
Project contracts		101,732	
Travel & vehicles		80,486	
Scientific laboratories:			
Maintenance	$ 19,352		
Materials & supplies	40,221	$ 59,573	
Office supplies		19,500	
Postage & freight		10,763	
Printing		107,606	
Equipment		51,535	
General expenses:			
Telephone	$ 21,458		
Subscriptions & dues	4,559		
Computer service	4,492		
Overhead & audit	50,329		
Heat, water, electricity	31,861	$ 112,699	$1,709,358
Balance June 30, 1981			$ 674
Grants and contracts			
Staff salaries	$230,206		
Student wages	16,055		
Employee benefits	16,044		
Supplies and expenses	171,259		
Travel	91,003		
Computer	10,697		
Overhead	83,639		
Total grants and contracts	$618,903		

*changed by NMIMT auditors from $22,945