Annual Report

July 1, 1977 to June 30, 1978

Contributed articles

see page 34

PRIONOCYCLUS NOVIMEXICANUS
(MARCOU), 1858
IMPORTANT UPPER CRETACEOUS GUIDE
FOSSIL FOR THE WESTERN INTERIOR.

New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF

NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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
After hours: 505/835-5011

January 8, 1979

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

We have the honor of transmitting to you the Annual Report of the New Mexico Bureau of Mines and Mineral Resources for the fiscal year July 1, 1977 through June 30, 1978, as required by Section 3, Chapter 115, of the Eighth New Mexico Legislature sessions laws, approved March 14, 1927.

In this, our 51st year of service and applied research, the Bureau distributed more than 18,500 technical and scientific documents and provided information concerning exploration, development, and conservation of New Mexico's mineral resources and geology in 7750 letters, in 4550 telephone inquiries, and to 4700 office visitors. Twenty-two new geologic reports were published. More than 8500 copies of our publications were distributed without charge to state officials, libraries, and scientific agencies worldwide.

The Bureau's effectiveness is based on the expertise and dedicated efforts of our staff. Professional staff was at authorized strength until the latter part of the year when 11 percent of the staff, all newer employees, resigned. With the increasing demand for geologists and engineers, and the higher salaries paid by industry and the federal government, we anticipate difficulty in hiring and retaining quality professionals.

In March, Senior Paleontologist Rousseau H. Flower retired but as Emeritus Paleontologist continues to work as diligently as ever. Senior Geologist Charles E. Chapin was elected as Honorary Member of the New Mexico Geological Society, the fourth staff member so honored. Editor-Geologist Robert W. Kelley was chosen President of the Association of Earth Science Editors.

The 1977-78 budget recommended by the Regents and the Board of Educational Finance, and approved by the Legislature and the Governor, was very adequate to carry out our duties. However, funding cuts by the Legislature in the budget recommended for 1978-79, a decrease to 7-percent increment in salaries and a one-percent cut overall, do not allow us to keep pace with the 10-percent inflation. We hope the 1979-1980 Legislature will allow us a sufficient appropriation. As New Mexico surges forward to increased utilization of its mineral resources, our program continues to be dedicated to aid exploration, development, and the wise handling of those resources. We will continue to strive for technical and scientific excellence to accrue 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, 1977 to June 30, 1978

by

Frank E. Kottlowski
and staff

SOCORRO 1979

Published by Authority of State of New Mexico, NMSA 1953 Sec. 63–1–3
Printed by University of New Mexico Printing Plant, March 1979

Available from New Mexico Bureau of Mines & Mineral Resources, Socorro, NM 87801 $1.00

Purpose and functions

Introduction

By law, the New Mexico Bureau of Mines & Mineral Resources is the official state organization charged with investigating and reporting on the geology, mineral resources, and energy resources of New Mexico. The Bureau is required to give technical and scientific assistance in the exploration, development, production, and conservation of New Mexico's mineral wealth. That is the basis of our program.

We accomplish this program by: 1) giving technical advice to all who visit, write, or telephone us, 2) preparing scientific reports on applied mineral-resource research, and 3) making available basic data such as well records, chemical analyses, and open-file geologic maps and reports.

In 1977, the value of minerals extracted in New Mexico totalled more than $2.9 billion. Payments from the U.S. Bureau of Land Management and compensatory reimbursement in lieu of taxes totalled $62.9 million; this amount includes the state's share of income from leasing of mineral rights on federal lands administered by USBLM. State severance taxes collected on minerals extracted in New Mexico during fiscal year 1977-1978 totalled $91 million. Thus, New Mexico's mineral industry contributes substantially to the state's economy.

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

Geology and mineral resources

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

The scientific and technical literature generated by the Bureau contributes significantly to mineral exploration. Sales of Bureau publications totalled $46,366 this fiscal year; about 8,700 copies of the new publications were issued free to state officials, libraries, and scientific organizations. A complete set of Bureau publications was given to the University of New Mexico Geology Department. Sales performance for a particular publication, however, does not necessarily reflect its ultimate worth to New Mexico; any report or map may contain the clue that leads to the discovery of a huge orebody or a million-barrel oil pool.

Many New Mexicans, and most of the tourists visiting the state, are not concerned directly with technical geologic investigations but do have a lively interest in our enchanting landscapes. They want to know how the canyons and

TABLE OF ORGANIZATION

as of January 1979

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

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

Drafting & illustrating
- Chief Scientific Illustrator
- 3 Scientific Illustrators

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

Environmental geology
- Environmental Geologist
- Field Geologist

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

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

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

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

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

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

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

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

mountains, arroyos and mesas, and volcanoes and desert playas were formed. The popular guides *Scenic Trips to the Geologic Past* explain the geology of local areas and point out scenic and geologic wonders. These booklets also are designed to keep tourists in the state "that extra day"—so important to New Mexico's economy. Tens of thousands of copies have been distributed, and the demand continues. Other more technical guidebooks are also published.

Most of our geologic work comprises "ground truth" investigations, as demonstrated by the more than 260,000 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. Our records show that 7,750 letters

and 4,550 telephone inquiries were answered, and 4,700 office visitors counseled. Many adults and school children toured the Bureau's mineral museum. More than 4,600 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 70,000 test wells drilled in New Mexico, including cuttings from selected wells and a variety of borehole logs such as electric, radioactive, and sonic. Up-to-date petroleum exploration maps for most counties are maintained and available.

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

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

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

LABORATORIES

Analytical and X-Ray

The Bureau's laboratories are equipped to perform extensive chemical, mineralogical, and petrological tests. Chemical analyses, both qualitative and quantitative, are performed by classic wet-chemical and optical-spectrographic procedures as well as by atomic absorption, X-ray, and electron-microprobe spectrometry. Capabilities include analyzing water, ores, concentrates, geological samples, and leach liquids for the common elements and parameters. A total of 3,135 analytic reports on 795 samples were prepared, in addition to partial analyses of 1,505 samples by X-ray methods.

The analytical laboratory has been cooperating with the Environmental Improvement Division (New Mexico Health and Environment Department) on selenium analyses of water samples from the Grants area. The high-sulfate content of these waters makes the selenium analyses very difficult. We have also cooperated with Kerr-McGee Corp. and four other laboratories in testing for selenium in synthetic water samples. Our laboratory evaluated three different methods of selenium analysis in synthetic water samples of varying sulfate content.

New Mexico Library of Subsurface Data

During the year 919 sets of drilling samples were added, bringing the total number of sets on hand to more than 10,072. Also electric and other types of mechanical logs for 902 wells and 1,445 well records were acquired from drilling operations. Two special donations were received. Superior Oil Company donated 488 boxes of samples from 280 wells; Continental Oil Company contributed core chips and slabs from 170 wells.

Carbon dioxide exploration programs in northeastern New Mexico, Bureau projects in coal and ground water, and stratigraphic studies accounted for a marked increase in use of the subsurface library during the year. The library also continues to be an important source of data for uranium exploration. At the close of the fiscal year, a national consulting firm was conducting a test of all 34,400 cartons of samples for signs of radioactivity.

METALLURGY

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

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 ongoing projects, wholly or partly funded by the Bureau, are listed in this section. An index map of field projects is shown on pages 8 and 9. A list of part-time research associates on contract to the Bureau appears on page 14. Current Bureau staff is listed on pages 21 and 22; staff employed during fiscal year is given on page 22.

Industrial minerals and coal

1. Austin—Shale and clay resources of New Mexico
2. Austin—Geology and mineral deposits of Ochoan rocks in Delaware Basin and adjacent areas (in cooperation with New Mexico Geological Society; circ. 159)
3. Austin and Siemers—1981 Industrial Minerals Forum
4. Austin and Weber—Perlite deposits of New Mexico
5. Brierley—Leaching of pyritic sulfur from coal (in cooperation with Texas Industries)
6. Cima—Scoria deposits in New Mexico
7. Eveleth—Inventory of abandoned surface mines in New Mexico (in cooperation with New Mexico Bureau of Surface Mining)
8. Frost—Coal lease file (continuing update)
9. Frost—Coal bibliography (continuing update)
10. Frost—Coal mine file (continuing update)
11. Frost and Tabet—Coal resources map of New Mexico (Resource Map 10)
12. Kottlowski, Tabet, and Frost—New Mexico coal seams (1978 Keystone Coal Industry Manual)
13. Massingill—Cretaceous coals and Tertiary uranium in Riley-Puertecito area
14. Massingill and Tabet—Coal geology of the Pinehaven 7½′ quadrangle (in cooperation with U.S. Geological Survey)
15. McAnulty—Fluorspar deposits of New Mexico (Mem. 34)
16. Nickelson and Frost—History of coal mining in New Mexico
17. Owen and Levinson—Analyses of coals and shales in Dakota Sandstone of southern and western San Juan Basin

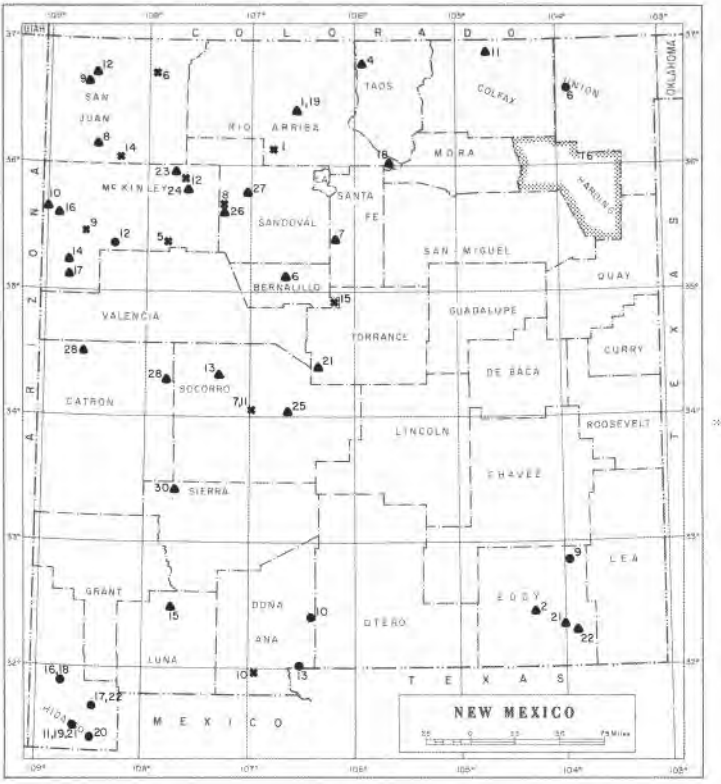
18. Pringle–Magnetitic pegmatite near Truchas Peaks
19. Russell–Refractory clays of Dakota Formation of eastern San Juan Basin
20. Siemers–Evaluation of the economic potential of New Mexico limestones
21. Siemers and Austin–Industrial minerals of New Mexico (in this report)
22. Siemers, Hawley, Rautman, and Austin–Evaluation of mineral potential (excluding hydrocarbons, potash, and water) of the WIPP site (in cooperation with Sandia Corp.; Open-file Rept. 87)
23. Shomaker and Whyte–Geologic appraisal of deep coals, San Juan Basin, New Mexico (in cooperation with U.S. Bureau of Mines and Energy Resources Board; Circ. 155)
24. Speer, Beaumont, and Shomaker–Coal resources of the San Juan Basin (in cooperation with New Mexico Bureau of Geology; Open-file Rept. 84)
25. Tabet–Jornada del Muerto coal field in Socorro County
26. Tabet and Frost–Reserves of Menefee coals in Torreon Wash area (in cooperation with U.S. Geological Survey)
27. Tabet and Frost–Coal resources of New Mexico (continuing update)
28. Tabet, Frost, Hook, and Massingill–Coal resources of the Salt Lake and Datil Mountains coal fields (in cooperation with U.S. Geological Survey)
29. Tabet, Frost, and Robinson–Computerization of point-source coal data for New Mexico (in cooperation with U.S. Geological Survey)
30. Weber–Zeolites of New Mexico

Oil and gas

1. Austin, Myers, Bieberman, Reiter, and Frost–Energy resources map of New Mexico (in cooperation with U.S. Geological Survey)
2. Bieberman–Oil and gas fields, exploration tests, and major pipelines map of New Mexico
3. Bieberman–Catalog of samples available in New Mexico Library of Subsurface Data (continuing update)
4. Bieberman–Scout information file, mechanical log file, lithologic log file, driller's log file, and county petroleum exploration maps (continuing update)
5. Christiansen–History of oil and gas exploration and production in New Mexico
6. Foster–Occurrence and origin of carbon dioxide in Western United States
7. Foster–Subsurface geology of northeastern New Mexico
8. Foster and Gutjahr–Oil pool reserves and estimated future oil production (in Circ. 167)
9. Foster, Gutjahr, and Warner–Estimates of New Mexico's future oil production including reserves of the 50 largest pools (Circ. 166)
10. Foster, Hawley, and Austin–Evaluation of oil, gas, and other mineral resources on state lands in White Sands Missile Range (Open-file Rept. 92)
11. Greenwood, Kottlowski, and Thompson–Petroleum potential and stratigraphy of the Pedregosa Basin in comparison with the Permian and Orogrande Basins (American Association of Petroleum Geologists Bull.)
12. King–Petroleum potential of Paleozoic strata of San Juan Basin
13. Potter and Thompson–Paleocurrents in the Bliss Formation of southwestern New Mexico and western Texas
14. Renault–Application of carbonate thermoluminescence to petroleum exploration
15. Renault–Application of crystallite size variation in cherts to petroleum exploration
16. Thompson–Petroleum geology of southwestern New Mexico
17. Thompson–Petroleum reservoir and source rocks exposed in Big Hatchet Mountains, Hidalgo County
18. Thompson–Analyses of petroleum source and reservoir rocks in southwestern New Mexico
19. Thompson–Subsurface geology of the Cockrell No. 1 Playas well, Hidalgo County
20. Thompson–Subsurface geology of the Humble No. 1 State BA well, Hidalgo County
21. Thompson, Tovar, and Conley–Oil and gas exploration wells in the Pedregosa Basin (New Mexico Geological Society guidebook 29th field conference)
22. Thompson and Jacka–Pennsylvanian stratigraphy, petrography, and petroleum geology of the Big Hatchet Peak section, Hidalgo County

Water resources and geothermal

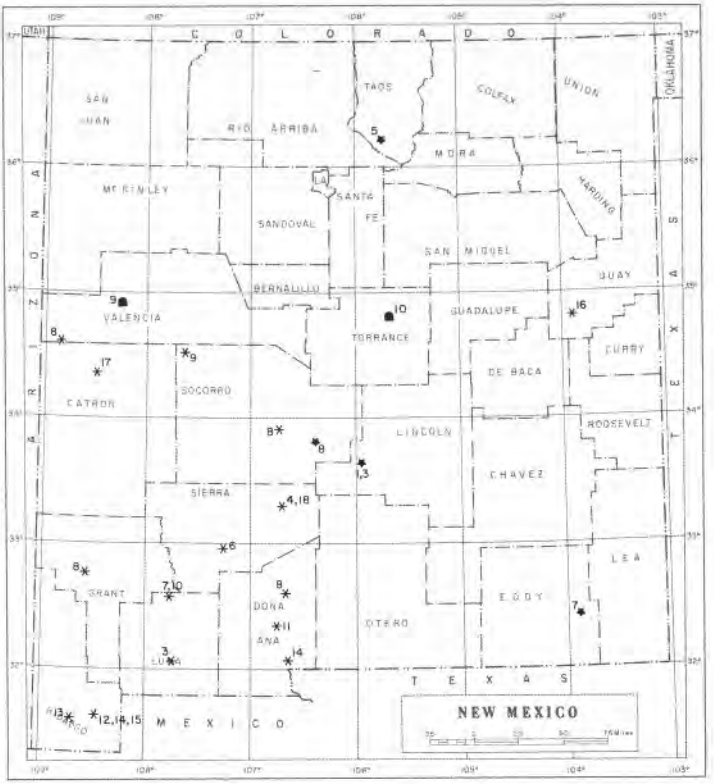
1. Anderholm and Stone–Hydrogeology and water resources of Cuba 15′ quadrangle
2. Brandvold–Mercury in New Mexico surface waters (Circ. 162)
3. Brandvold–Water Quality Control Commission projects

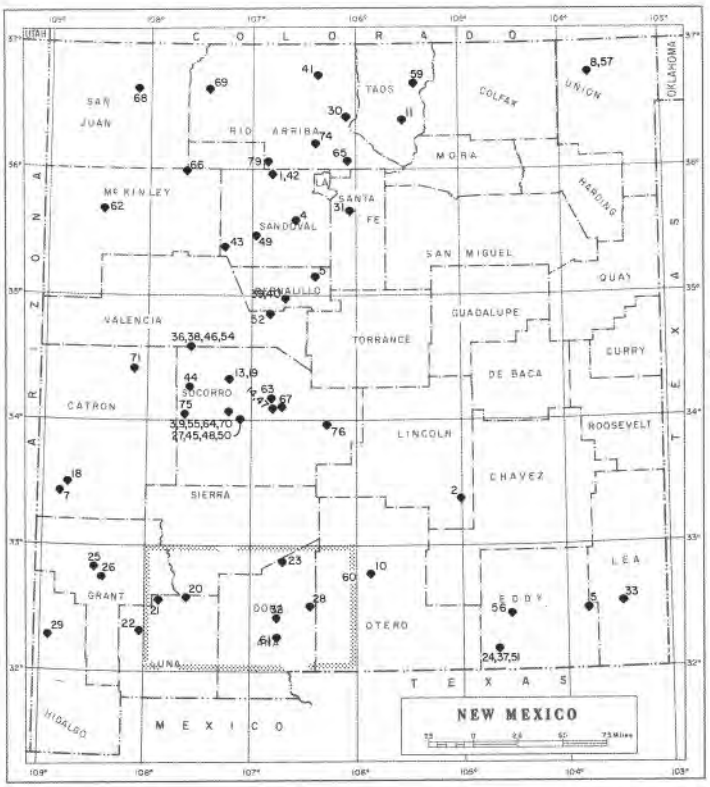


- Industrial minerals and coal
- Oil and gas
- Water resources and geothermal

- Environmental geology
- Metallic ores and mining districts
- Metallurgy and chemistry

INDEX MAPS OF BUREAU FIELD PROJECTS





INDEX MAPS OF BUREAU FIELD PROJECTS

4. Brandvold—Water analyses file (continuing update)
5. Brod and Stone—Hydrogeology and water resources of the Ambrosia Lake–San Mateo area
6. Brown and Stone—Hydrogeology of Aztec quadrangle (Hydrogeologic Sheet 1, in press)
7. Chapin, Chamberlin, and Osburn—Geology and geothermal potential of Socorro area (supported by Energy Resources Board)
8. Craigg and Stone—Hydrogeology and water resources of the Torreon Wash–Chico Arroyo area
9. Mizell and Stone—Relationship of ground-water quality and facies in Gallup Sandstone
10. Mizell and Stone—Geothermal leasing and exploration activity computer data file/display (continuing update)
11. Reiter and Mansure—Subsurface temperature data in the Socorro Peak KGRA
12. Stone—Hydrogeology and water resources of northwestern New Mexico (in cooperation with U.S. Geological Survey and New Mexico State Engineer)
13. Stone—Hydrogeology and water resources of New Mexico
14. Stone, Brod, and Anderholm—Description of cuttings from Navajo water wells drilled in New Mexico (Open-file Rept. 82)
15. Titus—Ground-water resources of Sandia and Manzano Mountains (in cooperation with U.S. Geological Survey)
16. Trauger—Ground-water resources and geologic map of Harding County (in cooperation with U.S. Geological Survey)

Environmental geology

1. Foster—Evaluation of proposed site for disposal of nuclear waste, WIPP: I. Mineral resources, and II. Historical review
2. Foster, Austin, Hawley, and Stone—Preliminary selection of sites geologically suitable for disposal of hazardous wastes in New Mexico (Open-file Rept. 83)
3. Hunt—Surficial geology of New Mexico (Geologic Maps 40, 41, 42, and 43)
4. Hunt—Physiographic map and description of New Mexico
5. Tabet, Sheffer, and Inglis—Landsat imagery as a tool for monitoring coal surface mining

Metallurgy and chemistry

1. Brandvold—Directory of commercial analytical laboratories in the southwest (Bureau leaflet)
2. Brandvold—Reliability of commercial laboratories for gold and silver analyses
3. Brandvold—Heavy metal and nutrient load of the Rio San Jose–Rio Puerco system
4. Brandvold—Round-robin selenium analyses (in cooperation with Environmental Improvement Division, Kerr-McGee Corp., United Nuclear–Homestake Partners, and Controls for Environmental Pollution)
5. Brierley—Review of bacterial leaching processes in extraction of copper and uranium (to be published by Chemical Rubber Co. in Critical Reviews in Microbiology)
6. Brierley—Column leaching of low-grade chalcopyrite ores using thermophilic bacteria (in cooperation with U.S. Bureau of Mines)
7. Brierley—Electrochemistry of bacterial attack of copper sulfide minerals (in cooperation with Metallurgy Dept., University of Utah)
8. Roman, Sheffer, Brierley, Shantz, and Stone—Copper leaching practices in the western United States (in cooperation with U.S. Bureau of Mines)
9. Shantz—Cyanide leaching-electrowinning tests on copper-bearing products
10. Shantz and Reich—Mathematical model of static cathode potentials in copper-cyanide system

Metallic ores and mining districts

1. Cather—Sedimentary petrology of the Baca Formation in Alamo Reservation area (in cooperation with University of Texas at Austin)
2. Chapin and Osburn—Geology and mineral resources of Socorro County
3. Chapin and Osburn—Geology and mineral resources of Magdalena area
4. Chapin and Osburn—Data bank of radioactive dates, isotopic analyses, and chemical analyses of igneous rocks in New Mexico (continuing update)
5. Eveleth, Mardirosian, Weber, and Siemers, T.—Mineral industry location system (MILS) for New Mexico (in cooperation with U.S. Bureau of Mines)
6. Eveleth—The 1872 Mining Law—Is it really obsolete? (in this report)

7. Grambling–Precambrian rocks and mineral deposits in Truchas Peaks area
8. Griswold, Austin, Rautman, and Robertson–Uranium resources of Santa Fe 2° quadrangle (in cooperation with Dept. of Energy and Bendix Field Engineering)
9. Griswold, Austin, Rautman, and Robertson–Uranium resources of Raton 2° quadrangle (in cooperation with Dept. of Energy and Bendix Field Engineering)
10. Jahns and Willard–Manganese deposits of Luis Lopez district, Socorro County
11. Jahns and Willard–Gold deposits of White Oaks mining district, Lincoln County
12. McMillan and Jahns–Structure, petrology, and ore deposits of Chise quadrangle in southern Sierra Cuchillo, Sierra County
13. Proctor–Trace base metals in Cooke's Peak stock
14. Rautman–Uranium resources of New Mexico (general survey; maintain library of uranium reports including Energy Research and Development Administration open-file reports; continuing status file of uranium industry in New Mexico)
15. Rautman–Non-sandstone uranium deposits in New Mexico
16. Robertson–Evaluation of geology and mineral potential of Pecos Wilderness in north-central New Mexico (in cooperation with U.S. Geological Survey)
17. Robertson–Precambrian rocks and mineral deposits of Doctor Creek area, Santa Fe County
18. Robertson and Budding–Geology and ore deposits of Rociada–Elk Mountain area
19. Seager–Geology and mineral deposits of Organ Mountains
20. Sheffer and Eveleth–Minerals in the economy of New Mexico (published by U.S. Bureau of Mines, SMP-5)
21. Siemers, Austin, Bieberman, Robertson, Rautman, Shantz, Tabet, and Weber–Map of active mines, mills, and operators (Resource Map 9, in preparation)

Mineralogy and X-ray

1. Renault–Geochemistry of Carrizozo basalt flow
2. Renault–Resolution of x-ray diffraction lines–a numerical model
3. Renault–Trace elements in Carrizozo basalt flows
4. Taggart–Polishing technique for geologic samples (American Mineralogist)
5. Taggart–Harding pegmatite, outdoor museum and historic site
6. Taggart–Relationships of uranium ores to organic matter
7. Taggart–Mineralogy of halite-filled vesicles in basalt, Kermac mine, Carlsbad, New Mexico
8. Taggart and Rosenzweig–Mineralogy of the Hansonburg mining district (in preparation)

Geophysics

1. Sanford–Continuing survey of earthquakes in New Mexico
2. Shearer and Reiter–Regional heat-flow studies in western New Mexico and Arizona (in cooperation with U.S. Dept. of Energy)
3. Shearer and Reiter–Compilation of basic heat-flow data in New Mexico (Open-file Rept. 93)
4. Reiter and McMahon–Subsurface temperature map of New Mexico
5. Reiter, Mansure, and Shearer–Geothermal characteristics of the Colorado Plateau
6. Reiter–Geothermal characteristics of the San Juan and Blanding Basins
7. Reiter, Shearer, and Mansure–Geothermal characteristics of the southern Rocky Mountain complex (in press)
8. Reiter–Temperature logging and gas zone detection
9. U.S. Bureau of Land Management–Aeromagnetic mapping of malpais region south of Zuni Mountains (matching funding with New Mexico Bureau of Mines and Mineral Resources)
10. U.S. Geological Survey–Aeromagnetic mapping of central New Mexico, Pedernal area (matching funding with New Mexico Bureau of Mines and Mineral Resources)

Paleontology

1. Cobban and Hook–Paleontology of the Late Cretaceous "Cephalopod Zone" of Herrick (1900)
2. Cobban and Hook–*Collignoniceras woollgari woollgari* (Mantell) subzone ammonite fauna from Upper Cretaceous of western United States (Mem. 37)
3. Flower–Ordovician correlations
4. Flower–Faunas of the New Mexico Devonian
5. Flower–Studies of Endoceratida and Tarphyceratida

6. Flower and LeMone—Faunal and petrographic studies of Bliss Sandstone, El Paso Group and Montoya Group
7. Hook and Cobban—Stratigraphy and paleontology of Cretaceous rocks of Cooke's Range
8. Hook and Cobban—Stratigraphy and paleontology of Upper Cretaceous of a) Silver City area, b) Fence Lake area, c) southern San Andres Mountains, and d) Carthage area
9. Hook and Cobban—Stratigraphy, paleontology and regional relationships of Upper Cretaceous Tres Hermanos Sandstone
10. Johnson and Hattin—Sedimentology and fauna of Cooke's Peak Greenhorn beds
11. King—Fusulinids of the Hueco Formation in the Las Cruces area
12. LeMone—Cretaceous faunas in Big Hatchet Mountains
13. LeMone and Simpson—Upper Paleozoic faunas of Winkler anticline, Hidalgo County
14. LeMone and Simpson—Wolfcampian megafauna and biostratigraphy of Franklin and Big Hatchet Mountains
15. LeMone, Simpson, and Neilsen—Permian megafaunas of Big Hatchet Mountains
16. Leonard and Frye—Stratigraphy and paleontology of Ogallala Formation in New Mexico
17. Schiebout—Biostratigraphy of Baca Formation near Quemado
18. Sorauf—Devonian corals from south-central New Mexico

Geology, geologic mapping, stratigraphy, and special projects

1. Adams and Anderson—Petroliferous Pennsylvanian rocks in Nacimiento Mountains
2. Allen, J., and Kottlowski—Revision of Scenic Trip No. 3 Roswell-Capitan-Ruidoso
3. Allen, P.—Geology of the northwest flank of Magdalena Mountains
4. Anderson and Wells—Cenozoic terrace and pediment deposits in Rio Salado and Jemez River area
5. Armstrong, Kottlowski, Stewart, Mamet, Baltz, Siemers, and Thompson—Mississippian and Pennsylvanian Systems of New Mexico (summary chapter for U.S. Geological Survey Prof. Paper for IX-ICC International Carboniferous Congress)
6. Balk—Stratigraphic nomenclature of New Mexico
7. Bikerman—Age-dating volcanic rocks in Mogollon area
8. Bond and Asquith—Upper Dakota Sandstone in northeastern New Mexico
9. Bowring—Geology of the central Magdalena Mountains
10. Caldwell and Wilson—Regional Early and Middle Pennsylvanian rocks of southern New Mexico
11. Casey and Scott—Basin evolution of Late Paleozoic Taos Trough, northern New Mexico
12. Cather—Baca Formation in Alamo area
13. Chaiffetz—Palynological and thermal maturation studies of Cretaceous and Baca units in Riley area
14. Chamberlin—Geology of the Socorro Peak and Lemitar Mountains
15. Chapin—Origin and evolution of the Rio Grande rift
16. Chapin—Cenozoic tectonic and magmatic evolution of New Mexico
17. Chapin—Mechanics of transport and deposition of ash-flow tuffs
18. Chapin, Chamberlin, Clemons, Elston, Finnell, Ratte, and Seager—Geologic road logs for Socorro-Datil-Mogollon-Silver City-Hillsboro loop (New Mexico Geological Society Special Pub. 7)
19. Chapin and Hook—Geology and energy potential of the Colorado Plateau margin in the Riley-Alamo Reservation region (supported by Energy Resources Board)
20. Clemons—Geology of Good Sight Mountains (Circ. 169)
21. Clemons—Geology and mineral resources of Massacre Peak 7½′ quadrangle
22. Clemons, Thompson, and Stone—Revision of Scenic Trip No. 10, southwestern New Mexico
23. Condie and Budding—Geology and geochemistry of Precambrian rocks of south-central New Mexico (Mem. 35)
24. Crawford and Pray—Carbonate facies of Goat Seep reef in Guadalupe Mountains
25. Cunningham—Circle Mesa quadrangle
26. Cunningham—Revised geologic map of Silver City 7½′ quadrangle
27. D'Andrea—Geochemistry of potassium metasomatized ash-flow tuffs in the Socorro area (in cooperation with Florida State University)
28. Dunning and Wilson—Channel deposits in Holder Formations (Pennsylvanian) of Sacramento Mountains
29. Fleischhauer—Quaternary geology of Lake Animas, Hidalgo County
30. Griffiths and Ingersoll—Tertiary stratigraphy in Ojo Caliente-La Madera area
31. Hawley—Guidebook to the Rio Grande rift in New Mexico and Colorado (Circ. 163)

32. Hawley–Quaternary geology and soil-geomorphic relations in Las Cruces region
33. Hawley and Sandor–Quaternary map of New Mexico–southeast sector
34. Holts–History of New Mexico Bureau of Mines and Mineral Resources as recorded in legislation, annual reports, and notes
35. Holts and Heljeson–Bibliography of New Mexico geology and mineral technology, 1976 through 1980
36. Hook and Massingill–Geology of Puertecito quadrangle
37. Hurley and Pray–Facies of Seven Rivers and Yates Formations, North McKittrick Canyon, Guadalupe Mountains
38. Jackson–Geology of the Abbey Springs–Puertecito area
39. Kelley, V.–Geology of Albuquerque Basin (Mem. 33)
40. Kelley, V., and Kudo–Volcanoes and related basalts of Albuquerque Basin (Circ. 156)
41. Kent and Robertson–Precambrian rocks of the Tusas area
42. Kurtz and Anderson–Poleo Sandstone member of Chinle Formation in Nacimiento Mountains
43. LaFon–Sedimentology and depositional environments of Upper Cretaceous Semilla Sandstone Member of Mancos Shale
44. Laroche–Geology of the Gallinas Peak area
45. Lindley–Geochemistry of propylitically altered ash-flow tuffs in the Socorro area (in cooperation with Florida State University)
46. Massingill and Hook–Geology of Pueblo Viejo quadrangle
47. Mayerson–Geology of the Corkscrew Canyon–Abbey Springs area
48. Osburn–Geology of the Water Canyon Mesa–Sixmile Canyon area
49. Owen and Siemers, C.–Dakota units in southeast San Juan Basin between Laguna and La Ventana
50. Petty–Geology of the southeastern Magdalena Mountains
51. Pray, Neese, and Schwartz–Lithofacies of Yates–Tansill Formations in Walnut and Rattlesnake Canyons, Guadalupe Mountains
52. Renault–Petrology and geochemistry of volcanic rocks of Cerro de Los Lunas, Cat Hills, and Wind Mesa, Socorro and Bernalillo Counties
53. Renault–Thermoluminescence dating of ancient land surfaces
54. Robinson, B.–Geology of the D-Cross 7½′ quadrangle
55. Roth–Geology of the Sawmill Canyon area, Magdalena Mountains
56. Sarg–Carbonate-evaporite transition facies of Seven Rivers Formation
57. Savela and Asquith–Mineralogy of Exeter Sandstone in northeastern New Mexico
58. Schilling–Isochron/West, a periodic journal of isotopic geochronology
59. Schilling, Taggart, and Pendleton–Revision of Scenic Trip No. 2, Taos–Red River–Eagle Nest
60. Seager, Clemons, and Hawley–Geology of Las Cruces 1:250,000 quadrangle
61. Seager, Kottlowski, Hawley, and King–Geology of Robledo Mountains
62. Shetiwy–Sedimentologic and stratigraphic analysis of Point Lookout Sandstone, southeast San Juan Basin
63. Siemers, T.–Pennsylvanian stratigraphy of Socorro County region
64. Siemers, T.–Permian rocks in northern Magdalena Mountains
65. Steinpress and Ingersoll–El Rito Formation in Española Basin
66. Stone–Nature of Lewis Shale–Pictured Cliffs Sandstone contact
67. Stone–Quaternary geology and geomorphology of Loma de las Cañas quadrangle
68. Stone, Baltz, and O'Sullivan–Tertiary-Cretaceous boundary in the Farmington area (in cooperation with U.S. Geological Survey)
69. Stone and Wolberg–Geology of west half of Aztec 1:250,000 quadrangle (in cooperation with U.S. Geological Survey)
70. Sumner–Geology of the North Fork Canyon–Jordan Canyon area, Magdalena Mountains
71. Tabet, Hook, Massingill, and Frost–Surface and subsurface correlation of Cretaceous rocks in west-central New Mexico
72. Taggart and Renault–Improved sample pelletization technique for x-ray fluorescence spectrometry
73. Thompson and Slaczka–Concepts and type examples of fluxoturbidites
74. Vazzana and Ingersoll–Abiquiu Formation near Abiquiu
75. Weber–Geology of Plains of San Agustin
76. Weber–Geology of Mockingbird Gap site
77. Weber–Petrographic and chemical characteristics of six new meteorites from New Mexico
78. Wright and Russell–Bibliography of New Mexico geology and mineral technology, 1971 through 1975 (Bull. 106)
79. Woodward–Geology and mineral resources of Jarosa quadrangle

Research associates

Professional

John Eliot Allen, Portland State University
John B. Anderson, Rice University
Augustus K. Armstrong, U.S. Geological Survey
George B. Asquith, West Texas State University
Elmer H. Baltz, Jr., U.S. Geological Survey
Michael Bikerman, University of Pittsburgh
Antonius J. Budding, New Mexico Tech
Paige W. Christiansen, New Mexico Tech
Russell E. Clemons, New Mexico State University
William A. Cobban, U.S. Geological Survey
Kent C. Condie, New Mexico Tech
John E. Cunningham, New Mexico Western University
Wolfgang E. Elston, University of New Mexico
John C. Frye, Geological Society of America
George B. Griswold, Albuquerque
Donald E. Hattin, Indiana University
Charles B. Hunt, Salt Lake City
Raymond V. Ingersoll, University of New Mexico
Michael H. Inglis, TAC, University of New Mexico
Alonzo D. Jacka, Texas Tech University
Lynn C. Jacobson, Albuquerque
Richard H. Jahns, Stanford University
Vincent C. Kelley, New Mexico State University
William E. King, New Mexico State University
Edwin R. Landis, U.S. Geological Survey
David V. LeMone, University of Texas at El Paso
A. Byron Leonard, University of Kansas
Charles A. Mardirosian, Albuquerque
William N. McAnulty, University of Texas at El Paso
Donald A. Myers, U.S. Geological Survey
Howard B. Nickelson, U.S. Geological Survey
Donald E. Owen, Cities Service Oil Company
Paul E. Potter, University of Cincinnati
Lloyd C. Pray, University of Wisconsin at Madison
Bruce Reid, Albuquerque
Allan R. Sanford, New Mexico Tech
Judith A. Schiebout, Louisiana State University
John H. Schilling, Nevada Bureau of Mines & Geology
William R. Seager, New Mexico State University
Herman W. Sheffer, U.S. Bureau of Mines
James E. Sorauf, State University of New York at Binghamton
Wendell J. Stewart, Texaco Inc.
Jorge C. Tover R., Petroleos Mexicanos
Frederick J. Trauger, Albuquerque
Karl Vonder Linden, Earth Science Associates
Stephen G. Wells, University of New Mexico
James Lee Wilson, Rice University
Lee A. Woodward, University of New Mexico

Graduate student

Roy Adams, Rice University
Phillip Allen, New Mexico Tech
Scott K. Anderholm, New Mexico Tech
Sandra J. Anderson, University of New Mexico
Julie Atkinson, New Mexico Tech
Rodney C. Bond, West Texas State University
Sam Bowring, New Mexico Tech
Robert Brod, New Mexico Tech
Craig Caldwell, Rice University
James M. Casey, University of Texas at Austin
Steve Cather, University of Texas at Austin
Michael Chaiffetz, University of Texas at El Paso
Richard Chamberlin, Colorado School of Mines
Jo Anne Cima, New Mexico Tech
Gerry W. Clarkson, New Mexico Tech
Steven D. Craigg, New Mexico Tech
G. Allen Crawford, University of Wisconsin at Madison
Julie F. D'Andrea, Florida State University
Martin A. Donze, New Mexico Tech
Charles Dunning, Rice University
K. Babette Faris, New Mexico Tech
Jeffrey A. Grambling, Princeton University
Scott A. Griffiths, University of New Mexico
Neil F. Hurley, University of Wisconsin at Madison
Robert A. Jackson, New Mexico Tech
Marcus Johnson, Indiana University
Susan C. Kent, New Mexico Tech
Dennis Kurtz, Rice University
Neal LaFon, University of New Mexico
T. Matthew Laroche, New Mexico Tech
David L. Mayerson, New Mexico Tech
Kent McMillan, Stanford University
Douglas A. Neese, University of Wisconsin at Madison
Thomas Neilsen, University of Texas at El Paso
David M. Petty, New Mexico Tech
Malcolm S. Pringle, Jr., Princeton University
Bob R. Robinson, University of Texas at El Paso
Sue Roth, New Mexico Tech
Judy A. Russell, New Mexico Tech
Jon J. Sandor, University of California at Berkeley
J. Frederick Sarg, University of Wisconsin at Madison
Craig E. Savela, West Texas State University
Arthur H. Schwartz, University of Wisconsin at Madison
Charles R. Shearer, New Mexico Tech
Mohamed M. Shetiwy, New Mexico Tech
Ronald O. Simpson, University of Texas at El Paso
Ward Sumner, New Mexico Tech
Michael E. Vazzana, University of New Mexico

Publications

The Bureau issued 22 new publications; one older book was reissued. Eight reports were released to open-file. Twelve large-scale, full-color map sheets were issued (4 in 4 book reports, 8 in 6 map reports).

Pages printed in new publications totaled approximately 730 (667 scientific, 32 pricelist, 26 annual report, and 5 announcement cards). Pages in reissued publications totaled 178. Funds allocated to printing totaled $69,177, or about 5.8 percent of the overall budget for the Bureau.

Approximately 10 percent of new-publication pages were composed in the Bureau as camera-ready copy; 15 percent of the new-publication pages were printed at the New Mexico Tech print shop. In accordance with a practice established many years ago, the Printing Plant at the University of New Mexico (in Albuquerque) continued to serve as the Bureau's main printer. At the close of the fiscal year, 38 manuscripts were in review or were pending; another 21 were in edit or in press.

The editing function was staffed with an editor-geologist, an assistant editor, and editorial assistant, a student proofreader (part time), and a student bibliographer (part time). During the first month of the fiscal year the assistant editor position was vacated but filled immediately by promotion from the editorial assistant position; the latter vacancy was filled in three months. The period required to restore the editing function to full-time effectiveness resulted in a decrease in production. The editors also assisted staff members with manuscripts destined for outside publication.

The drafting and illustrating function was staffed by three scientific illustrators who prepare almost all of the maps, figures, and illustrations appearing in the Bureau's publications. Also, 27 drawings requiring 283 hours of drafting were completed for other offices at Tech. Two members of the drafting section participated in a paste-up short course. Color-proofing techniques were further perfected. The Bureau's stand-alone composer was moved into the drafting room to enable a scientific illustrator to use it for preparing camera-ready legends for maps.

New publications

Memoir 33—GEOLOGY OF ALBUQUERQUE BASIN, NEW MEXICO, by V. C. Kelley, 1977, 60 p., 9 tables, 24 figs., geologic map (scale 1:190,000) and tectonic map (scale 1:280,000) in pocket. $9.50

Discusses stratigraphy, geomorphology, and structure of the Albuquerque Basin, central New Mexico.

Memoir 34—FLUORSPAR IN NEW MEXICO, by W. N. McAnulty, 1978, 64 p., 31 figs., 11 photographs, 14 maps in pocket. $8.00

Describes geology, mining, and uses of fluorspar; lists deposits and discusses major occurrences.

Bulletin 106—BIBLIOGRAPHY OF NEW MEXICO GEOLOGY AND MINERAL TECHNOLOGY 1971 THROUGH 1975, by J. R. Wright and J. A. Russell, 1977, 137 p. $8.00

Lists approximately 2,000 publications concerning New Mexico geoscience and mineral technology issued between January 1, 1971, and December 31, 1975.

Circular 155—GEOLOGIC APPRAISAL OF DEEP COALS, SAN JUAN BASIN, NEW MEXICO, by J. W. Shomaker and M. R. Whyte, 1977, 39 p., 6 tables, 13 figs., 2 appendices. $4.00

Outlines area of Cretaceous coal resources.

Circular 160—LATE CENOZOIC SEDIMENTS, MOLLUSCAN FAUNAS, AND CLAY MINERALS IN NORTHEASTERN NEW MEXICO, by J. C. Frye, A. B. Leonard, and H. D. Glass, 1978, 32 p., 5 tables, 18 figs. $3.50

Discusses Pliocene, Pleistocene, and Holocene stratigraphy, paleontology, and clay-mineral assemblages; stratigraphic zonation of the Ogallala formation is extended north to the

Colorado border and correlated with the floral zones occurring in the Ogallala formation throughout the region. Detailed clay-mineral analyses are also included.

Circular 161—PALEONTOLOGY OF OGALLALA FORMATION, NORTHEASTERN NEW MEXICO, by A. B. Leonard and J. C. Frye, 1978, 22 p., 2 plates, 3 figs. $3.00

Describes fossil seed floras from the Clayton South and Seneca Northeast sections, confirming the correlation between clay-mineral zonation and floral zonation in the Ogallala. An extensive Molluscan fauna is also discussed.

Circular 166—ESTIMATES OF NEW MEXICO'S FUTURE OIL PRODUCTION INCLUDING RESERVES OF THE 50 LARGEST POOLS, by R. W. Foster, A. L. Gutjahr, and G. H. Warner, 1978, 56 p., 8 tables, 58 figs. $4.50

Projects New Mexico's future oil production based on rate of decline in average daily production during 1975-76; projections are made for the entire state, for the northwest and southeast producing areas, and for the 50 largest oil pools.

Circular 167—NEW MEXICO'S ENERGY RESOURCES '77—OFFICE OF THE STATE GEOLOGIST, by E. C. Arnold and others, 1978, 47 p., 29 tables, 17 figs. $3.00

Annual summary of energy developments in New Mexico; discusses reserves of uranium and fossil fuels and availability of geothermal resources.

Progress Report 10—WASHABILITY TESTS AND HEAT-CONTENT PREDICTIONS FOR NEW MEXICO COALS, by R. Shantz, 1978, 16 p., 28 tables, 3 figs. $1.00

Discusses feasibility of washing New Mexico coals and describes a new procedure for predicting heat content from ash percentage.

Geologic Map 31 *rev.*—GEOLOGY OF GRANTS URANIUM REGION, by Chapman, Wood, and Griswold, Inc., 1977, 3 sheets, text. Scale 1:1,000,000. $6.00

Updated version of 1974 edition.

Geologic Map 40—SURFICIAL GEOLOGY OF NORTHEAST NEW MEXICO, by C. B. Hunt, 1977, text. Scale 1:500,000. $3.00

Geologic Map 41—SURFICIAL GEOLOGY OF SOUTHEAST NEW MEXICO, by C. B. Hunt, 1977, text. Scale 1:500,000. $3.00

Geologic Map 42—SURFICIAL GEOLOGY OF SOUTHWEST NEW MEXICO, by C. B. Hunt, 1977, text. Scale 1:500,000. $3.00

Geologic Map 43—SURFICIAL GEOLOGY OF NORTHWEST NEW MEXICO, by C. B. Hunt, 1977, text. Scale 1:500,000. $3.00

Resource Map 10—COAL FIELDS AND MINES OF NEW MEXICO, by D. E. Tabet and S. J. Frost, 1978, text, 3 tables, 4 figs., scale 1:1,000,000. $2.00

Presents an overview of the occurrence and characteristics of coal in New Mexico; introduces the Salt Lake coal field; and lists thicknesses, locations, and geologic units for the 6 active mines and 201 of the inactive mines in the state.

Isochron/West—Nos. 19, 20, 21, edited by J. H. Schilling, 18 p., 29 p., and 35 p. Available by subscription (4 issues for $8.00)

A serial journal of isotopic geochronology.

Pricelist 12—PUBLICATIONS AVAILABLE FROM NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, February 1978, 32 p. Free

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

Annual Report—NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, July 1, 1976, to June 30, 1977, by F. E. Kottlowski and staff, 1977, 88 p. $1.00

Summarizes Bureau activities and services. Also includes articles on Bureau history, Cretaceous guide fossil, uranium industry, thermoluminescence of quartz, mineral processing, and reclamation of mined lands.

Leaflet—DIRECTORY OF COMMERCIAL ANALYTICAL LABORATORIES IN THE SOUTHWEST, by L. A. Brandvold, 6 p. Free

Re-issued publications

Scenic Trips to the Geologic Past No. 8—MOSAIC OF NEW MEXICO'S SCENERY, ROCKS, AND HISTORY, edited by P. W. Christiansen and F. E. Kottlowski, 1972, 170 p., 47 photos. $3.50

Open-File reports

OF-81—PETROLOGY AND GEOCHEMISTRY OF THE PALISADES SILL, NEW MEXICO, by R. P. Cannon, 1977, 76 p., 4 tables, 31 figs., 3 appendices. $18.60

OF-83—PRELIMINARY SELECTION OF SITES GEOLOGICALLY SUITABLE FOR THE DISPOSAL OF HAZARDOUS WASTES IN NEW MEXICO, by R. W. Foster, G. S. Austin, J. W. Hawley, and W. J. Stone, 1977, 64 p., 29 figs. $12.80

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

OF-85–A RECONNAISSANCE STUDY OF JASPEROID IN THE KELLY LIMESTONE, KELLY MINING DISTRICT, NEW MEXICO, by J. Iovenitti, 1977, M.S. thesis, New Mexico Institute of Mining and Technology, 222 p., 2 tables, 85 figs., 1 plate, 1 appendix. $44.40

OF-86–HYDROGEOLOGIC STUDIES OF THE SOCORRO LANDFILL SITE, by R. W. Foster, and W. J. Stone, 1977, 67 p., 4 tables, 5 figs., 2 appendices. $13.40

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

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

Outside papers sponsored in part by Bureau

Adams, R. D., 1978, Effects of localized tectonic activity on regional sedimentation in the Pennsylvanian Madera Formation and the Permian Abo Formation, north-central New Mexico (abs.): Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 10, no. 5, p. 209

Armstrong, A. K., and Mamet, B. L., 1978, Carboniferous (Mississippian) microfacies and stratigraphy, New Mexico and adjacent southeastern Arizona (abs.): American Association of Petroleum Geologists, Bull., v. 62, no. 5, p. 879

Babcock, J. A., and Yurewicz, D. A., 1978, Syndepositional submarine cementation of Capitan Limestone (Permian), Guadalupe Mountains, west Texas and New Mexico–Nature and origin of cements (abs.): American Association of Petroleum Geologists, Bull. v. 62, no. 3, p. 492

Brierley, C. L., 1977, Biogenic extraction of uranium from ores of the Grants region, *in* Proceedings of the International Symposium on Metallurgical Applications of Bacterial Leaching and Related Microbiological Phenomena, Murr, L. E., Torma, A. E., and Brierley, J. A., eds.: New York, Academic Press, p. 345-363

Brierley, C. L., with Brierley, J. A., 1977, Microbial leaching of copper at ambient and elevated temperatures, *in* Proceedings of the International Symposium on Metallurgical Applications of Bacterial Leaching and Related Microbiological Phenomena, Murr, L. E., Torma, A. E., and Brierley, J. A., eds.: New York, Academic Press, p. 477-490

Chapin, C. E., Chamberlin, R. M., Osburn, G. R., Sanford, A. R., and White, D. W., 1978, Exploration framework of the Socorro geothermal area, New Mexico: New Mexico Geological Society, Spec. Pub. 7, p. 114-129, 1 plate

Chapin, C. E., Jahns, R. H., Chamberlin, R. M., and Osburn, G. R., 1978, First day road log from Socorro to Truth or Consequences via Magdalena and Winston: New Mexico Geological Society, Spec. Pub. 7, p. 1-31

Dunning, P. C., 1978 Provenance and paleotectonic setting of Virgilian channel deposits, Holder Formation, Sacramento Mountains (abs.): Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 10, no. 5, p. 215

Eveleth, Robert, and Sheffer, Herman W., 1978, Minerals in the economy of New Mexico: United States Department of the Interior, Bureau of Mines, SMP-5, 18 p.

Hawley, J. W., with Sridhar, K., Jackson, M. L., Clayton, R. N., and Gillette, D. A., 1978, Oxygen isotopic ratios of quartz from wind-erosive soils of southwestern United States in relation to aerosol dust: Soil Science Society of America, Journal, v. 42, no. 1, p. 158-162

Kottlowski, F. E., Beaumont, E. C., and Shomaker, J. W., 1977, Coal seams in New Mexico, *in* 1977 Keystone coal industry manual: New York, McGraw-Hill, p. 633-641

Kottlowski, F. E., with Greenwood, Eugene, and Thompson, Sam III, 1977, Petroleum potential and stratigraphy of Pedregosa Basin: Comparison with Permian and Orogrande Basins: American Association of Petroleum Geologists, Bull., v. 61, p. 1448-1469

Kottlowski, F. E., 1977, New Mexico geology and petroleum potential: Interstate Oil Compact Commission Committee, Bull., v. 19, no. 2, p. 26-30

Kurtz, D. D., 1978, Upper Triassic Chinle Formation–north-central New Mexico: Effects of waning influence of the Southern Ancestral Rocky Mountains of sedimentation (abs.): Geological Society of America, Abstracts with Programs, Rocky Mountain Section, v. 10, no. 5, p. 219

Massingill, G. L., 1978, Geology of the southeastern edge of the Colorado Plateau, Riley area, Socorro County, New Mexico (abs.): Geological Society of America, Abstracts with Programs, v. 10, no. 5, p. 233

Owen D. E., Walters, L. J., Jr., Depetro, L. M., and Turmelle, J. M., 1978, Paleocurrents of Jackpile Sandstone, Burro Canyon Formation, and Dakota Sandstone of San Juan Basin Region, New Mexico, Colorado, and Utah (abs.): American Association of Petroleum Geologists, Bull., v. 62, no. 6, p. 1093

Rautman, C. A., with Wright, R. P., Brenner, R. L., and Hileman, M. E., 1977, Depositional models and paleobiogeography of the Jurassic in the western interior United States (abs.): Journal of Paleontology, v. 51, no. 2, pt. III, p. 32-33

Reiter, Marshall, Shearer, Charles, and Edwards, C. L., 1978, Geothermal anomalies along the Rio Grande rift in New Mexico: Geology, v. 6, no. 2, p. 85-88

Reiter, Marshall, and Smith, Rodger, 1977, Subsurface temperature data in the Socorro Peak KGRA, New Mexico: Geothermal Energy, v. 5, no. 10

Renault, J., and Iovenitti, Joe, 1978, Resolution of x-ray diffraction lines: A model of the 68-degree 2-theta quartz quintuplet: Geological Society of America: Abstracts with Programs, v. 10, no. 5, p. 236

Robertson, J. M., with Silver, L. T., Anderson, C. A., and Crittenden, M., 1977, Chronostratigraphic elements of the Precambrian rocks of the southwestern and far western United States (abs.): Geological Society of America, Abstracts with Programs, v. 9, no. 7, p. 1176

Shantz, R. and Reich, J., 1978, A review of copper-cyanide metallurgy: Hydrometallurgy, v. 3, no. 2, p. 99-109

Stone, W. J., with Lyford, F. P., 1978, Ground-water resources of northwestern New Mexico (abs.): Geological Society of America, Abstracts with programs, v. 10, no. 5, p. 220

Taggart, Joseph E., Jr., 1977, Polishing techniques for geological samples: American Mineralogist, v. 62, no. 8, p. 824-827

Thompson, S., III, with Mitchum, R. M., Jr., and Vail, P. R., 1977, Seismic stratigraphy and global changes of sea level, Part 2: The depositional sequence as a basic unit for stratigraphic analysis: American Association of Petroleum Geologists, Mem. 26, p. 53-62

Thompson, S., III, with Mitchum, R. M., Jr., and Vail, P. R., 1977, Seismic stratigraphy and global changes of sea level, Part 3: Relative changes of sea level from coastal onlap: American Association of Petroleum Geologists, Mem. 26, p. 63-81

Thompson, S., III, with Mitchum, R. M., Jr., and Vail, P. R., 1977, Seismic stratigraphy and global changes of sea level, Part 4: Global cycles of relative changes of sea level: American Association of Petroleum Geologists, Mem. 26, p. 83-97

Thompson, S., III, with Greenwood, E., and Kottlowski, F. E., 1977, Petroleum potential and stratigraphy of Pedregosa basin: Comparison with Permian and Orogrande basins: American Association of Petroleum Geologists, Bull., v. 61, p. 1448-1469

Van Wagoner, J. C., 1978, Pennsylvanian carbonate and siliciclastic depositional patterns and sequences across Sacramento Shelf, New Mexico (abs.): American Association of Petroleum Geologists, Bull., v. 62, no. 3, p. 569

Yurewicz, D. A., 1978, Syndepositional submarine cementation of Capitan Limestone (Permian), Guadalupe Mountains, west Texas and New Mexico—Cement evolution (abs.): American Association of Petroleum Geologists, Bull., v. 62, no. 3, p. 573

Other activities

Participation in scientific & professional conferences

American Association for the Advancement of Science: Regional meeting, April

American Association of Petroleum Geologists: Annual meeting, April

American Chemical Society: Conference on Sensing of Environmental Pollutants, November

American Institute of Mining Engineers: 107th American Institute of Mining, Metallurgical and Petroleum Engineers, Annual meeting, February and March; Central New Mexico Section of American Institute of Mining, Metallurgical, and Petroleum Engineers, March; Society of Mining Engineers, Annual meeting, October

American Society of Agronomy: November

American Society for Microbiology: New Mexico Branch meeting, October

Archaeological Society of New Mexico: Annual meeting, April

Archaeological Society of New Mexico—Museum of New Mexico: Ghost Ranch seminar, September

Department of Energy, Public Forum—Waste Isolation Pilot Plant site: April

Geological Society of America: Annual meeting, November; South-central section meeting, March; Rocky Mountain section meeting, April; Rocky Mountain Ground Water Conference, May

Gordon Research Conference: Microbial Degradation, July

Governor's Conference on Geological Hazards: February

Industrial Minerals Forum: May
Institute de Geologia (Mexico) at the University of Sonora: First Symposium on the Geology and Mineral Potential in the State of Sonora, May
Los Alamos Scientific Laboratory: Fifth Life Sciences Symposium, Hazardous Solid Wastes and Their Disposal, October
Mineral Waste Stabilization Liaison Committee: Annual meeting, July
National Science Foundation and New Mexico Tech: International Symposium on Metallurgical Applications of Bacterial Leaching and Related Microbiological Phenomena, August
New Mexico Geological Society: Fall meeting and field conference, San Juan Basin, September; Spring meeting and field conference, Datil volcanic field, May
Nuclear Regulatory Commission: September
Oak Ridge National Laboratory: Symposium on Biotechnology in Energy Production and Conservation, May
Soil Conservation Society of America, New Mexico Chapter: Annual meeting, February
Soil Science Society of America: Annual meeting, November
Southwest Minerals Conference: October
Water Resources Research Institute: Water Conference, May

Participation in committees and commissions

GOVERNMENTAL

Brandvold—New Mexico Water Conference Advisory Board; New Mexico Water Quality Control Commission, Director's appointee
Eveleth—Federal Office of Surface Mining, Task Force hearing, Denver, Colorado; Coal Surfacemining Commission—Department of the Interior meeting, Denver, Colorado; represented Bureau and Coal Surfacemining Commission on spring coal mine inspection, McKinley and San Juan Counties
Foster—Waste Isolation Pilot Project (WIPP) Review Committee
Hook—New Mexico Paleontological Task Force, alternate member; United States Geological Society Geologic Names Committee meeting
Kottlowski—New Mexico Mine Safety Advisory Board (chairman); New Mexico Coal Surfacemining Commission (director and secretary); Energy Resources Board; Governor's Energy and Science Subcabinet; Governor's Commerce and Industry Subcabinet; Governor's Energy Related Growth and Development Committee; Energy Research and Development Review Board; Association of American State Geologists (Federal Liaison Committee)
Stone—New Mexico Water Conference Advisory Committee; Landfill Committee, city of Socorro (City Council Committee); Water Resources Research Institute, Program development and review board
Weber—New Mexico Mapping Advisory Committee

PROFESSIONAL

Austin—New Mexico Geological Society (Publication Committee); Sigma Xi (Executive Council, past-President 1977-78; Nominations Committee; Committee for Chapter Status, organizer)
Bieberman—American Association of Petroleum Geologists (House of Delegates, Representing New Mexico Geological Society; Rules and Procedures Committee, chairman; Committee on Preservation of Samples and Cores; Membership Committee)
Brierley—American Society for Microbiology (Project 6, Geomicrobiology, US/USSR Joint Commission on Science and Technology)
Chapin—International Symposium on the Rio Grande rift, Program chairman, New Mexico Geological Society, 1978 spring meeting, general chairman
Eveleth— New Mexico Geological Society registration chairman, 1978 spring field trip
Flower-Cambro—Ordovician Boundary Committee
Hawley—Geological Society of America/GSA Soil Science Society of America, Interdisciplinary Committee; Soil Science Society of America/Geological Society of America, Liaison representative; Rift Zones of the Earth-International symposium, field trip coordinator
Kelley—Association of Earth Science Editors, Board of Directors, Vice President
Kottlowski—Geological Society of America (Publications Committee, chairman; Coal Geology Division: Publications Committee and Nominating Committee); American Association of Petroleum Geologists (Publications Committee); Strategic Committee on Public Affairs, Associate Editor; Petroleum Resources Estimation Project; Regional Coordinator for Correla-

tion of Stratigraphic Units of North America; American Commission on Stratigraphic Nomenclature (representing Association of State Geologists); New Mexico Mining Association (Board of Directors; Information and Education Committee); Potential Gas Committee

Renault—New Mexico Energy Institute, New Mexico State University Executive Committee, Visiting Scientist; Sigma Xi, Vice President

Thompson—New Mexico Geological Society, road log committee

Weber—Archaeological Society of New Mexico (Board of Trustees, Vice President)

NEW MEXICO TECH

Austin—Financial Aids and Scholarship Committee, chairman; Graduate Council; Institute Insurance Review Committee; Engineering Planning Committee; Geological Engineering Committee; Long-Range Planning Committee; Building, Space, and Equipment Subcommittee of the Long-Range Planning Committee, chairman; Geoscience Department Kitchen Kabinet; Geoscience Department staff member

Brierley—Earth Sciences Brown Bag Seminar, co-chairman; Budget and Finance Committee for Long-Range Planning; Science and Engineering Symposium '77: A Woman's Perspective, co-director

Holts—Affirmative Action Committee, chairman

Reiter—Graduate Council; Sabbatical Leave Council; Geoscience Department Adjunct Professor

Siemers—Non-college division subcommittee of Long-Range Planning Committee

Stone—Council of Chairpersons

Articles in Bureau publications

Arnold, E. C., Hill, J. M., Donaldson, D. A., Martinez, L. B., Foster, R. W., and Gutjahr, A. L., 1978, Oil and Gas, *in* Circular 167, p. 9-27

Hook, S. C., and Cobban, W. A., *Pycnodonte newberryi* (Stanton)—Common guide fossil in Upper Cretaceous of New Mexico, Contributed article to Annual Report 1976-77, p. 48-54

Merillat, C. H., Sketch of the first fifty years of the New Mexico Bureau of Mines and Mineral Resources, Contributed article to Annual Report 1976-77, p. 29-33

Merillat, C. H., Acts of the New Mexico Legislature 1927-77 relating to New Mexico Bureau of Mines and Mineral Resources, Contributed article to Annual Report 1976-77, p. 34-47

Rautman, C., Uranium industry of New Mexico, Contributed article to Annual Report 1976-77, p. 55-65

Renault, J. R., and Hayslip, D. L., Thermoluminescence of quartz in uraniferous sandstones—Methods and initial tests, Contributed article to Annual Report 1976-77, p. 66-75

Shantz, R., Mineral processing in New Mexico, Contributed article to Annual Report 1976-77, p. 76-79

Tabet, D. E., Reclamation of coal surface-mined lands in New Mexico, Contributed article to Annual Report 1976-77, p. 81-85

Off-campus talks

Arnold W., "Map making techniques" at New Mexico State University, Las Cruces, February

Brandvold, L., "Careers in chemistry" for Women's Idea Conference, Socorro, January

Brierley, C., "The use of thermophilic microbes in metals extraction" at the University of Cardiff, Wales, September

———, "Mining by nature's easy way: microbial extraction of copper" for Visiting Scientist Program, Raton, New Mexico, November

———, "Recent developments in bioextractive metallurgy" at the University of Utah, Salt Lake City, April

———, "Studies on the effects of heavy metals on nitrogen-fixing bacteria" at Mineral Waste Stabilization Liaison Committee meeting, Billings, Montana, July

———, "Microbial extraction of metals from ores" at Gordon Research Conference on Microbial Degradation, Tilton, New Hampshire, July

———, "Energy and the urban environment: a systems approach based on use of surface-mined coal" at Symposium on Biotechnology in Energy Production and Conservation, Gatlinburg, Tennessee, May

———, "The effects of hydrogen peroxide on leach dump bacteria" at Society of Mining Engineers, American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME) annual meeting, St. Louis, October

Chapin, C., "Evolution of the Rio Grande rift" for Geoscience Dept., University of Arizona, Tucson, March

———, "Evolution of the Rio Grande rift" for Geology Dept., University of New Mexico, Albuquerque, November

Hawley, J., "Approaches to environmental geology in New Mexico" at University of New Mexico geology seminar, Albuquerque, March

———, "Geologic history and geomorphology of the Las Cruces area, New Mexico" at National Soil Judging Contest; New Mexico State University, Las Cruces, April

———, "Geologic hazards in New Mexico" at State Office of Civil Defense conference, Las Cruces, April

Hook, S., "Cretaceous stratigraphy of the Acoma Basin" at U.S. Geological Survey Geologic Names Committee meeting in Denver, February

Kottlowski, F., "New Mexico's geology and petroleum potential" at Interstate Oil Compact Commission annual meeting, Santa Fe, December

Renault, J., "Crystallization" at Bernalillo Jr. High, Bernalillo, December

Shantz, R., "New Mexico Bureau of Mines and Mineral Resources metallurgy program" at Southwestern New Mexico AIME section, Silver City, October

———, "New Mexico Bureau of Mines and Mineral Resources metallurgy program" at Carlsbad AIME potash section meeting, Carlsbad, April

Stone, W., "Overview of hydrogeology and proposed uranium mining, San Juan Basin" at 8th Rocky Mountain Ground Water Conference, Tucson, May

———, "Water and energy development, San Juan Basin" at Four Corners Geological Society, Farmington, October

Weber, R., "An iron meteorite from an archaeological site near Quemado, New Mexico" at Archaeological Society of New Mexico annual meeting, Farmington, April

———, "Lithic materials and their archaeological utilization" at Archaeological Society of New Mexico-Museum of New Mexico Ghost Ranch seminar, Abiquiu, September

———, "Lithic materials and their archaeological utilization" at Archaeological Society of New Mexico field school, Gallup, June

Staff

New employees joining the Bureau were: Brenda R. Broadwell, Assistant Laboratory Geoscientist, 3 April 1978; Jim P. Dodson, Technician I, 1 September 1977; Robert Eveleth, Mining Engineer, 1 December 1977; Bradley B. House, Technician I, 1 August 1977; Don F. Jordan, Technician I, 5 June 1978; Terri R. Jaramillo, Secretary I, September 1977; Thomas D. Kameron, Technician I, 2 February 1978; Gary L. Massingill, Coal Stratigrapher (Post-Doctoral Fellow), 1 June 1977; Robert Mattis, Technician I, 19 December 1977; Karen D. Patterson, Secretary, 29 August 1977; Arleen Montoya, Typist, 22 May 1978; Jeanette L. Chavez, Typist, 14 June 1978; Wm. Terry Siemers, Industrial Minerals Geologist, 10 October 1977; Roy G. Taylor, Technician I, 20 July 1977; and William T. Willis, Driller, 20 February 1977.

Resignations during the fiscal year were: Thea Davidson, Technician I, 15 July 1977; Terri R. Jaramillo, Secretary I, 11 November 1977; Thomas D. Kameron, Technician I, 31 May 1977; Arthur J. Mansure, Geophysicist (Post-Doctoral Fellow), 30 June 1977; Gloria Padilla, Secretary, 2 September 1977; Judy A. Russell, Assistant Editor, 15 July 1977; Joseph E. Taggart, Jr., Mineralogist, 31 May 1978; Roy G. Taylor, Driller, 31 May 1978; David L. White, Geochemist

(Post-Doctoral Fellow), 24 April 1978; and Michael R. Whyte, Field Geologist, 31 May 1978.

Promotions were: Stephen C. Hook to Paleontologist, 1 April 1978; Candace L. Holts to Assistant Editor, 1 July 1977; Judy A. Russell to Assistant Editor, 1 July 1977; Joan C. Pendleton to Editorial Assistant, 16 August 1977; and Roy G. Taylor to Driller, 1 April 1978.

Rousseau H. Flower retired after 26 years and 5 months service with the Bureau, 1 March 1978. Rejoining the Bureau were Nancy H. Mizell, Geologist, 3 January 1978, and Julie A. Zepeda, Secretary I, 17 November 1977.

Contributed articles

The 1872 Mining Law: is it really obsolete?

by Robert W. Eveleth, *Mining Engineer*

The 1872 Mining Law has been in force for more than one hundred years. This remarkable legislation has provided the sound basis for discovering and producing much of the supply of mineral resources needed in the phenomenal growth and development of this nation. The law allows each citizen, regardless of wealth or social standing, using little more than brawn and brains, to prospect, discover, and develop valuable mineral deposits on the public domain. Because the law is based upon the principle of self initiation, countless individuals have discovered and developed many valuable deposits, creating wealth not only for themselves but also for all who ultimately use the minerals and the finished products. The list of major discoveries is long and impressive. Gold—California; Deadwood, South Dakota; Cripple Creek, Ouray, and Telluride, Colorado. Silver—Coeur d'Alene, Idaho; Virginia City, Nevada; and Leadville, Colorado. Copper—Bisbee, Morenci, and Tucson, Arizona; Silver City, New Mexico; and Butte, Montana. All have one thing in common: they were discovered by the "little guys."

But memories are short, and many people do not see beyond the speeches of a growing number of officials and politicians who claim that our nation is being "ripped off" by the miners—that the public is not receiving its share of the profits (that is, a royalty) from mineral production. These same officials fail to tell the public that in reality our mineral industry's ability to produce raw materials cheaply and efficiently allows so many to own automobiles and home appliances, all requiring tremendous quantities of minerals and metals. The average citizen is surprisingly uninformed about the source of the materials for these modern conveniences. The general impression seems to be that minerals and metals are lying about on the ground free for the taking by the first prospector or miner who happens along. This misconception is partly due to a readily available supply of these materials at the local store; we unconsciously assume that they must also be readily obtained from the ground. But they are not. Only the stimulus of our "obsolete" mining law, coupled with ingenious exploration and extraction methods, has assured a more than ample supply.

The law is not perfect, however. Parts need to be strengthened and modernized. Some entirely new parts, not even considered in 1872, need to be incorporated. Nevertheless, the main concepts embodied in the law are just as applicable now as they were more than one hundred years ago. Today competition for land is much more intense; therefore, some changes in the law are inevitable. To understand the effect of some of the changes being considered, let's go back to the time when the basic concepts of our present mining law were first conceived and note the forces and events that brought them about.

On January 24, 1848, at Coloma, California, on the south fork of the American River, John Sutter and James Marshall were building a sawmill to provide lumber for Captain Sutter's numerous construction projects. While inspecting the millrace on this particular day, Marshall found some yellow metallic flakes on the freshly scoured bedrock and casually mentioned the discovery to one of his laborers. A few days later he and Sutter tested the density of the metal and

confirmed that the flakes were gold. Because of Marshall's indiscretion, however, word of the discovery was already out, spreading slowly at first but quickly gaining speed. In May, only a few hundred gold seekers were in the area, but by July, 4,000 or more were on hand. By the time California entered the Union on September, 1850, the local population had mushroomed to several hundred thousand—nearly all seeking gold. This gold rush was probably the greatest the world had ever seen or is ever likely to see. This great mass of immigrants was confronted with a unique set of circumstances that compelled the miners to create the forerunners of our present day mining laws. What right did these ragtag immigrants have to mine the gold? None, really, as we shall see.

When the treaty of Guadalupe-Hidalgo was concluded February 2, 1848, more than half a million square miles were added to the territories of the United States. The new territory included the future states of California, Nevada, Utah, Arizona (exclusive of the Gadsden Purchase), New Mexico (west of the Rockies and north of the Gadsden Purchase), Colorado (west of the Rockies), and southwest Wyoming. Had communications been a little faster or the gold discovered a little sooner, possibly none of this would have ever happened. Nevertheless, just ten days after the treaty was concluded, Colonel Mason, the new military governor of California, declared the Mexican mining laws to be null and void. The 49'ers, as they would come to be called in later years, were already entering the newly acquired lands and mining the gold. This occupancy was definitely illegal; indeed, the very idea ran counter to the English and Spanish laws of sovereign mining rights.

Furthermore, there were no federal statutes to regulate the mining of minerals on the public domain. The 1830 gold rush in Georgia had not produced federal legislation on mining because Georgia, being one of the original 13 colonies, had no public domain. On the other hand, nearly all of California was public domain, and the miners were taking possession and mining as soon as they arrived. They were clearly trespassing, but for several reasons the military governor chose not to interfere. First, he commanded only a small armed force (which more than likely grew smaller as the gold fever grew larger). Second, the sheer size of the region, coupled with the number and character of the miners, made a policy of non-interference the wisest choice. Governor Mason was "resolved not to interfere but to permit all to work freely unless broils and crimes should call for my interference" (*Donaldson's Public Domain, August 17, 1848, 314*). The 49'ers, probably led by the Cornish and Welsh miners, were left to come up with a system of rules and regulations. They accomplished this task so well that their rules were eventually approved by the local courts, the states, and finally the federal government.

The so-called common laws of mining recognized first the discoverer's right of immediate possession; second, his right to maintain his claim by the performance of labor; and third, the citizen's right to absolute equality in locating and working his claim. These three concepts are the cornerstones of the common mining laws and the basis of the 1872 law. While the miners in the various districts agreed on these three points, there were invariably differences regarding claim dimensions, how a claim was to be located, and how much labor was necessary to keep it valid. The miner, then, had to be familiar with the regulations of each district to be sure his claim was properly located, filed, and maintained. Doubtless, Congress would have remedied these problems much sooner had not the 1853 California Supreme Court laid claim to the mineral rights. The rationale was that under the Spanish government the minerals were vested in the Crown and that

when Mexico separated from Spain the right vested to Mexico; when California was ceded to the United States by treaty, "the minerals of gold and silver which passed by the cession were held by the United States in trust for the future state, and that upon the admission of California, the ownership of them vested in her" (*MOORE v. SMAW, 17 CAL, 199, 217, 79 Am Dec 123 and HICKS v. BELL, 3 CAL 219*).

Surprisingly, these assertions were not contested in the U.S. Supreme Court. California continued to lay claim to the minerals within her boundaries until 1861, when the California Supreme Court reversed its prior assertion and acknowledged that the mineral rights were vested in the United States (*MOORE v. SMAW, 17 CAL 199, 218-222, Am Dec 123*).

Perhaps because of the Civil War, Congress made little attempt to legislate a mining law for five years. The Act of February 27, 1865, did provide "that no pending action between individuals in any of the courts for the recovery of a mining title, or for damages to any such title shall be affected by the fact that the paramount title to the land on which such mines lie is in the United States, but each case shall be judged by the law of possession" (*13 STAT. 441, c. 64*). A year later, Congress passed the Act of 1866 declaring the mineral lands of the public domain "to be free and open to exploration and occupation by all citizens and those who declared their intention to be citizens of the United States" (*14 STAT. 251, c. 262*). The Act of 1866 recognized the customs and rules of the various mining districts where those rules and regulations were not in conflict with the laws of the United States. Also included was a provision recognizing extralateral rights, a method for obtaining a patent on a lode claim, and a provision protecting water rights vested by priority of possession. Now the miners could do legally what they had been doing in trespass all along. Furthermore, when the Act of 1866 was passed, it was recognized that "not only without interference by the national government, but under its implied sanction, vast mining interests have grown up, employing many millions in capital, and contributing largely to the prosperity and improvement of the whole country (*SPARROW v. STRONG, 3 Wall. 97, 104, 18 L. Ed. 49*). Supposedly, the idea of a royalty from the minerals produced was forever relinquished (*Ivanhoe Mining Co. v. Consolidated Mining Co., 102 U.S. 167, 173, 26 L. Ed. 126*).

More legislation was passed during the next six years clarifying the language concerning ownership of multiple veins on the claim surface and setting forth complete details regarding the patent procedure. The whole package became known as the Mining Law of 1872. With relatively little change, the same law is in force today. Some of its many beneficial aspects follow.

1) The law is easy to understand and does not require the interference of a large federal bureaucracy to implement.
2) The public domain was opened up for exploration and production of minerals.
3) Each citizen has the right to prospect, locate, and produce minerals from the public domain.
4) The procedure was not capital intensive. Valuable minerals could be located using little more than time and effort (large capital outlays are generally necessary for development, however).
5) The law recognized the discoverer's right of possession to the minerals he located, his right to mine those minerals, and his right to retain the same as long as he performed at least $100 worth of annual assessment work.

6) A means was provided whereby patent (title) could be obtained on lands that proved to contain a valuable deposit.

These rights and benefits were obtained only after the performance of certain acts, including: 1) discovery of a mineral deposit "of such character that a person of ordinary prudence would be justified in the further expenditure of his labors and means, with a reasonable prospect of success in developing a paying mine" (*Mineral patents, U.S. Dept. Interior, B.L.M., 1967, 1*), 2) posting a proper location notice, 3) marking the boundaries of the claim with sufficiently visible monuments, and 4) recording the location of the claim according to local requirements.

A proper discovery is the basis of the right to locate a claim and mine the minerals. A valid mineral location cannot be made without a proper discovery. A *lode claim* is located on a vein or an outcrop of ore-bearing "rock in place." The simplest claim configuration is a rectangle. A claim may also be laid out as a parallelogram or perhaps some other configuration, providing: the claim does not extend for more than 1,500 ft along the course of the vein or lode, not more than 300 ft either side of the vein or lode, and the endlines remain parallel. The latter requirement is necessary because of the extralateral rights provision.

A *placer claim* may be located on minerals that are not contained "in rock in place," such as gold, platinum, and other dense mineral grains that have been concentrated in sands and gravels by the action of erosion and gravity. A placer claim must generally conform to the public survey, or, if located on unsurveyed land, the claim must conform to north-south, east-west lines where practicable. A single person is allowed to claim up to 20 acres (but no less than 10 acres except under special circumstances) and as many as 8 persons may claim 20 acres each, up to a total of 160 acres, in 1 placer. A placer claim is staked much the same as a lode claim; only 1 discovery is necessary. The corners are marked with substantial monuments similar to those of a lode claim. More detailed rules and regulations concerning the staking of lode and placer claims are available from the U.S. Department of the Interior, Bureau of Land Management. The citizen should acquaint himself with these regulations before locating a claim.

If a claim or a group of claims contains a valuable mineral deposit, the owner may apply for a patent. The patenting of a claim can be an expensive procedure, and the claimant should be familiar with all the legal requirements prior to such an undertaking (see *Basic Procedure for Obtaining Patent to a Mining Claim, U.S. Dept. Interior, B.L.M., 1976*). Occasionally, patented mining claims are encountered in the field. Corner monuments are usually squared, inscribed stones planted securely in the ground or a steel pipe and brass cap and are easy to recognize. Mineral-survey data may or may not be inscribed in the stone or cap. The plat maps of patented claims are on file in the office of the U.S. Bureau of Land Management; copies may be obtained for a nominal fee.

Despite beneficial aspects, the law suffers from several deficiencies that should be corrected. The main complaint today is that the law is completely silent in regard to how the environment is to be protected during the life of an operation and how the lands are to be reclaimed for other uses when the facility ceases to operate. A trip through a major mining district will show that past abuses are relatively easy to find. In many areas, large dumps and tailings piles have been left to decompose by weathering processes and be blown away by wind.

Dumps and piles containing pyrite and other sulphides have been especially detrimental to surface waters and vegetation. Where rainfall is plentiful and ground water abundant, natural leaching of these dumps is accelerated. In some

districts acid waters draining directly from abandoned mine openings cause additional damage. Certainly provisions protecting land and water resources should be included in amendments to the existing law. Serious consideration should also be given to the elimination of hazards, mainly on abandoned sites, including unfenced and unmarked open shafts, gassy mine tunnels, and abandoned or rundown surface structures. Although filling in or sealing off hazardous mine openings may seem to be the answer, old and accessible mine workings could prove to be invaluable by providing ready access for future exploration.

For some people, the royalty question is the most significant shortcoming of the whole law. Formerly, the nation's lawmakers felt that every citizen benefited from the prosperity created by the production of minerals from the public domain, and therefore a royalty was unnecessary. But philosophies have changed and many persons are clamoring for such a royalty. The added burden of any royalty on mineral production would be passed on to the consumer in the form of higher prices, except in the metals industry where prices are determined in the international market and where increased costs cannot be passed on to the consumer or absorbed out of profits.

Would the public benefit once these royalty funds are deposited in the various public treasuries? Would this benefit offset the increased costs incurred, starting with the raw material and continuing on through to the finished product? Probably not. Politicians and bureaucrats would prefer to have the money. Royalty is definitely a point of contention in the present fight to amend or repeal the 1872 law.

Something else has helped to bring about a general feeling of dissatisfaction with our mining industry—the tarnished image portrayed by some of the operators. The public has an uneasy, suspicious feeling regarding big business in general. This feeling toward the mining industry in particular is, in part, a response to the attitudes of some of the companies. Not all are guilty, but the mining industry in general has never really been adept at polishing its public image. Many of the more progressive companies have done an excellent job of informing the public about the absolute necessity of mining. They have also taken the lead in making efforts to protect the environment and have taken a general interest in the affairs of their communities. But their accomplishments are little noticed by the nation as a whole when other companies fail to keep the public well informed through various news releases and to hold open houses and tours of reclamation efforts. For example, a company was preparing a new area for open-pit mining. The topsoil was stripped off and discarded on the waste dump along with the rubble from the existing operation. The topsoil was forever lost. The suggestion was made to stockpile the topsoil for some future use, perhaps to cover a tailing pond or a waste dump area. The reaction was "we don't have to do that." Soon a law may compel such conservation practices at both ongoing and inactive operations. Reclamation of past abuses will be very costly. In some cases, the "we don't have to" attitude is so deeply entrenched that some of the operators still refuse to talk to the public. A variation of "we don't have to" is the "none of your business" attitude. Recently, for example, an obviously biased newspaper reporter interviewed several of the major mining companies around the state regarding their views on the location-patent system. These companies are, almost without exception, conducting mining operations on lands on the public domain or that were once part of the public domain and are now patented. Here was a real opportunity for the mine operators to point out the beneficial aspects of the 1872 law, but little was said in its behalf. One

company that had no constructive comments is fortunate enough to actually have on its staff a U.S. mineral surveyor who is intimately familiar with the patent procedure. But not one word in defense of the law was uttered. Clearly, these attitudes on the part of a few operators have helped create the public furor today for the repeal of the 1872 law. Such attitudes and the resulting tarnished image of these operators definitely need correction although time may have already run out.

What is in the future for the minerals industry? The entire law may be repealed and replaced with a leasing system similar to the present regulations covering the fuel and fertilizer minerals. A leasing system for those minerals presently locatable is probably the worst thing that could happen to the country. Indeed, society is already paying for the present leasing system. The officials and politicians who are advocating these procedures ought to know better.

How will such a leasing system do more harm than good? Judging from the current federal leasing system for fuel and fertilizer, mining may not take place at all. Because of unrealistic requirements in federal leases, not one coal-prospecting permit has been issued since 1971; only a few token leases have been approved in the meantime. Also, few leases or exploration permits for potash and trona have been issued in the last decade.

Exploration for minerals presently locatable under the 1872 Mining Law would virtually come to a standstill under such a leasing system. The federal leasing system is a bureaucratic mess that simply does not work. Under such conditions, only the largest of the mineral producers will be able to survive. Ironically, the public, on the one hand, is suspicious of giant corporations and, on the other hand, is paving the way toward their creation! So much red tape is involved, so much delay in reviewing and approving or rejecting mining and reclamation plans, that a great number of mine operators would go broke just waiting for an answer. Few companies have employees capable of preparing such a plan. Smaller outfits can't afford to hire a consulting firm to prepare a plan like many of the large companies do. Under such a leasing system small operators would become part of history; that would be an economic loss for the country. A recent study by Congressman Jim Santini of Nevada has found that 64 percent of the nonfuel operations in our country today are conducted by companies composed of nine employees or less. Proponents of the leasing system say that the small operators would be given special consideration, but some officials in Washington would limit the "small operator" to three employees!

According to a 1977 study by the U.S. Bureau of Mines, the nation's small operators produce: 100 percent of the crude asbestos, talc, industrial garnet, graphite, and kyanite; over 60 percent of the perlite and dimension stone; over 50 percent of the barite and feldspar; 49 percent of the mica; and 24 percent of the gypsum. The story of silver and gold production is much the same. In California, small operators account for 59 percent of the silver and 80 percent of the gold produced. In Nevada, they account for 56 percent of the silver; in New Mexico, 35 percent of the gold. Furthermore, the nation's small operators produce 71 percent of the silver in 37 other states. We simply cannot afford to put the small operators out of business. Without their domestic production, our nation would be forced to import these products.

But aren't these minerals being produced from deposits discovered years ago? Won't our future mineral needs be found by the big companies? The role of the small operator is still vital today in discovering new deposits. Recently AMAX, Inc. learned that from 1970-1975, small operators submitted annually 1,900-2,500

mineral prospects to 41 large mining companies. Almost half of these prospects were investigated further, resulting in 12-18 new mines planned or developed annually—proof enough that the small operator or prospector is effectively contributing to the mineral needs of our nation. Whether we continue to allow him to do so remains to be seen. Under the leasing system being proposed today, a prospector or small operator has no guarantee that he will be able to mine the minerals he has discovered. Thus, the incentive to find new deposits simply won't be there.

SUMMARY—the 1872 Mining Law has served us well and, with some amending, will continue to do so in the future. Reclamation provisions and realistic environmental standards should be added. The $100 annual assessment should be adjusted upward to a more realistic figure ($100 was a tidy sum in 1872). Patent fees should be adjusted upward to reflect the present market value of real estate. Replacing the present law with a leasing system is not acceptable. Amended, the 1872 law is more than capable of providing the stimulus for finding the nation's mineral needs in the future.

Coal industry of New Mexico in 1978

by Stephen J. Frost, *Coal Geologist*

Coal is one of the fossil fuels. It is also a sedimentary rock formed from the carbonaceous residue of vegetative debris that accumulated in ancient swamps and lagoons. The major coal deposits in New Mexico originated 50-100 m.y. ago (late Cretaceous to early Tertiary) in an environment resembling the deltaic swamps along the present coast of the Gulf of Mexico. The coal beds in New Mexico are irregular in thickness and elongated parallel to the ancient shorelines. Unlike the coal beds of the eastern United States, individual coal beds in New Mexico extend relatively short distances and are therefore difficult to correlate over wide areas (fig. 1).

The main coal-bearing geologic units are: 1) the Mesaverde Group and Fruitland Formation in the San Juan Basin, 2) the Mesaverde Group in central New Mexico, and 3) the Vermejo and Raton Formations in the Raton Basin.

The total coal resource in New Mexico is an estimated 180.5 billion short tons. Of this total, 6.4 billion short tons (3.5 percent) are considered strippable (less than 250 ft of overburden) ranking New Mexico third behind Montana and Wyoming in strippable coal resources. The thickness of an average strippable coal bed in New Mexico is 11 ft compared with 67 ft in Wyoming and 24 ft in Montana.

formation	rank	% ash	Btu	% sulfur
Fruitland	subbituminous	15.85	12,100	<1
Mesaverde	subbituminous	11.0	13,000	<1
Raton	bituminous	11.98	13,465	<1
Vermejo	bituminous	13.68	12,204	<1

High-quality coking coal occurs in the Raton and Carthage fields; weak to moderate quality coking coal occurs in the Cerrillos and Sierra Blanca fields.

Of the state's 121,666 sq mi of surface area, 14,650 sq mi (12 percent) is underlain by coal deposits. The coal and surface rights in New Mexico are typical of the western states with a mixed checkerboard pattern of federal, state, Indian, and private ownership. For example, of the strippable coal resources in the San Juan Basin, 45 percent are controlled by the U.S. Department of the Interior, 34 percent by the Indian tribes, 7 percent by the state, and 10 percent by private ownership. Frequently surface and coal ownership are mixed.

A sudden resurgence of interest in New Mexico coal began in the early 1960's with the opening of two large strip mines in the San Juan Basin. These mines supplied electric-generating complexes in Arizona and New Mexico. Production has increased steadily from around 3 million tons in the early 1960's to over 11.5 million tons with a value of $87,841,748 in 1977. Current production is from six mines with four others coming on stream in the early 1980's.

Most of the 1977 tonnage was used as steam coal for coal-fired electric-power generation and was produced from three large strip mines in the San Juan Basin. The mine-mouth power plants supplied by the Navajo and San Juan mines (only 8 mi apart) compose the largest single concentration of electrical generating facilities west of the Mississippi River. The Pittsburg and Midway McKinley mine near Gallup supplies the Cholla generating plant in Arizona. The Amcoal #1 mine, a small surface mine near Gallup, now provides coal for cement plants in Phoenix, Arizona, and Long Beach, California. The York Canyon mines, in the Raton field, ship high-quality coking coal to Kaiser's steel mills in Fontana, California.

FIGURE 1—MAP SHOWING COAL FIELDS AND MINES OF NEW MEXICO

At present New Mexico exports only a small percentage of its steam coal; however, this situation will change considerably over the next decade with increased exports to neighboring states. The increasing interest and demand for New Mexico coal arises from a growing need for steam coal for the electric utilities in California, Texas, and Arizona. New Mexico's proximity to these markets, combined with the lack of appreciable reserves of similar quality in the area, gives New Mexico coal an edge.

The U.S. Bureau of Land Management regional San Juan Basin EIS (Environmental Impact Statement) for the new federal leasing program brought forth 11 company proposals for mines in the basin, involving over 900 million tons of coal. However, the 1976 decision by U.S. District Judge John H. Pratt,

has caused federal leasing in the basin to be set back. New federal leases are not expected before the early 1980's. This situation has hindered the plans of a number of companies but has not stopped all development. During 1978 three mining permits for strip mines in the basin were issued by the New Mexico Coal Surfacemining Commission. These mines will be on private, state, Indian, or existing federal leases. Permits were issued to the Con Pase mine (Consolidation Coal), the Gallo Wash mine (Tucson Gas and Electric), and the Arroyo #1 mine (Albert Firchau). At least two other companies with interest in the basin are preparing for permit hearings in the next year or so. Involved are the Cimarron Coal mine near La Plata and the Ideal Basic Industries mine near La Ventana.

With the EIS tying up leasing in the San Juan Basin to a large extent, activity outside the basin has increased sharply, notably in the larger outlying fields such as Sierra Blanca, Raton, and Salt Lake. Since the state leasing sale of 1977, two companies have begun applying for surface-mining permits in the Sierra Blanca field, north of Carrizozo (in Lincoln County). Coastal States Energy Company and Hamilton Brothers have state leases in the Salt Lake field; another two companies are looking at properties in the Raton field, but definite mining plans are not available as yet.

The 1977 New Mexico Legislature passed a new severance tax on coal. The purpose of this tax is to assure that New Mexico shares in the natural wealth within its boundaries. The old .05-percent severance tax was changed to a new unit tax of 38¢ per ton for steam coal and 18¢ per ton for coking coal. With the average price of steam coal in New Mexico now at $5.00, the effective tax rate for steam coal is 4 percent. The New Mexico tax is much lower than that of other western states and more favorable to the mining companies because it does not escalate as the price of coal rises.

New Mexico's hot, arid climate poses unique conditions to coal producers. The milder, shorter winters mean fewer problems in keeping men and machines working year-round, but the combination of poor soils and low annual rainfall greatly hinder restoration of vegetative cover. Seeds of some plants may take two or more years to germinate. Nevertheless, mined land can be reclaimed in New Mexico; the state has been supervising successful reclamation efforts by various companies since 1973 (fig. 2).

New Mexico is closely watching implementation of new federal surface-mining regulations. The new regulations, however, may not be suited to New Mexico's

FIGURE 2—VIEW OF NAVAJO MINE, NEAR FARMINGTON, NEW MEXICO, SHOWING RECLAMATION (LEFT) KEEPING PACE WITH MINING.

problems. The new federal law calls for preservation of topsoil, often nonexistent or consisting only of blow sand in New Mexico. The law also calls for preservation of alluvial valleys with mostly intermittent streams or dry arroyos in New Mexico. The new law also specifies restoration of the original contours—but what should be done where the original surface was barren badlands? New Mexico will be working with the U.S. Office of Surface Mining to ensure continued development and protection of our natural resources.

One of our greatest concerns is the availability of water for the development of coal resources. Water is needed for washing coal, dust suppression, reclamation, boiler feed, cooling, and gasification. Virtually all of the surface water in northwestern New Mexico has been appropriated. Water has always been in short supply; our water law is based upon the doctrine of prior appropriation, where the landowner does not necessarily have inherent rights to use water from sources on, contiguous to, or underlying his land. Thus water rights for future industrial development must be negotiated for either ground water or surface water.

Ground water has been ignored for several reasons: surface water was more easily available; the quantity and quality of ground water has been questionable; and knowledge of aquifers has been limited. Present Bureau studies, in cooperation with the U.S. Geological Survey, indicate the Gallup Sandstone formation and Westwater Canyon Member (Morrison Formation) are two of the more promising potential aquifers in the San Juan Basin. However, reaching them may require drilling to depths of 5,200 ft. High drilling costs will require careful analysis of water needs and water availability. Other aquifers offer some promise, but less is known about their potential; greater depths make them less attractive.

Wise use of ground water will ensure availability of water needed for further coal development in the San Juan Basin. Because of the growing use of ground water, the State Engineer issued Special Order 124 on July 29, 1976, officially declaring the San Juan Basin an underground water basin. The purpose is to protect existing water rights from impairment by future ground-water development. Once a basin is declared, ground-water development is carefully regulated.

SUMMARY—New Mexico has a 180.5-billion-ton coal resource base with large amounts of strippable coal in the San Juan Basin. As a result of increased federal regulations, the Bureau of Surface Mining of the Energy and Minerals Department of the State of New Mexico was established on March 31, 1978. This new state organization will monitor and regulate the surface mining of coal in New Mexico. Neighboring states with limited coal resources would like to see New Mexico's coal developed for electric power. Federal leasing has slowed, but not stopped, coal development in the San Juan Basin. The smaller outlying fields being investigated show potential from the mines being planned. Although water resources are a limiting factor, ground water could be the key to future development. Thus, the overall picture for the future of the coal industry in New Mexico is promising.

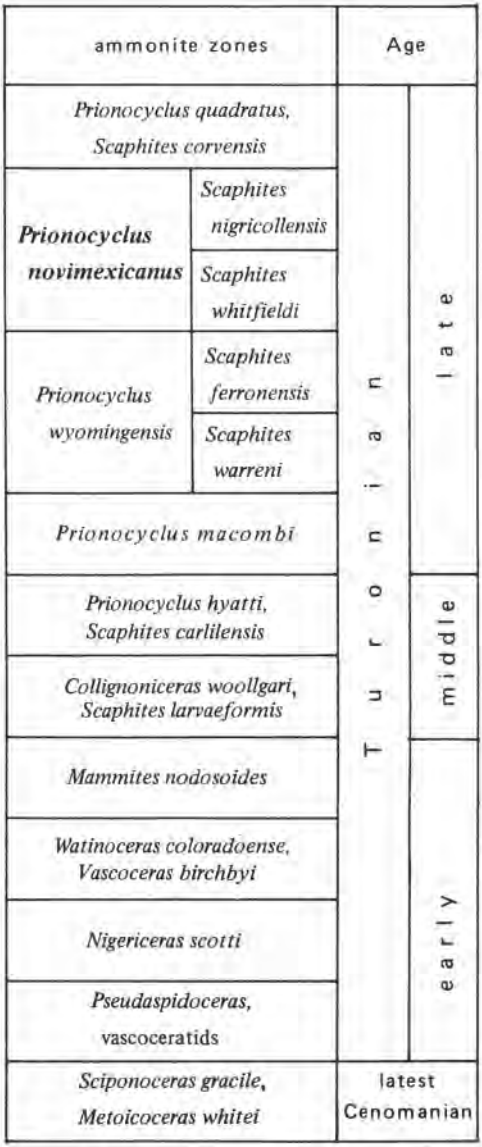


FIGURE 1—AMMONITE ZONATION OF LATEST CENOMANIAN THROUGH TURONIAN AGE IN THE WESTERN INTERIOR OF NORTH AMERICA. The oyster *Pycnodonte newberryi* (see Hook and Cobban, 1977) ranges from the *Sciponoceras gracile-Metoicoceras whitei* Zone through the *Pseudaspidoceras* Zone.

PRIONOCYCLUS NOVIMEXICANUS (MARCOU)—COMMON UPPER CRETACEOUS GUIDE FOSSIL IN NEW MEXICO

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

INTRODUCTION—This paper is the second in a series that concerns stratigraphically important fossils of Cretaceous age in New Mexico and adjacent states. The first paper (Hook and Cobban, 1977) concerned the late Cenomanian-early Turonian oyster *Pycnodonte newberryi* (Stanton). This second paper includes a detailed description of the late Turonian ammonite *Prionocyclus novimexicanus* (Marcou) and a brief description of the commonly associated ammonite, *Scaphites whitfieldi* Cobban (fig. 1).

Prionocyclus novimexicanus was described by Jules Marcou in 1858 as *Ammonites Novi-Mexicani* in his report entitled *Geology of North America.* The holotype was found ". . . not far from Albuquerque and also las Lunes" (Marcou, 1858, p. 36) and was named in honor of the Territory of New Mexico.

Ammonites Novi-Mexicani was among the first fossils from New Mexico to be formally named. Marcou (1855, not 1851 as listed in Stanton, 1947, p. 26, and Stenzel, 1971, p. N1114) had previously described the Early Cretaceous oyster *Texigryphaea tucumcarii,* which had been found on Pyramid Mountain, southwest of Tucumcari, New Mexico. This gryphaea, originally described as *Gryphaea dilatata* var. *tucumcarii* and thought to be of Jurassic age, is the first formally named species from New Mexico. Prior to 1855, fossils from New Mexico had been mentioned and illustrated in the accounts of early explorers (for example, Wislizenus, 1848; Bailey, 1848), but no new species or varieties were formally described (Merrill, 1924; Northrop, 1962).

MARCOU AND THE PACIFIC RAILROAD SURVEY—On March 3, 1853, Congress authorized Secretary of War Jefferson Davis ". . . to employ such portion of the Corps of Topographical Engineers and such other persons as may be deemed necessary, to ascertain the most practical and economical route for a railroad from the Mississippi River to the Pacific Ocean. . . ." The Army Topographic Corps dispatched several exploration parties, which generally included a civilian geologist.

Jules Marcou, a French geologist, who had just published a geological map of the United States (1853), was offered the position of Geologist and Mining Engineer, Pacific Railroad Survey, by Joseph Henry, Secretary of the Smithsonian Institution. Marcou accepted the position in a party (under the command of First Lieutenant A. W. Whipple) that explored near the thirty-fifth parallel of north latitude. Marcou was paid a salary of $100.00 a month plus traveling expenses to undertake ". . . a crossing from the Mississippi to the Pacific shores . . . so hazardous, that all the geologists of any standing, to which the offer . . . was made, declined to go" (Marcou, 1889, p. 225). Marcou was, by his own modest admission, ". . . happily prepared by rare training for the work before me."

Whipple's expedition departed from Fort Smith, Arkansas, on June 16, 1853; arrived in the Tucumcari, New Mexico, area on September 22, 1853; and reached Albuquerque on October 5, 1853. In the vicinity of Albuquerque, Marcou collected many of the Pennsylvanian and Cretaceous fossils that are described in his *Geology of North America* (several of Marcou's plates are reproduced in Kelley and Northrop, 1975). Near Camp No. 27 (fig. 2), on the west bank of the Rio Puerco just above its confluence with Arroyo Salado (not the Rio San Jose as

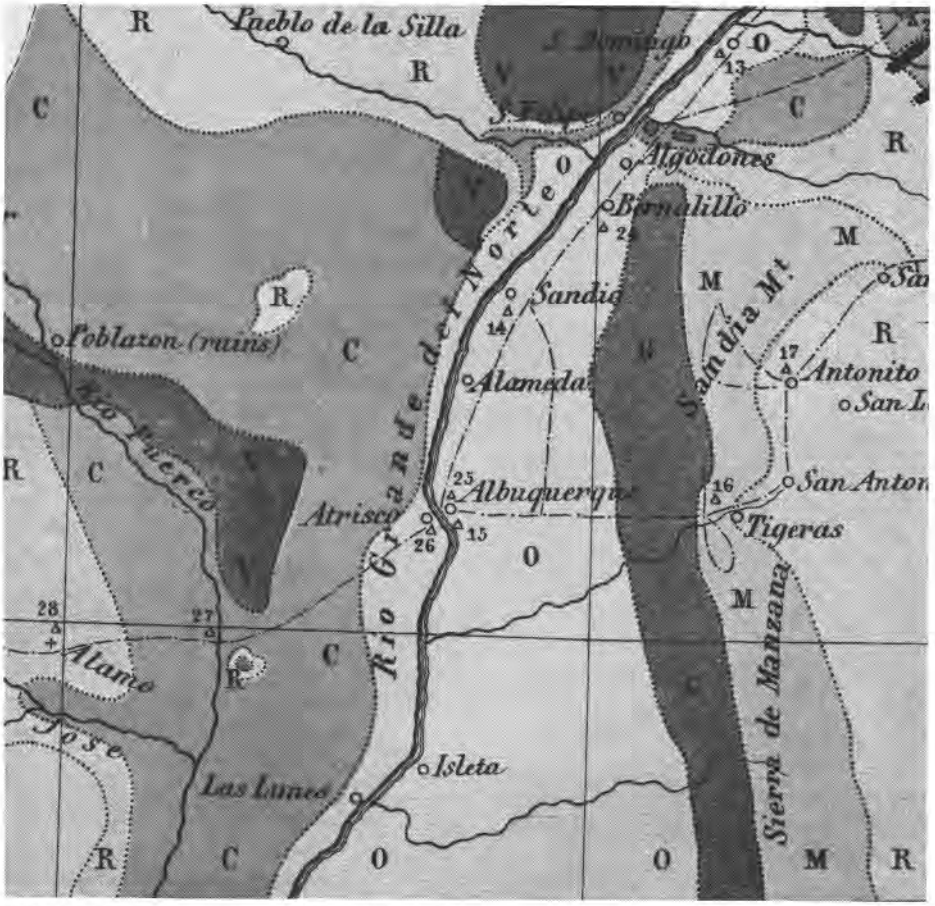


FIGURE 2—A PORTION OF MARCOU'S (1858) GEOLOGIC MAP OF PARTS OF NEW MEXICO. Triangles represent campsites; dashed lines border the mapped area; dotted lines are contacts of rock units; and dashed and dotted lines are traverse routes. O is the symbol used for Quaternary rocks; C, Cretaceous; J, Jurassic; R, New Red Sandstone (name formerly applied to Triassic and Permian rocks); M, Carboniferous; G, granite, gneiss, porphyry, etc.; V, volcanoes (approximate scale, 1 inch to 15 miles). *Prionocyclus novimexicanus* was collected near Camp No. 27.

shown on Marcou's map; fig. 2), Marcou collected two fragments of *Ammonites Novi-Mexicani* and poorly preserved specimens of *Baculites* and *Inoceramus* from the ". . . *White Sandstone* that constitutes the sandy mountain extending between the Rio Grande del Norte and the Rio Puerco" (Marcou, 1858, p. 36). Marcou was correct in assigning a Late Cretaceous age to *A. Novi-Mexicani,* but erred in mapping all the sandstones between the Rio Grande and the Rio Puerco as Cretaceous (fig. 2). Most of these rocks are of Tertiary and Quaternary age; however, Upper Cretaceous rocks do crop out a few miles north and south of Marcou's campsite (Dane and Bachman, 1965).

The holotype of *A. Novi-Mexicani* (fig. 3 E-G), which is in the British Museum of Natural History, London, is of septarian preservation (W. J. Kennedy, Oxford, England, written communication, April 1978) and presumably was a limestone concretion in shale. However, the Cretaceous rocks that contain *A. Novi-Mexicani* do not crop out close enough to Marcou's Camp No. 27 to have been visited during the one day the expedition was in the area. We are assuming,

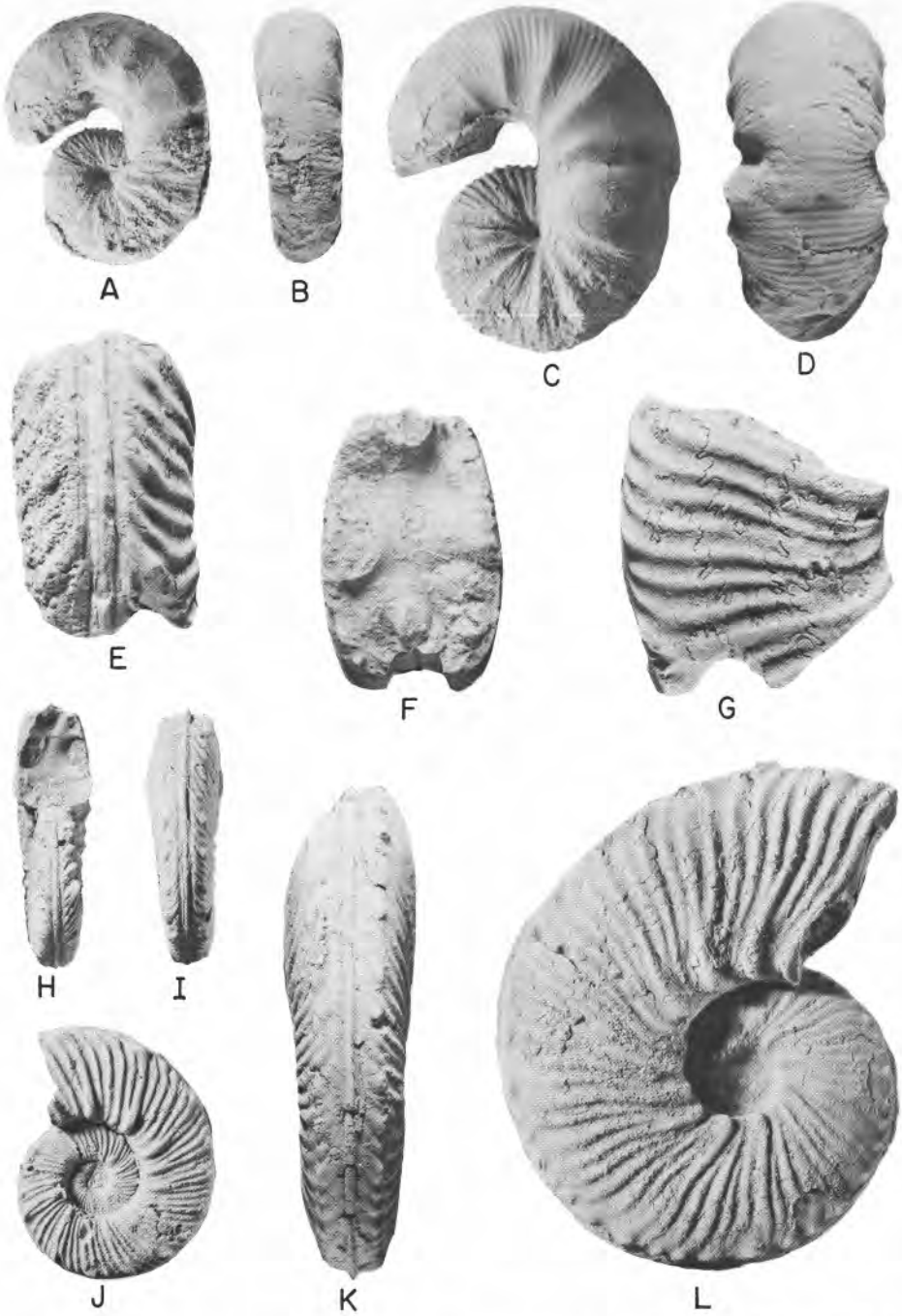


FIGURE 3—*Scaphites whitfieldi* COBBAN (A-D) AND *Prionocyclus novimexicanus* (MARCOU) (E-L), ALL NATURAL SIZE. A and B, side and rear views of a small, slender adult probably representing a male; hypotype USNM 254553. C and D, side and rear views of a large, stout adult probably representing a female; hypotype USNM 254554. E-G, rear, front, and side views of a plaster cast of the holotype, BMNH C49764. H-J, front, rear, and side views of hypotype USNM 254555. K and L, rear and side views of a larger specimen, hypotype USNM 254556.

therefore, that the holotype of *A. Novi-Mexicani* was a float specimen collected along the Rio Puerco, which drains rocks that contain *A. Novi-Mexicani.*

PRIONOCYCLUS NOVIMEXICANUS—Marcou assigned his new species to the genus *Ammonites,* a form-genus used at that time for all planispirally coiled ammonites whose whorls were in contact. His reasons for describing the fragmentary specimen as a new species were ". . . the large and square form of the back, with a strongly marked, but not prominent keel, and the quadrangular form of the whorl. . . . The ribs do not all begin at the umbilicus, more than half of them begin at a third of the distance from the umbilicus; they are sinuous and at the back turn rapidly towards the mouth. Several of these ribs appear to be ornamented where they bend towards the keel, with a sort of round swelling, which seems also to exist near the umbilicus; but only on the ribs starting from the umbilicus, each one of these umbilical ribs being separated by two lateral ribs" (Marcou, 1858, p. 35-36). Photographs of a plaster cast of the holotype (British Museum No. C49764) are shown in fig. 3 E-G.

Ammonites Novi-Mexicani was largely ignored for the next 84 years and was listed as an obsolete or invalid species by Diener (1925). In 1942, Moreman identified a specimen from the Arcadia Park Formation of central Texas as Marcou's species. Although Moreman (1942) did not illustrate his specimen, he transferred *Novi-Mexicani* to the modern genus *Prionocyclus.*

Prionocyclus is an evolute, moderately large, ribbed ammonite, which is characterized by a subquadrate section with a broad venter and a continuous, finely serrate keel. Ribs are irregular in strength and length and are dominant over the umbilical and ventrolateral tubercles in some growth stage (Wright, 1957, p. L426-L427; Matsumoto, 1965, p. 17-18).

Haas (1946), in a study of the intraspecific variation in *Prionocyclus wyomingensis,* was apparently unaware of Marcou's (1858) and Moreman's (1942) work and described several specimens of *P. novimexicanus* from the Black Hills of South Dakota as *P. wyomingensis* var. *elegans.* Since 1946, specimens of *P. novimexicanus* have been referred to Haas' variety *elegans* (for example, Dane and others, 1966; Jeletzky, 1970; Merewether and Cobban, 1972), although Matsumoto (1965, p. 20) was aware that Marcou's specimen closely resembled the middle growth stage of *P. wyomingensis.*

The holotype of *Prionocyclus novimexicanus* is a portion of a phragmocone weathered on one side. A plaster cast of the specimen (fig. 3 E-G) reveals an internal mold about 43 mm long. The whorl section is higher than it is wide and subrectangular, with the greatest width a little below the middle. Ornamentation consists of closely spaced flexuous ribs, which are narrower than the interspaces; a row of ventrolateral tubercles; and a conspicuous keel. The ribs consist of primaries and secondaries that are about equal in strength on the outer part of the flank. Primary ribs rise from arcuate bullae on the umbilical shoulder, cross the flank with sinuosity, and curve forward at the ventrolateral shoulder, where they rise into low tubercles, which are elongated in the direction of the ribbing (here at an angle of approximately 45 degrees to the keel).The primaries continue on the venter slightly beyond the tubercles and terminate on a low ridge that parallels the keel. This ridge is separated from the keel by a conspicuous furrow about as wide as the keel. The keel is worn and does not show the serrations typical of well-preserved specimens of *Prionocyclus.* Primary ribs are separated by one or two secondary ribs that originate a little below midflank and follow a sinuous course to the ventrolateral shoulder, where they curve forward and terminate on the low ventral ridge. The external suture is shown in Marcou's sketch of the holotype.

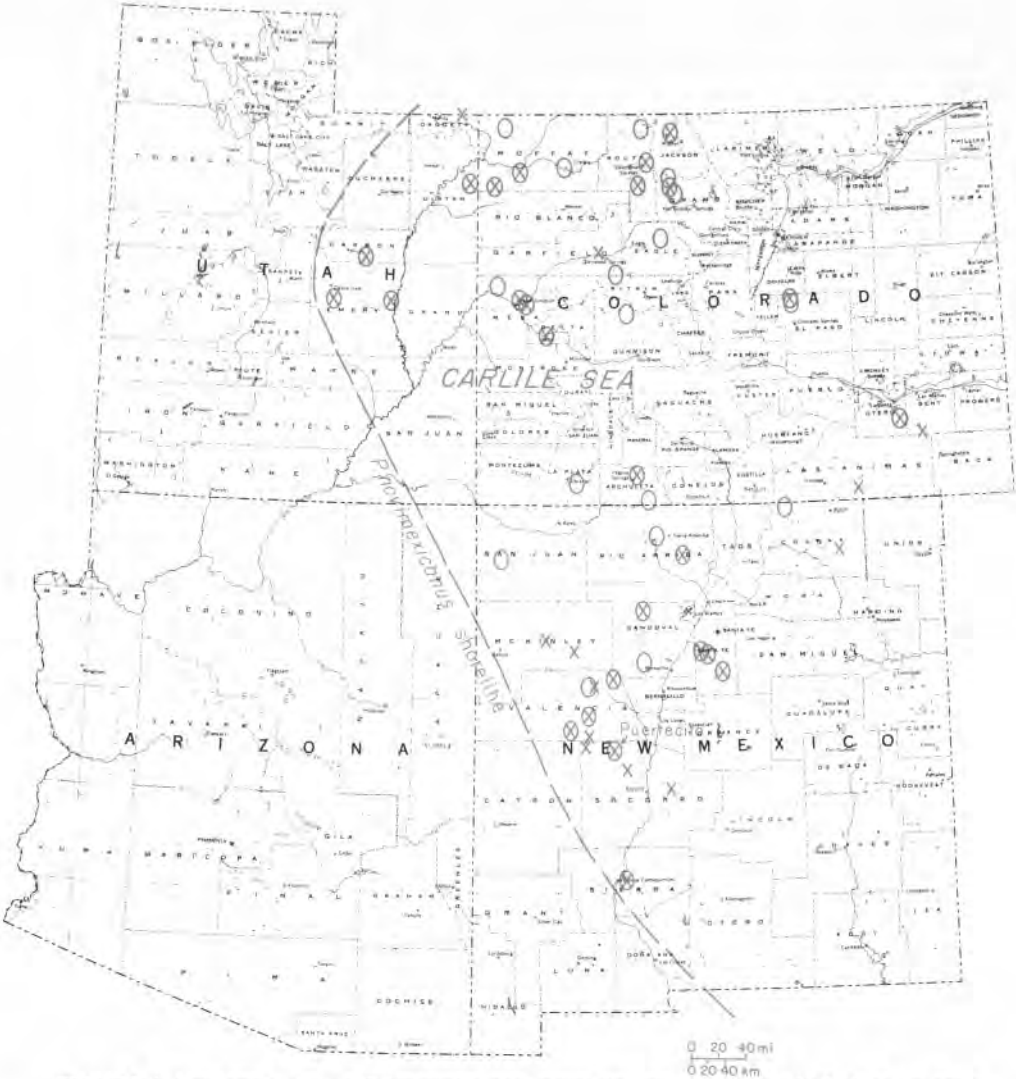


FIGURE 4—LOCALITIES WHERE *Prionocyclus novimexicanus* AND *Scaphites whitfieldi* HAVE BEEN COLLECTED. x = *P. novimexicanus* and 0 = *S. whitfieldi*, --- = approximate location of the Cretaceous shoreline during the time represented by the *P. novimexicanus* Zone.

Marcou's type can be easily matched by specimens from the Black Hills of South Dakota and eastern Wyoming that were described as *Prionocyclus wyomingensis* Meek var. *elegans* Haas (1946, p. 200, pl. 19, figs. 1-7, 11-14; pl. 20, fig. 4; pl. 21, figs. 1-3, 5; pl. 22, figs. 1, 2; text figs. 98-104). Haas' specimens as well as Marcou's type differ from *P. wyomingensis* Meek (1876, p. 452), which was first illustrated by White (1880, p. 35, pl. 15, fig. la-e), chiefly in tending to have single ventrolateral tubercles instead of the double ventrolateral tubercles of Meek's types and in tending to have a low ventral ridge bordering a smooth

ventral furrow. Haas (1946, p. 200-201) observed that his variety *elegans* differed from the typical form of *P. wyomingensis* by having a more compressed whorl section and by having more distinctly ribbed juvenile whorls.

Haas' types of *P. wyomingensis* var. *elegans* (=*P. novimexicanus*) came from the Turner Sandy Member of the Carlile Shale in the Black Hills area. Many collections of fossils from the Turner Sandy Member provide evidence that *P. novimexicanus* is younger than *P. wyomingensis* and that these two forms should be regarded as distinct species. The associated fossils are also different; *Scaphites whitfieldi* Cobban and *Inoceramus perplexus* Whitfield occur with *P. novimexicanus,* whereas *S. warreni* Meek and Hayden and *I. dimidius* White occur with *P. wyomingensis.* The stratigraphic position of *P. novimexicanus* above that of *P. wyomingensis* is well documented by collections from the Frontier Formation in Wyoming (Merewether and Cobban, 1972) and by collections from the Juana Lopez Member of the Mancos Shale of New Mexico, Colorado, and Utah (Dane and others, 1966).

The common associate of *P. novimexicanus, Scaphites whitfieldi* Cobban (1951, p. 24, pl. 4, figs. 30-40; pl. 5, figs. 1-4), is easily recognized by its dense ribbing, in which the ribs tend to be uniformly spaced on the venter of the body chamber. The species occurs in two forms, a larger one that has an inflated body chamber, (fig. 3C, D) and a smaller one that has a more slender body chamber (fig. 3A, B). The larger form is believed to represent a female, and the smaller is thought to be a male. (For treatments on dimorphism in scaphites, see Cobban, 1969, and Crick, 1978.)

Prionocyclus novimexicanus has been found throughout the Western Interior of North America from southern New Mexico to Canada. Figure 4 shows localities within the Four Corners States where *P. novimexicanus* has been collected and the approximate location of the Cretaceous shoreline during the time represented by the *P. novimexicanus* Zone (late Turonian). Within New Mexico, this shoreline represents not only the maximum extent of the sea during Carlile time, but also the second greatest marine transgression of the Late Cretaceous seas. Only the Greenhorn sea of late Cenomanian and early Turonian age inundated more of New Mexico (Hook and Cobban, 1977, fig. 1).

P. novimexicanus has been collected from the Mancos Shale and Mesaverde Formation of New Mexico, the Mancos Shale of Utah, the basal part of the Niobrara Formation of Colorado, the Carlile Shale of western South Dakota, the Cody Shale of south-central Montana, and the Frontier Formation of Wyoming. In the southern Acoma Basin near Puertecito, New Mexico, *P. novimexicanus* occurs abundantly in limestone concretions near the base of the D-Cross Tongue of the Mancos Shale (fig. 5). The specimen shown on the cover was collected from the Puertecito area.

ACKNOWLEDGMENTS—Stuart Northrop, Emeritus Professor of Geology, University of New Mexico, and Clifford Nelson, U.S. Geological Survey, Reston, Virginia, supplied copies of Marcou's reports. W. J. Kennedy, Oxford University, Oxford, England, provided photographs of the holotype of *P. novimexicanus* and a description of the preservation of the specimen. Robert E. Burkholder, U.S. Geological Survey, Denver, Colorado, prepared and photographed the fossils and the cast of the holotype. E. A. Merewether and J. H. Hanley, U.S. Geological Survey, Denver, Colorado, critically reviewed the manuscript. M. K. Howarth, British Museum (Natural History), London, England sent us the plaster cast of the holotype of *P. novimexicanus* shown in fig. 3E-G.

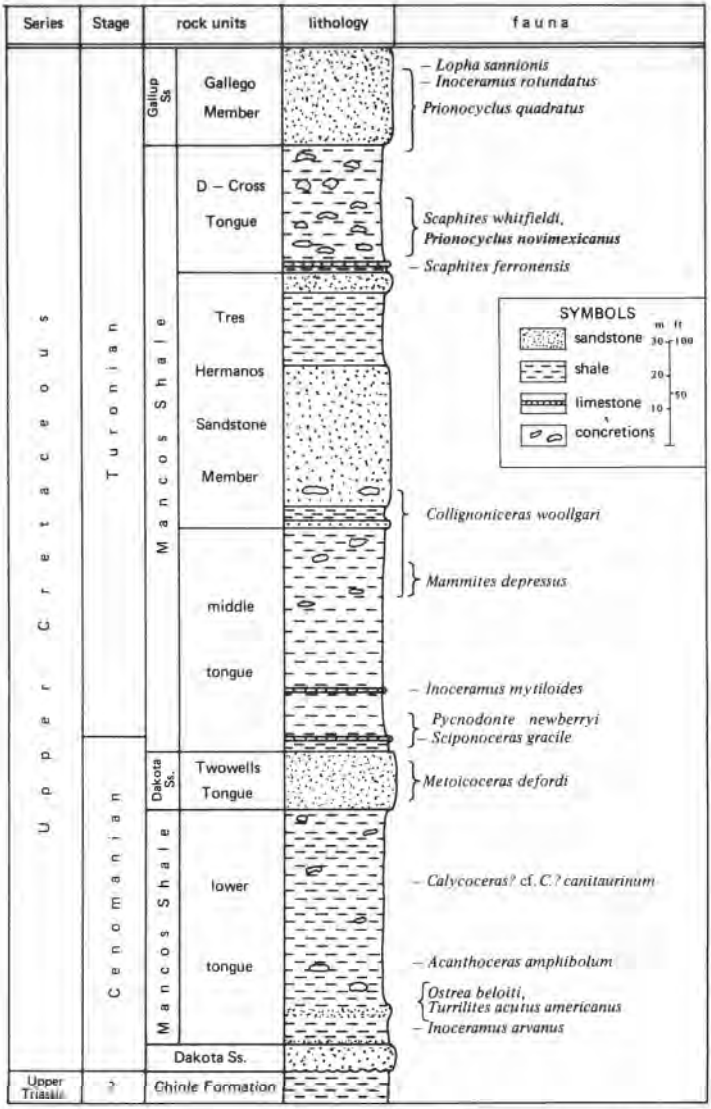


FIGURE 5—GENERALIZED COMPOSITE OUTCROP SECTION OF LOWER UPPER CRETACEOUS ROCKS AT PUERTECITO, NEW MEXICO, showing approximate vertical range of *P. novimexicanus* and occurrences and ranges of other guide fossils. Dash indicates single occurrence.

REFERENCES

Bailey, J. W., 1848, Notes concerning the minerals and fossils collected by Lieutenant J. W. Abert, while engaged in the geographical examination of New Mexico: U.S. 30th Congress, 1st session, Senate Executive Document 23, p. 131-132, House Executive Document 41, p. 547-548

Cobban, W. A., 1951, Scaphitoid cephalopods of the Colorado Group: U.S. Geological Survey, Prof. Paper 239, 42 p., 21 pls., 4 figs.

———, 1969, The Late Cretaceous ammonites *Scaphites leei* Reeside and *Scaphites hippocrepis* (DeKay) in the Western Interior of the United States: U.S. Geological Survey, Prof. Papers 619, 27 p., 5 pls., 21 figs.

Crick, R. E., 1978, Morphological variations in the ammonite *Scaphites* of the Blue Hill Member, Carlile Shale, Upper Cretaceous, Kansas: University of Kansas Paleontological Contributions, Paper 88, 28 p., 2 pls.

Dane, C. H., and Bachman, G. O., 1965, Geologic map of New Mexico: U.S. Geological Survey, scale 1:500,000

Dane, C. H., Cobban, W. A., and Kauffman, E. G., 1966, Stratigraphy and regional relationships of a reference section for the Juana Lopez Member, Mancos Shale, in the San Juan Basin, New Mexico: U.S. Geological Survey, Bull. 1224-H, 15 p., 3 figs.

Diener, Carl, 1925, Ammonoidea neocretacea, part 29 *of* Animalia, [v.] 1, *in* Fossilium catalogus, Carl Diener, ed.: Berlin, W. Junk, 244 p.

Haas, Otto, 1946, Intraspecific variation in, and ontogeny of, *Prionotropis woollgari* and *Prionocyclus wyomingensis:* American Museum of Natural History, Bull., v. 86, art. 4, p. 141-224, pls. 11-24, figs. 1-108

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 Report 1976-77, p. 48-54, 5 figs.

Jeletzky, J. A., 1970, Cretaceous macrofaunas *in* Geology and economic minerals of Canada, R. J. W. Douglas, ed: Geological Survey of Canada, Economic Geology Report No. 1, p. 649-662, pls. 23-28

Kelley, V. C., and Northrop, S. A., 1975, Geology of Sandia Mountains and vicinity: New Mexico Bureau of Mines and Mineral Resources, Mem. 29, 136 p., 4 tables, 92 figs., 4 maps

Marcou, Jules, 1853, A geological map of the United States, and the British provinces of North America; with an explanatory text, geological sections and plates of fossils which characterize the formations: Boston, Map and text, 92 p.

———, 1855, Résumé explicatif d'une carte géologique des Etats-Unis et des provinces anglaises de l'Amérique du Nord, avec un profil géologique alant de la vallée du Mississippi aux côtes du Pacifque et une planache de fossiles: Bulletin de la Société Géologique de France, 2nd ser., v. 12, p. 813-936, pl. 21.

———, 1858, Geology of North America; with two reports on the prairies of Arkansas and Texas, The Rocky Mountains of New Mexico and the Sierra Nevada of California: Zurich, 144 p.

———, 1889, The Mesozoic series of New Mexico: American Geologist, v. 4, p. 155-165, 216-229

Matsumoto, Tatsuro, 1965, A monograph of the Collignoniceratidae from Hokkaido—Part 1 (studies of the Cretaceous ammonites from Hokkaido and Saghalien—XIV): Memoirs of the Faculty of Science, Kyushu University, Ser. D., Geology, Vol. XVI, no. 1, p. 1-80, pls. 1-18, 40 figs.

Meek, F. B., 1876, Invertebrate Cretaceous and Tertiary fossils: U.S. Geological Survey of the Territories, v. 9, 629 p., 45 pls., 85 figs.

Merewether, E. A., and Cobban, W. A., 1972, Unconformities within the Frontier Formation, northwestern Carbon County, Wyoming: U.S. Geological Survey, Prof. Paper 800-D, p. 57-66, 1 table, 5 figs.

Merrill, G. P., 1924, The first one hundred years of American geology: New Haven, Yale University Press, 773 p.

Moreman, W. L., 1942, Paleontology of the Eagle Ford Group of north and central Texas: Journal of Paleontology, v. 16, p. 192-220, pls. 31-34, 2 figs.

Northrop, S. A., 1962, New Mexico's fossil record: New Mexico Quarterly, v. 32, nos. 1 and 2, 75 p.

Stanton, T. W., 1947, Studies of some Comanche pelecypods and gastropods: U.S. Geological Survey, Prof. Paper 211, 256 p., 67 pls.

Stenzel, H. B., 1971, Oysters, *in* Treatise on invertebrate paleontology, R. C. Moore, ed.: Geological Society of America and University of Kansas, part N, v. 3, p. N953-N1224, 153 figs.

White, C. A., 1880, Contributions to invertebrate paleontology, No. 2; Cretaceous fossils of the western states and territories: preprint of part of U.S. Geological Survey of the Territories, 1883, Annual Report 12, part 1, p. 1-39, pls. 11-18

Wislizenus, F. A., 1848, Memoir of a tour to northern Mexico . . . in 1846 and 1847: U.S. 30th Congress, 1st session, Senate Miscellaneous Document 26, 141 p.

Wright, C. W., 1957, Family Collignoniceratidae, *in* Treatise on invertebrate paleontology, R. C. Moore ed.: Geological Society of America and University of Kansas, part L, p. L426-L437

INDUSTRIAL ROCKS AND MINERALS OF NEW MEXICO

by Wm. Terry Siemers, *Industrial Minerals Geologist* and George S. Austin, *Deputy Director*

Many commodities, including ground water, mineral fuels, metallic minerals, and industrial rocks and minerals are used to carry on the nation's industrial activities. This paper summarizes the geology and production of industrial rocks and minerals currently produced in New Mexico. In presenting such a summary, we have drawn from the work of many others, and four publications—Bates (1960), Lefond (1975), Talmage and Wootton (1937), and U.S. Geological Survey (1965)—have been especially useful sources of information.

The definition and classification of industrial rocks and minerals is difficult because such materials, their occurrences, and their uses are exceedingly diverse. Indeed, diversity is their only common attribute; consequently, it is often easier to say what industrial rocks and minerals are not than to say what they are. Generally, "industrial rocks and minerals" refers to any rock or mineral or other naturally occurring substance of economic value, exclusive of metallic minerals, mineral fuels, and gem stones; the materials are commonly equated with nonmetallics. Any industry belongs to the industrial-minerals field if its operations consist of extraction and processing, but not of manufacturing. Industrial rocks and minerals permeate the entire fabric of the world's industrialized society; more than 35 different such commodities are fundamentally important in modern industry.

The genesis and geologic occurrence of industrial rock and mineral deposits are as diverse as their industrial uses. Moreover, the geology of the deposits is related to a spectrum of geologic processes that defy integration into unifying geologic principles that promote understanding and facilitate exploration. Developments in the geologic sciences and improved technology are providing some insight into such problems, but the field of industrial rocks and minerals remains a fertile branch of economic geology for future work.

Before 1960, economic geologists focused their attention primarily on fuels and metallic minerals; the geology and use of industrial rocks and minerals was generally neglected. In the 1960's, however, increased awareness of the significance of industrial rocks and minerals in world industry was spurred by the publication of *Geology of Industrial Rocks and Minerals* (Bates, 1960), one of the first college textbooks to emphasize the geology and importance of these commodities. By the middle of the 1960's, the value of industrial rocks and minerals became almost twice that of the metallic ores; stone, sand, and gravel producers alone handled about as much tonnage as the coal and metal-mining industries combined. Since the 1960's, industrial rocks and minerals have continued to strengthen their position in the nation's industry (fig. 1) and have begun to receive the attention they merit.

The value of industrial rocks and minerals produced in New Mexico in 1977 was in excess of $300 million. The state ranked first in the production of potash and perlite and continued to be a leader in pumice production. The remainder of New Mexico's industrial-minerals production was accounted for by calcite, clay, gypsum, humate, limestone, mica, salt, sand and gravel, silica, stone, and sulfur.

Industrial rock and mineral resources are widely distributed throughout the state and reflect a wide variety of geologic conditions and processes. Most producers, however, are concentrated in western New Mexico and in the Carlsbad area (fig. 2). A directory of industrial rock-and-mineral producers in New Mexico (numerically keyed to fig. 2) may be found at the end of the paper.

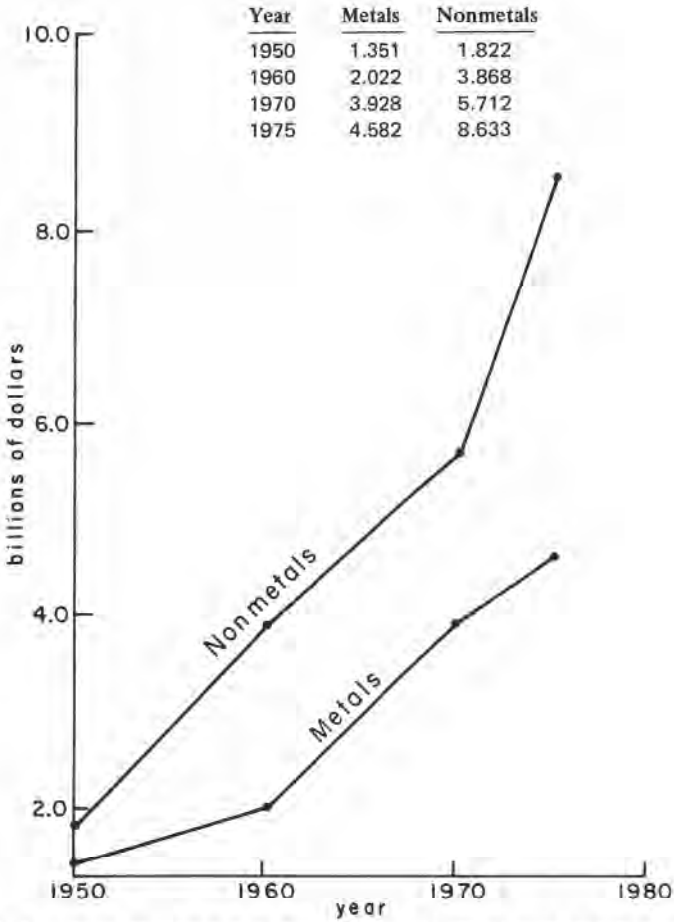


FIGURE 1—U.S. ANNUAL PRODUCTION IN BILLIONS OF DOLLARS OF PRINCIPAL RAW MINERAL COMMODITIES, 1970-1975 (SOURCE: U.S. BUREAU OF MINES, 1975).

Clay and shale

GENERAL—Clay material is any naturally occurring, fine-grained, earthy, clayey material and includes clays, shales, and soils. A clay contains more than 50 percent clay-sized material. A shale is a fine-grained, earthy, sedimentary rock with distinct laminations; shale may have as little as 25 percent clay-sized material with silt-sized material accounting for most of the remainder. A soil is a loose, clayey material with some organic content and is usually found at the surface. Clay-sized particles found in clay materials consist dominantly of clay minerals—platey hydrous aluminum silicates that commonly contain iron, potassium, sodium, calcium, and other elements. Clay materials have many properties, including plasticity, refractoriness, absorbent properties, chemical inertness, bonding strength, gel properties, and large ion-exchange capacity—all giving clay materials a wide range of industrial applications.

USES—The U.S. Bureau of Mines divides clays and shales into six categories —kaolin, ball clay, fire clay, bentonite, fuller's earth, and common clay or shale.

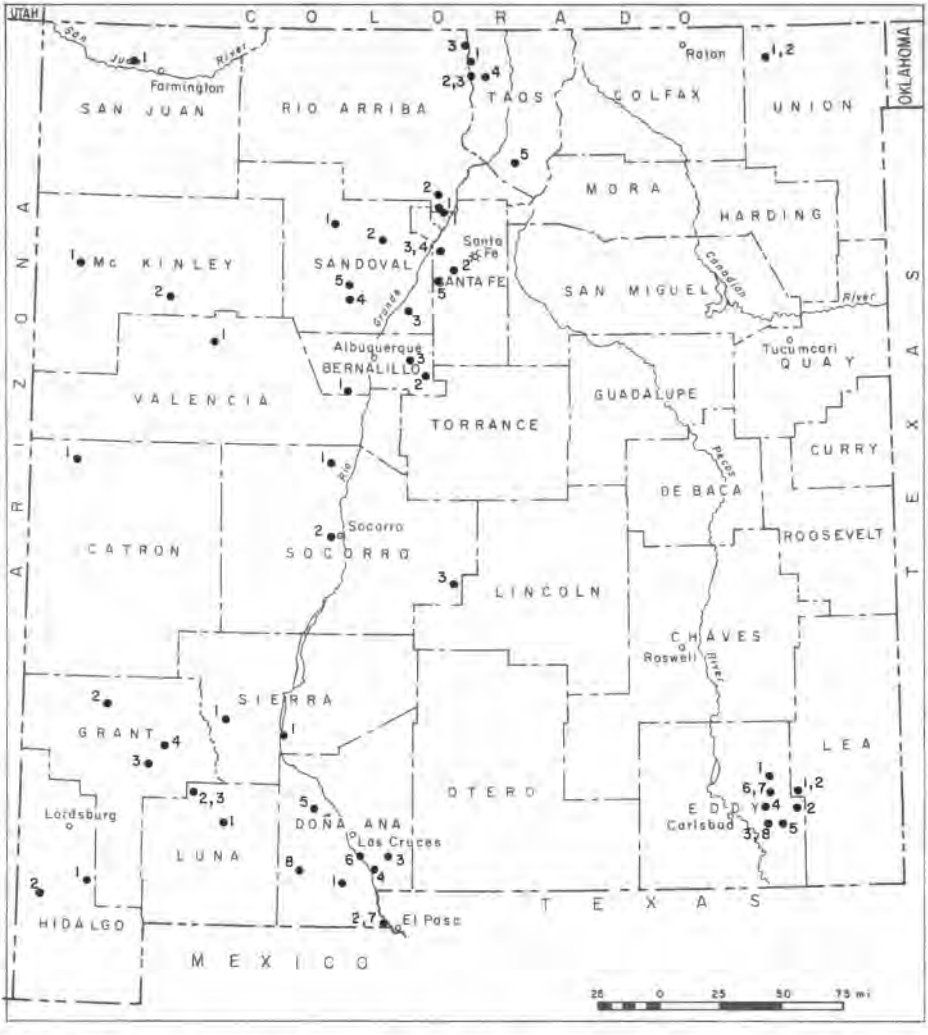


FIGURE 2—MAJOR INDUSTRIAL ROCK AND MINERAL OPERATIONS (EXCLUDING SAND AND GRAVEL) IN NEW MEXICO.

Kaolin, essentially pure hydrous aluminum silicate, is a white, highly refractory material consisting primarily of the kaolinite group of clay materials—kaolinite, dickite, nacrite, and halloysite. Kaolin is used in paper, ceramics, paint, rubber, and plastics industries, and by foundries. Fire clay, consisting mostly of kaolinite and known for its refractoriness and non-plastic nature, is used primarily in the manufacture of commercial refractory products, such as fire brick or insulating brick. Ball clays, while mostly composed of kaolinite, are more plastic than any other kaolinite-bearing clay materials and are used by the ceramics industry to impart high, unfired strength and plasticity, as well as a light color when fired, to clay bodies.

Bentonites consist mostly of the expandable smectite group of clay minerals. The expandable quality comes from this group's ability to expand by picking up

one or two layers of water while maintaining the general crystal structure of the group. Bentonites have the ability to exchange ions in a manner similar to water softeners. In addition, sodium-rich bentonites are able to form a gel with water, and they are widely used by the petroleum industry in drilling muds. Calcium-rich bentonites make up a large proportion of what is called fuller's earth, which is used to absorb oils and/or impurities in the food and textile industries. Fuller's earth is widely used by the pet-products industry as a bedding material to absorb liquid wastes and odors. Bentonites are used by the chemical industry as carriers and extenders. Much of what is called "inert materials" in many products is clay, commonly bentonite or kaolinite. Impure clay materials, commonly high in smectitic clay minerals, are widely used in the Southwest in the making of adobe brick, a sun-dried product still used today in large quantities in New Mexico.

Common clays and shales permit molding when wet and generally vitrify below 1,100°C; they are widely used for fabricating earthenware pottery and structural clay products such as bricks, sewer pipes, and drain tiles. Although only a few of the many uses of clay and shale have been mentioned, this list serves to give a general impression of the wide uses of clay materials.

OCCURRENCES—Refractory (kaolin-rich) clays occur in New Mexico under many types of geologic conditions. Large deposits of well-crystallized kaolinite occur in hydrothermally altered tuffs and other igneous rocks in Socorro, Luna, Grant, Doña Ana, and Sierra Counties. Kaolin and fire clay occur in sedimentary rocks of Jurassic and Cretaceous age in northwestern New Mexico. Halloysite frequently occurs in small veins and pockets; the largest of these is a pocket or channel fill at the base of the Dakota Sandstone (Cretaceous), northeast of Amistad in northeastern New Mexico.

Bentonite deposits are widespread in New Mexico but have been mined only on a small scale at a few locations. They occur in sedimentary rocks ranging from Permian to Quaternary in age, with the best quality bentonites in New Mexico being Tertiary lake deposits. One such deposit occurs in the Santa Fe Group, about 25 mi north of Socorro on the southeast flank of the Ladron Mountains. The deposit is as much as 8 ft thick and is believed to be laterally extensive. Common clay and shale occur in several types of rocks, including altered volcanic rocks and sedimentary units that range in age from Devonian to Recent.

PRODUCTION—The five major clay producers in New Mexico include: Kinney Brick Company, which has a pit near Cerrillos and another in the Manzanito Mountains in the central part of the state, and El Paso Brick Company, which operates a clay pit just west of the Rio Grande near the Mexican border. Production from this operation is probably about 36,000 cu yd daily. Other producers are the Cement Division of Ideal Basic Industries near Albuquerque and Phelps Dodge Corporation and Mathis and Mathis Mining & Exploration in southwestern New Mexico. Excluding fire clay, clay production in the state currently amounts to about 60,000 tons. The amount of fire clay produced in the state in 1976 was about 11,500 tons. In that year, New Mexico ranked about 40th in the nation in the production of clay and shale.

RESERVES—Several of the clays and shales that have been used for structural clay products occur in nearly inexhaustible quantities. The same is true of the resource materials for making sun-dried adobe. The prospects for future production of bentonite in the state also appear good, and the potential is high for the discovery of more high-grade bentonite. The future production of kaolin in the state is a definite possibility, but not enough information is available to

presently evaluate kaolin resources or uses in New Mexico. Fire-clay resources appear adequate to fulfill a limited local demand; coal stripping in the Gallup area may uncover kaolinitic clays that are suitable as low- and moderate-duty fire clay.

Gypsum

Gypsum is the mineral name for hydrated calcium sulfate ($CaSO_4 \cdot 2H_2O$). Pure gypsum contains 32.6 percent CaO, 46.5 percent SO_3, and 20.9 percent H_2O. Because of the metastable relationships between gypsum and anhydrite (the anhydrous phase of calcium sulfate), pure gypsum deposits are seldom found. Most mine-produced gypsum is therefore only about 85 to 95 percent pure, but in some cases the product can be upgraded by beneficiation.

Calcium sulfate has the unique property of readily giving up or taking on water of crystallization, and most uses for gypsum are based on this property. With a moderate application of heat, gypsum is converted to a hemihydrate of calcium sulfate ($CaSO_4 \cdot \frac{1}{2}H_2O$), which, when mixed with water, will set to harden as the calcium sulfate returns to the dihydrate form. The calcined product is manufactured into a variety of plasters, wallboard, and block for construction or industrial application. Crude gypsum is used as a retarder in portland cement, as a soil conditioner, and as a filter.

Most New Mexico gypsum deposits consist largely of beds deposited from solution during the evaporation of sea water, whereas others are a result of the evaporation of highly saline lakes. Individual gypsum beds or series of beds range from less than an inch to several hundred feet in thickness.

Three gypsum mines (White Mesa, San Felipe, and Rosario), all in north-central New Mexico, currently operate in the state. Their combined annual capacity is uncertain but is estimated to be about 250,000 tons. Almost all of the gypsum produced is consumed by the construction industry in New Mexico; small quantities are also used for agricultural purposes and for the manufacture of portland cement.

New Mexico's gypsum reserves are substantial. Deposits are distributed widely throughout the state in rocks ranging from Pennsylvanian to Pleistocene in age, with local dune sands of Pleistocene and Holocene age. The White Mesa deposit, for example, contains measured reserves of 98 million tons and an estimated additional 123 million tons available by stripping relatively thin overburden.

Humate

Chemically, humates are salts or esters of humic acid; however, in a lithologic sense (as used here), the term refers to brownish, carbonaceous mudstone. Crushed humate is marketed as a soil conditioner, although the effects of such use have not been completely determined or documented. The claimed potential benefits of humate application to soils include: increased retention of water and soluble fertilizer additives, increased acidity, improved physical character, and beneficial color changes. Humate was previously considered only marginally acceptable for agricultural purposes, but some recent studies support its usefulness, and markets are being developed.

Humates in the Menefee Formation of northwestern New Mexico occur as dark-brown to brownish-gray, carbonaceous, blocky to slightly fissile mudstones containing abundant woody plant material (Siemers and Wadell, 1977). The thin, laterally persistent humate units may grade laterally into barren mudstone and are vertically interlayered with barren mudstone, coal, or sandstone. The deposits

represent moderately to poorly drained Cretaceous swamps that received abundant clay-mineral and organic matter.

New Mexico produced 26,431 tons of humate in 1976. The Clod Buster mine (operated by Farm Guard Products, Inc., and located between Cuba and La Ventana) has a daily capacity of 80-100 tons of humate, but production is generally variable, depending largely on intermittent sales. Another humate mine, the Tenorio mine (operated by Humas Organic Products, near San Ysidro), is in operation, but no current production figures are available. Production for 1974, however, was about 6,000 tons.

Humate resources in New Mexico are substantial with the coal-bearing Cretaceous strata in the northwestern part of the state containing millions, if not billions, of tons of humate. These deposits represent a potential resource that needs further study and development.

Limestone and dolomite

Limestone and dolomite are sedimentary rocks composed mostly of calcium and magnesium carbonate. Both are used for their physical and chemical properties in industries as diverse as construction, agriculture, manufacturing, and smelting. Low-calcium limestone will be discussed as a source of crushed stone. High-calcium limestone (95 percent calcium carbonate) is a source of lime and is used in the production of cement, paper, glass, alkalies, and calcium carbide and as a metallurgical flux. Low-magnesium limestone with the proper amounts of silica, clay, and iron oxide can also be used directly to make portland cement. Dead-burned dolomite, refractory magnesia, basic magnesium carbonate, and magnesium metal are the chief products from dolomite.

Much of the limestone in New Mexico is late Paleozoic in age, in contrast to most dolomite deposits, which are typically early Paleozoic in age. Most of the units are marine, but some younger limestones, mostly travertines, are lake or spring deposits. Many New Mexico dolomites are secondary types because they result from replacement of the calcium in a limestone body by magnesium.

Production figures for 1977 are currently unavailable. In 1976, however, about 2.3 million tons of limestone and dolomite were produced in New Mexico, with the major producer being the stone industry. In addition, about 925 tons of limestone per day are produced by New Mexico's cement and lime industries.

Abundant carbonate reserves occur in most parts of New Mexico, with limestone occurring on or near the surface in about one-fourth of the state and attaining thicknesses of as much as 1,000 ft. Dolomites are generally restricted to the southern part of the state.

Mica

Mica is a group name for a number of complex hydrous potassium silicate minerals. The United States mica industry is small (163,779 tons in 1977), with North Carolina accounting for about 52 percent of the production. New Mexico is among nine states that produce mica. The bulk of the nation's production is processed into ground mica for various end uses, including joint cement and paint, roofing, and rubber filler.

The major mica reserves that occur in New Mexico are sericite schists that occur in the north-central part of the state. The Tojo mine (southern Taos County) is the only mica mine currently operating in the state. The annual capacity of the operation is about 13,000 tons. Little information is available regarding New Mexico mica reserves.

Perlite

Perlite originally referred to only natural, siliceous, volcanic glasses characterized by concentric fractures and a pearly luster. Industrial usage of the term now includes any volcanic glass that will expand appreciably by vesiculation with a proper heat treatment. The principal end uses of perlite are as aggregate, insulators, and filter aids. New Mexico, the nation's leading producer of crude perlite, supplies 87 percent of the domestic output.

All important New Mexico deposits are located west of the Rio Grande and occur discontinuously from Mexico to near the Colorado border. Most are not of current commercial interest because of their remoteness, small size, poor quality, or excessive mining costs. Perlite deposits are associated with volcanic fields, particularly those of rhyolitic composition, and are typically Tertiary or younger in age. Larger deposits are several hundred feet thick and may extend several miles laterally.

Perlite is now being produced by four operations in New Mexico with a combined daily capacity of about 2,300 tons. The El Grande mine (near Tres Piedras), with a daily capacity of about 1,200 tons, accounts for more than 50 percent of the state's crude perlite production. New Mexico's perlite resources are extensive, with developed commercial-grade reserves being large enough to meet any foreseeable demand.

Potash

Potash is the common term for compounds of the element potassium; sylvite (KCl) and langbeinite ($K_2SO_4 \cdot 2MgSO_4$) are the most important natural potassium compounds. Potash is discussed only briefly here, because this resource and its occurrence in New Mexico is reviewed in detail by Austin (1976).

About 95 percent of the United States' potash consumption is for fertilizer; potassium is an essential plant nutrient for which there are no substitutes. New Mexico contains the nation's largest known potash reserves and in 1976 accounted for about 83 percent of domestic production. Most United States potash needs were met by the Carlsbad mining district until 1962 when Canadian imports increased substantially. These imports now account for over 60 percent of the potash used in the United States.

The Permian Basin of New Mexico and Texas is subdivided into a number of smaller basins, platforms, and shelves. The Carlsbad mining district lies astride the boundary between the Delaware Basin and the Northeastern Shelf. Potash mineralization, in minable quantities, is concentrated in the McNutt potash zone of the Salado Formation of Ochoan (Upper Permian) age. The Salado, a marine evaporite, contains thick beds of halite, gypsum, and anhydrite. The McNutt is about 400 ft thick, plus or minus 100 ft, in the mining district and has about the same lithology and mineralogy as the other members of the Salado, with the exception of the potash minerals. Within the potash enclave, the McNutt contains 11 ore zones of varying thickness and lateral continuity. The 1st, 3rd, 4th, 5th, 7th, 8th, and 10th ore zones have proven concentrations of potash.

The grade of potash ores is commonly expressed in terms of potassium oxide (K_2O) content even though no oxide is actually present. Sylvite (KCl) is the mineral species highest in potassium. In terms of actual potassium present, sylvite contains 52 percent potassium by weight; however, sylvite contains 63.17 percent equivalent-weight percent K_2O. Langbeinite ($K_2SO_4 \cdot 2MgSO_4$), the other principal ore mineral of potassium in the United States, is rated at 22.69 percent K_2O equivalent. Although containing less potassium, langbeinite is low in chloride, for

which some plants have little tolerance. In addition, both magnesium and sulfate ions in langbeinite aid in conditioning leached soils.

The eight mines operated by seven different companies in the Carlsbad district have a maximum capacity of about 50,000 tons of ore per day. In recent years the grade of sylvite and langbeinite ores extracted has fallen to near the break-even mark. The current average sylvite ore is rated about 14 percent K_2O and langbeinite ore is about 8 percent K_2O, with halite and clay minerals accounting for the remainder. The district's minable potash reserves are estimated to be about 100 million tons of recoverable K_2O as sylvite and langbeinite at 1973 price levels. However, possible potash resources in the form of polyhalite and other potassium-bearing minerals are not included in this estimate.

Pumice

Pumice is a highly vesicular, light-colored, volcanic glass, typically of rhyolitic composition. Industrial usage of the term is commonly extended to include dark-colored, cellular, fragmental andesitic and basaltic lithologies, but in this report, these are designated as scoria. The principal use of pumice is as a lightweight aggregate, with smaller quantities finding application as abrasives, soil conditioners, and pozzolanic concrete additives; pumice has a host of other minor uses. The nation's leading pumice producers are Oregon and California; nevertheless, New Mexico has been a leading producer for many years.

Pumice deposits are widely distributed geographically throughout western New Mexico, but most of the state's resources occur in the southern and eastern Jemez Mountains in Sandoval, Santa Fe, and Rio Arriba Counties. Pumice deposits are associated with ash-fall and ash-flow tuffs, tuff breccias, and volcaniclastic sediments of Tertiary and Quaternary age.

Three pumice operations in the state produce about 710 cu yd daily. The largest of these, the Copar mine, has a daily capacity of about 300 cu yd. No published estimates of pumice reserves in New Mexico are available, but the reserves appear to be inexhaustible at present production rates.

Salt

Salt is used here to identify the mineral halite, or sodium chloride (NaCl). By weight, pure salt contains 39.34 percent sodium and 60.66 percent chloride, will depress the freezing point of water 21.2°C, and will melt at 800.8°C. Salt is the most abundant and least expensive source of the sodium and chlorine and is used in the manufacture of caustic soda, soda ash, chlorine, and metallic sodium. Salt is also used for highway de-icing, agricultural purposes, and for miscellaneous uses in the paper pulp, ceramics, plastics, glass, soap and detergent, petroleum, and metal industries.

Salt has been reported in many sedimentary units of Permian age in southeastern New Mexico and occurs in the Paradox Member of the Hermosa Formation (Pennsylvanian) in extreme northwestern New Mexico. Salt is also mined from playas and salt lakes, and considerable production is obtained from refinery waste of the potash industry.

New Mexico's salt-mining industry produced about 110,000 tons of salt in 1977, with most of the production coming from the Salt Lake mine east of Carlsbad, New Mexico. About 200 tons of salt are also produced annually from a solar evaporation operation at Zuni Salt Lake in west-central New Mexico. Although no estimates of salt reserves in New Mexico are available, there is little

doubt that salt supplies—including brine lakes, potash tailing piles, and subsurface rock salt—are substantial and are large enough to meet any foreseeable demand.

Sand and gravel

Sand and gravel are unconsolidated rock fragments formed by the action of air and water on bedrock surfaces. Sand refers to fragments that are 2 mm or smaller in diameter, whereas gravel includes fragments larger than 2 mm in diameter. Such materials are so common that most people rarely consider them as mineral commodities, yet they constitute the largest volume of mineral raw materials produced from the earth. An estimated 898 million tons of sand and gravel, valued at about $1.9 billion, was produced in 1977. Major uses are for concrete aggregate, road bases or coverings, fill, glassmaking, molding, metallurgy, sand blasting, and foundry purposes. California and Alaska are the leading producers of construction sand and gravel, whereas Illinois and Michigan are the leading producers of industrial sand and gravel. New Mexico ranked 35th among the states in the production of construction sand and gravel in 1976.

Sand and gravel deposits of New Mexico are so widespread that most of a map showing geologic units containing potential deposits would be covered. The principal deposits, however, are alluvial sands and gravels of Pleistocene to Holocene age along the Rio Grande valley. Similar deposits occur in the Pecos and Canadian river valleys and their tributaries in the northeastern part of the state. Such deposits are also associated with older Tertiary and Cretaceous formations in the western and eastern parts of the state.

Caliche constitutes a major sand and gravel resource in New Mexico. Caliche is a general term for a zone of secondary carbonate accumulation in surficial materials, formed by both geologic and pedologic processes in warm, arid to subhumid regions. Much of the caliche in southeastern New Mexico, where the commodity is widely used for roadstone, was formed by pedologic processes involving the leaching of carbonates from sandy surface sediments by downward percolating soil water and subsequent precipitation of the carbonate as cementing material deep in the soil profile. Commercially utilized caliche deposits in New Mexico produce only tens of thousands of cubic yards annually. A major sand and gravel pit in eastern New Mexico is located in caliche beds north of Portales, New Mexico.

Sand and gravel operations are now shown on the map (fig. 2), but the 1976 Annual Report of the New Mexico State Inspector of Mines lists more than 110 such producers in New Mexico, with a combined production of about 5.8 million tons annually. No comprehensive reports assess the quantity or quality of New Mexico sand and gravel; however, nearly half of the state is covered by materials that could be used for such purposes. Except for local areas, especially in eastern New Mexico, there appears to be no shortage of sand and gravel resources in New Mexico.

Scoria

Scoria is a dark-colored, cellular, commonly andesitic to basaltic volcanic rock. Scoria is often mistakenly referred to as pumice but differs from pumice in its composition, darker color, higher density, coarser vesicles, more crystalline texture, and generally higher strength. Major uses of scoria are for concrete and road-surfacing aggregate and for railroad ballast. Arizona, California, Hawaii, New Mexico, Nevada, and Oregon are the nation's leading scoria producers.

Scoria deposits result from the explosive eruption of basaltic lavas, and vesiculation is caused by expansion of intrafragmental water vapor during eruption. The pyroclastic fragments are usually deposited peripherally around a vent, which results in the development of a cinder cone. Such deposits are widely distributed among Tertiary and Quaternary deposits throughout western and northern New Mexico.

Currently, 13 scoria operations in New Mexico have a combined daily capacity of about 3,677 cu yd. The largest mine is the Black Pit (Taos County), with a daily capacity of about 1,250 cu yd. New Mexico's scoria resources are extremely large.

Silica

Elemental silicon is a brittle steel-gray metalloid that is commonly combined with oxygen to form quartz (SiO_2). Silicon also combines with oxygen and one or more metal ions to form the largest of all the rock-making families, the silicates. Second only to feldspar, quartz is the most abundant known mineral and accounts for roughly 12 percent of all surficial terrestrial rock. Siliceous raw materials are often used in industry directly as finished products, shipped without elimination of natural contaminants. Silicon is widely used in the iron, steel, and electronics industries and is also used to produce intermediate products such as silanes from which several hundred silicone resins, lubricants, plastomers, antifoaming agents, and water-repellant compounds are formed.

The Brockman Silica quarry (near Playas), operated by Phelps Dodge Corporation, is the only currently active silica operation in New Mexico. The quarry produces about 140,000 tons of silica annually from the Mojado Formation (Cretaceous). All of the material is used at the company's Hidalgo Smelter near Playas.

Stone

Stone, as used here, includes both crushed stone and dimension stone. Crushed stone is used mostly for roadbase, roadstone, concrete aggregate, and bituminous aggregate. Pennsylvania and Illinois are the leading producers of crushed stone. Dimension stone is used chiefly for blocks, monumental stone, building stone, curbing, and rubble. The nation's leading producers are Indiana and Georgia. New Mexico ranked 44th in the production of crushed stone; the state's ranking in the production of dimension stone is uncertain, but the most reasonable estimate is about 42nd.

Crushed stone is obtained from a variety of igneous and sedimentary rocks in New Mexico; limestone and basalt account for the largest part of the production. Dimension stone may be developed from a variety of rock types including sandstone, limestone, marble, quartzite, granite, and travertine.

There are about 75 crushed-stone producers in New Mexico, with total output of about 2.5 million tons per year. Much of the crushed stone, especially that used for highway construction, is produced by portable equipment from small roadside operations that operate only long enough to satisfy immediate local demand.

About 90 tons of dimension stone are produced on a daily basis in New Mexico from two quarries. The largest of these, the Placer flagstone operation (sec. 19, T. 20 S., R. 10 W.), has an annual capacity of about 50 tons. Another operation, the Rainbow Marble mine, produces about 90 cu ft of decorative "marble" per day from a travertine deposit near Radium Springs, New Mexico.

Abundant reserves of durable and attractive stone remain in New Mexico. The future of the industry depends on the development of new markets and new uses of this readily available resource.

Sulfur

Sulfur, constituting 0.06 percent of the earth's crust, is widespread in nature and is one of the few elements that occurs in the native form. Sulfur is also one of the world's most important industrial raw materials, with uses in most sectors of the fertilizer and industrial complexes of the world.

Sulfur occurs around vents and fumeroles associated with hot springs in the Jemez sulfur district (Sandoval County). Some native sulfur is also reported to occur near White Oaks (Lincoln County), north of Tres Piedras (Rio Arriba County), in the La Bajada district (Santa Fe County), southwest of Clines Corners (Torrance County), near Artesia (Eddy County), and near the Texas border (Otero County). However, these deposits are not currently significant sources of commercial sulfur.

A large potential sulfur resource in the state is production from oil and gas fields in the San Juan Basin of northwestern New Mexico and the Delaware Basin of southeastern New Mexico. The recovery of sulfur from natural gas began in New Mexico in 1953, and by 1977 the total production from natural gas amounted to about 113 tons per day. Another potential source of sulfur is the sulfide ore of various metalliferous deposits in New Mexico. Most of such known reserves are in the central mining district in Grant County, the Magdalena district in Socorro County, and the Pecos mine in San Miguel County.

Outlook

The importance of industrial rocks and minerals can hardly be overemphasized, because they are used in the arts and sciences, engineering, metallurgy, agriculture, and in many articles associated with daily life. New Mexico has an abundance of such materials and a superabundance of some. An important problem confronting the state is the use and commercial exploitation of these valuable commodites.

As with any other natural or manufactured product, the successful production of industrial rocks and minerals depends on the fundamental law of supply and demand. Prices may be temporarily elevated or depressed by manipulation, monopolies, or legislation, but if a commodity is scarce and needed, prices will be relatively high; if a commodity is abundant or of limited use, prices will be low. Therefore, availability and quality of material, production and transportation costs, and market size and location are important considerations in the development of New Mexico's industrial rock and mineral resources.

Many industrial rocks and minerals are low-cost commodities that are profitable only when large tonnages can be sold to a nearby market. Sizable markets in New Mexico are few and relatively isolated; moreover, population increases and consequent industrial growth are likely to be limited by the availability of water in the state's semiarid climate, and the prospects for the development of such markets for industrial rocks and minerals are not great. Because use of such resources in New Mexico will be limited to relatively small, scattered population centers, large markets—with the possible exception of the Albuquerque area—will have to be sought elsewhere. Most of the growth in New Mexico's industrial rock and mineral industry will depend on the local production and processing of

quality materials for which a national market, or a market in the Albuquerque area, exists or can be created.

REFERENCES

Austin, G. S., 1976, Potash in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Rept. 1975-76, p. 23-29

Bates, R. L., 1960, Geology of the industrial rocks and minerals: New York, Harper & Row, Publishers, 441 p.

Lefond, S. J., ed., 1975, Industrial minerals and rocks: New York, American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc., 1360 p.

Siemers, C. T., and Wadell, J. S., 1977, Humate deposits of the Menefee Formation (Upper Cretaceous) northwestern New Mexico: New Mexico Geological Society Guidebook, 28th field conference, Supplement, p. 1-22

Talmage, S. B., and Wootton, T. P., 1937, The non-metallic mineral resources of New Mexico and their economic features (exclusive of fuels): New Mexico Bureau Mines and Mineral Resources, Bull. 12, 159 p.

U.S. Bureau of Mines, 1975, Mineral facts and problems: U.S. Bureau of Mines, Bull. 667, p. 2

U.S. Geological Survey, 1965, Mineral and water resources of New Mexico: New Mexico Bureau Mines and Mineral Resources, Bull. 87, 437 p.

Directory of active industrial rock and mineral operations in New Mexico

Mine name Commodity	Location	Producer
	BERNALILLO COUNTY	
1. Black Bird scoria	sec. 18 T. 8 N., R. 1 E.	Rocky Mountain Stone Co. P.O. Box 6008 Albuquerque, NM 87107 (505) 344-2611
2. Hatti clay	sec. 18, 19 T. 9 N., R. 6 E.	Kinney Brick Co. P.O. Box 1804 Albuquerque, NM (505) 877-4550
3. Tijeras limestone & clay	sec. 22, 27 T. 10 N., R. 5 E.	Ideal Basic Industries Cement Division P.O. Box 100 Tijeras, NM 87059 (505) 281-3311
	CATRON COUNTY	
1. Zuni Salt Lake salt	sec. 31 T. 3 N., R. 18 W.	Pueblo Zuni Salt Corp. Star Route Salt Lake Quemado, NM 87829 (505) 773-4636
	DOÑA ANA COUNTY	
1. Black Bear Mt. scoria	sec. 1, 12 T. 26 S., R. 1 E.	Del Norte Masonry Products 4560 Ripley Dr. El Paso, TX 79922 (915) 584-4453

Mine name Commodity	Location	Producer
2. Clay Pits clay	Sec. 15 T. 29 S., R. 4 E.	El Paso Brick Co. P.O. Box 12336 El Paso, TX 79912 (915) 589-4474
3. Donna Mt. scoria	sec. 15 T. 24 S., R. 4 W.	Morton Bros. Cinders & Stone P.O. Box 2000 Las Cruces, NM 88001 (505) 523-5750
4. East Vado building stone	sec. 16 T. 25 S., R. 3 E.	Guillen Const. Co. 3416 Nahvile El Paso, TX 79930 (915) 566-7261
5. Rainbow Marble calcite	sec. 23 T. 21 S., R. 2 W.	Apache Springs Co. P.O. Box 48 Radium Springs, NM 88054 (505) 524-4032
6. Santo Tomas scoria	sec. 31 T. 24 S., R. 2 E.	Morton Bros. Cinders & Stone P.O. Box 2000 Las Cruces, NM 88001 (505) 523-5750
7. Silica Pit silica	sec. 9 T. 29 S., R. 4 E.	El Paso Brick Co. P.O. Box 12336 El Paso, TX 79912 (915) 589-4474
8. Volcano No. 1 Scoria	sec. 22 T. 25 S., R. 3 W.	Morton Bros. Cinders & Stone P.O. Box 2000 Las Cruces, NM 88001 (505) 523-5750

EDDY COUNTY

1. AMAX potash	sec. 9 T. 19 S., R. 30 E.	AMAX Chemical Corp. P.O. Box 279 Carlsbad, NM 88220 (505) 885-3157
2. Hobbs Potash Facility potash	sec. 4 T. 21 S., R. 31 E.	Kerr-McGee Chemical Corp. P.O. Box 610 Hobbs, NM 88240 (505) 397-3261
3. IMC potash	sec. 1, 12 T. 22 S., R. 29 E.	International Minerals & Chemicals Corp. P.O. Box 71 Carlsbad, NM 88220 (505) 887-5591
4. Mississippi Chemical Corp. potash	sec. 12, 13 T. 21 S., R. 29 E.	Mississippi Chemical Corp. P.O. Box 101 Carlsbad, NM 88220 (505) 887-5591

Mine name Commodity	Location	Producer
5. Nash Draw potash	sec. 33, 34 T. 22 S., R. 30 E.	Duval Corp. P.O. Box 511 Carlsbad, NM 88220 (505) 887-3175
6. North potash	sec. 13 T. 20 S., R. 30 E.	Duval Corp. P.O. Box 511 Carlsbad, NM 88220 (505) 887-3175
7. PCA potash	sec. 4 T. 20 S., R. 30 E.	Potash Company of America P.O. Box 31 Carlsbad, NM 88220 (505) 887-2844
8. Salt Lake salt	sec. 12 T. 22 S., R. 29 E.	United Salt Corp. P.O. Box SS Carlsbad, NM 88220 (505) 885-2105

GRANT COUNTY

1. Buckhorn zeolite	sec. 10 T. 15 S., R. 18 W.	Double Eagle P.O. Box 776 Casper, WY 82602 (307) 237-9330
2. Clum fluorite	sec. 33 T. 14 S., R. 16 W.	Frank Turley & John Foster Box 53 Deming, NM 88030 (505) 546-2408
3. Hurley Lime Quarry limestone	sec. 26, 27 T. 18 S., R. 13 W.	Kennecott Copper Corp. Chino Mines Division Hurley, NM 88043 (505) 537-3381
4. Mathis Lime Quarry limestone	sec. 19 T. 17 S., R. 12 W.	Mathis & Mathis Mining & Exploration P.O. Box 452 Silver City, NM 88041 (505) 538-9453

HIDALGO COUNTY

1. Brockman Silica Quarry silica sandstone	sec. 1 T. 26 S., R. 17 W.	Phelps-Dodge Corp. Drawer B Tyrone, NM 88065 (505) 538-5331
2. Fire Clay Pit 290082 clay	sec. 32 T. 27 S., R. 20 W.	Phelps-Dodge Corp. Drawer B Tyrone, NM 88065 (505) 538-5331

Mine name Commodity	Location	Producer
	LEA COUNTY	
1. Lea potash	sec. 18 T.20 S., R.32E.	National Potash Co. P.O. Box 731 Carlsbad, NM 88220 (505) 885-6514
2. Nat'l. Tailings Mine salt	sec. 18 T. 20 S., R. 32 E.	Williams Brine Service 851 Standpipe Rd. Carlsbad, NM 88220 (505) 885-6514
	LUNA COUNTY	
1. Greenleaf fluorite	sec. 18 T. 22 S., R. 8 W.	Frank Turley & John Foster Box 53 Deming, NM 88030 (505) 546-2408
2. Henry Clay clay	sec. 20 T. 20 S., R. 10 W.	Mathis & Mathis Mining & Exploration P.O. Box 452 Silver City, NM 88061
3. Placer flagstone	sec. 19 T. 20 S., R. 10 W.	W. H. Thomas P.O. Box 225 Silver City, NM 88061 (505) 538-9440
	McKINLEY COUNTY	
1. Red Dog cinder	sec. 32 T. 16 N., R. 18 W.	Mendoza Red Dog 301 E. Adams Gallup, NM 87301 (505) 863-5806
2. San Antone Pit limestone	sec. 17 T. 14 N., R. 12 W.	Gallup Sand & Gravel Co. P.O. Box 1119 Gallup, NM 87301 (505) 863-4824
	RIO ARRIBA COUNTY	
1. Cullum pumice	sec. 17 T. 20 N., R. 7 E.	General Pumice Corp. P.O. Box 5135 Santa Fe, NM 87501 (505) 982-0411
2. Diatomaceous Earth Mine diatomite	sec. 22 T. 21 N., R. 7 E.	American Exploration & Management, Inc. 2432 Jefferson, NE Albuquerque, NM 87110 (505) 265-3581
3. San Anton scoria	sec. 28 T. 31 N., R. 9 E.	Colorado Aggregate Co. P.O. Box 106 Mesita, CO 81142 (303) 672-4408

Mine name Commodity	Location	Producer
	SANDOVAL COUNTY	
1. Clod Buster No. 1 humate	sec. 9 T. 19 N., R. 1 W.	Farm Guard Products 5555 Montgomery NE, No. 13 Albuquerque, NM 87109 (505) 345-8441
2. Esquire Claims 5-9 pumice	sec. 34 T. 18 N., R. 3 E.	Utility Block Co. 7200 2nd St., NW Albuquerque, NM 87197 (505) 344-2368
3. San Felipe Mine gypsum	sec. 1, 2 T. 13 N., R. 5 E.	Ernest Teeter Trucking 145 Lamedia Rd., SW Albuquerque, NM 87105 (505) 836-4037
4. Tenrio humate	sec. 8 T. 14 N., R. 1 E.	Humas Organic Products Box 520 Bernalillo, NM 87004 (505) 867-5973
5. White Mesa gypsum	sec. 11-15 T. 15 N., R. 1 E.	Pomeroy, Inc. 5137 Russell Dr., N.W. Albuquerque, NM 87114 (505) 897-2120
	SAN JUAN COUNTY	
1. Red Shale cinder	sec. 30 T. 30 N., R. 15 W.	Garcia & Son 1103 Canyon Pl. Farmington, NM 87401 (505) 455-2541
	SANTA FE COUNTY	
1. Copar pumice	sec. 31, 32 T. 20 N., R. 7 E.	Copar Pumice Co., Inc. P.O. Box 38 Espanola, NM 87532 (505) 455-2541
2. La Cieniga scoria	sec. 18 T. 16 N., R. 8 E.	Crego Block Co. 6026 2nd St., NW P.O. Box 6025 Albuquerque, NM 87107 (505) 345-4451
3. North Red Bird scoria	sec. 31 T. 17 N., R. 7 E.	Ulibarri Trucking Co. P.O. Box 4 Santa Fe, NM 87501 (505) 982-2109
4. Red Bird scoria	sec. 36 T. 17 N., R. 7 E.	Colony Materials P.O. Box 4096 Santa Fe, NM 87501 (505) 982-8588
5. Rosario Gypsum Mine gypsum	sec. 32 T. 15 N., R. 7 E.	Dry Wall Supply, Inc. 1805 Irvington Pl. Denver, CO 80223 (303) 778-6381

Mine name Commodity	Location	Producer
	SIERRA COUNTY	
1. Lyda K fluorite	sec. 28, 29 T. 16 S., R. 4 W.	Allied Chemical Corp. Rt. 1 Cave In Rock, IL 62919 (618) 289-3213
	SOCORRO COUNTY	
1. Drake barite	sec. 23 T. 3 N., R. 1 W.	Donald F. Drake & Jo Drake P.O. Box 974 Socorro, NM 87801 (505) 835-2610
2. Grefco perlite	sec. 28 T. 3 S., R. 1 W.	Grefco Dicalite Div. P.O. Box 1436 Socorro, NM 87801 (505) 835-2892
3. Twin Peaks scoria	sec. 1 T. 6 S., R. 8 E.	Colorado Aggregate Co., Inc. P.O. Box 106 Mesita, CO 81142 (303) 672-4408
	TAOS COUNTY	
1. Black Pit scoria	sec. 26 T. 30 N., R. 9 E.	Colorado Aggregate Co. P.O. Box 106 Mesita, CO 81142 (303) 672-4408
2. El Grande perlite	sec. 15, 22 T. 29 N., R. 9 E.	Grefco Dicalite Div. P.O. Box 308 Antonito, CO 81120 (303) 876-5484
3. No Agua J-M perlite	sec. 11 T. 29 N., R. 9 E.	Johns-Manville Corp. P.O. Box 338 Antonito, CO 81120 (303) 376-5484
4. Silbrico perlite	sec. 34 T. 29 N., R. 10 E.	Silbrico Corp. P.O. Box 367 Antonito, CO 81120 (303) 376-5411
5. Tojo sericite	sec. 24, 25 T. 23 N., R. 12 E.	Minerals Industrial Commodities of America, Inc. P.O. Box 2403 Santa Fe, NM 87501 (505) 455-2551
	UNION COUNTY	
1. M-19204 scoria	sec. 23 T. 30 N., R. 29 E.	New Mexico Highway Dept. District 4 Grand Ave. Las Vegas, NM 88418 (505) 278-2694

Mine name Commodity	Location	Producer
2. Twin Mt. scoria	sec. 19 T. 30 N., R. 29 E.	Twin Mountain Rock Co. P.O. Box 37 Des Moines, NM 88418 (505) 278-2694
	VALENCIA COUNTY	
1. U.S. Gypsum Perlite perlite	sec. 3 T. 11 N., R. 9 W.	U.S. Gypsum Co. 209 E. Santa Fe Grants, NM 87020 (505) 287-4211

MINERAL PRODUCTION IN NEW MEXICO[1]

Prepared by U.S. Bureau of Mines, January 10, 1977

Mineral	1976 Quantity	1976 Value (thousands $)	1977 preliminary Quantity	1977 preliminary Value (thousands $)
Carbon dioxide ..... thousand cubic feet	856,548	80	850,000	94
Clays[2] ..... thousand short tons	56	116	61	81
Coal, bituminous ..... do	9,760	W	11,645	W
Copper (recoverable content of ores, etc.) short tons	172,360	239,925	167,100	222,911
Gemstones	NA	210	NA	150
Gold (recoverable content of ores, etc.) troy ounces	15,198	1,905	12,200	1,808
Manganiferous ore (5% to 35% Mn)—short tons	45,362	W	W	W
Natural gas ..... million cubic feet	1,230,976	695,501	1,191,535	934,164
Natural gas liquids:				
Natural gasoline and cycle products thousand 42-gallon barrels	9,490	51,369	9,660	75,586
Liquefied petroleum gases ..... do	32,654	180,577	32,340	239,414
Peat ..... thousand short tons	W	W	2	49
Perlite ..... do	481	8,403	478	8,762
Petroleum (crude)—thousand 42-gallon barrels	92,130	814,419	86,815	790,017
Potassium salts ..... thousand short tons	2,083	165,354	2,137	178,336
Pumice ..... do	486	1,560	465	1,968
Sand and gravel ..... do	7,702	16,671	8,000	17,000
Silver (recoverable content of ores, etc.) thousand troy ounces	892	3,880	878	4,041
Stone ..... thousand short tons	1,935	4,394	2,113	4,783
Uranium (recoverable content of U_3O_8) thousand pounds	11,880	191,271	13,200	264,000
Value of items that cannot be disclosed: Cement, (masonry and portland), fire clay, gypsum, helium (high-purity), lead, lime, mica (crude), molybdenum, salt, tin, vanadium, zinc, and values indicated by symbol W	XX	134,492	XX	162,736
Total	XX	2,510,127	XX	2,905,900

NA Not available

W Withheld to avoid disclosing individual company confidential data; included with "Value of items that cannot be disclosed"

XX Not applicable

[1]Production as measured by mine shipments, sales, or marketable production (including consumption by producers)

[2]Excludes fire clay; included with "Value of items that cannot be disclosed"

Composition: Text in 8-pt. and 10-pt. Times Roman, leaded one point
Display heads in 18 pt. Times Roman, letterspaced

Presswork: Miehle Single Color Offset

Binding: Sewn with softbound cover

Paper: Cover on 10 pt. C1S
Text on 70 lb. Matte White Offset

Financial Statements

New Mexico Bureau of Mines & Mineral Resources
July 1, 1977 to June 30, 1978

BOARD OF EDUCATIONAL FINANCE–LEGISLATIVE

Funds available			
Beginning balance July 1, 1977		$ 2,151	
State appropriation		1,139,800	
Publication receipts		46,366	$1,188,317
Expenditures			
Salaries:			
Full-time staff	$664,884		
Part-time (mostly students)	79,300	744,184	
Employee benefits		91,341	
Project contracts		55,751	
Travel & vehicles		47,271	
Scientific laboratories:			
Maintenance	7,877		
Materials & supplies	23,243	31,120	
Office supplies		7,869	
Postage & freight		8,765	
Printing		69,177	
Equipment		42,011	
General expenses:			
Telephone	12,453		
Subscriptions & dues	3,619		
Computer service	2,355		
Overhead & audit (to Tech)	38,000		
Heat, water, electricity	22,130	78,557	1,176,046
Balance June 30, 1978			$ 12,271

NEW MEXICO COAL SURFACE MINING COMMISSION

Funds available			
Beginning balance July 1, 1977		10,767	
Fees collected:			
Consolidation Coal (7/29/77)	$ 140		
Western Coal (10/21/77)	2,310		
Albert Firchau (11/2/77)	380		
Amcoal (10/28/77)	100		
Alamito Coal (11/21/77)	494		
Kaiser (3/8/78)	500		
Pittsburg & Midway (4/21/78)	2,450		
Utah International (5/1/78)	9,824	16,198	26,965
Expenditures			
Salaries & fees	20,798		
Travel	3,132		
Supplies and reports	1,730		25,660
Transferred to Bureau of Surface Mining			1,305
Balance June 30, 1978			-0-

MOUNTAIN RANGES OF NEW MEXICO

The mountains of New Mexico are a study in contrast. The high forested peaks of the north, which rise above 13,000 ft, are covered with snow during much of the year. To the south, barren peaks rise 5,000 ft above the cactus desert. New Mexico's mountains are rich in legend and scenery. New Mexico has approximately 75 mountain ranges, 72 of which are shown on this map.