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

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

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May 20, 1983

TO: Board of Regents, New Mexico Institute of Mining & Technology
Toney Anaya, Governor of New Mexico
Paul Biderman, Secretary, New Mexico Energy and Minerals Department
Charles Holmes, Acting President, New Mexico Institute of Mining & Technology

We have the honor of transmitting to you a detailed Annual Report of the New Mexico Bureau of Mines and Mineral Resources for the fiscal year July 1, 1981 through June 30, 1982 as required by law (Section 3, Chapter 115, Eighth New Mexico Legislature, approved March 14, 1927).

In this, our 55th year of service and applied research, the Bureau provided information concerning exploration, development, and conservation of New Mexico's mineral resources, as well as doing broad investigations of the State's geology. Twenty-six new publications were issued, along with 34 open-file reports, and normal numbers of New Mexico Geology and Isochron/West. Our staff members served professional and scientific organizations and cooperated with other state agencies, including our liaison with the Energy and Minerals Department.

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

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

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

Respectfully submitted,

Frank E. Kottlowski
Director

George S. Austin
Deputy Director

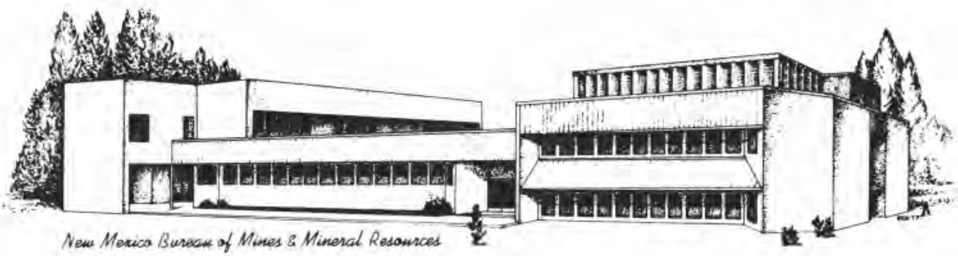
New Mexico Bureau of Mines & Mineral Resources

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

ANNUAL REPORT

for the fiscal year July 1, 1981, to June 30, 1982

by
Frank E. Kottlowski
and staff



SOCORRO 1983

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Purpose and functions

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

For 55 yrs NMBMMR has served New Mexico in this legislative-assigned role. Most of our investigations have been reported on in numerous bulletins, memoirs, circulars, ground-water reports, hydrologic reports, geologic maps, scenic-trip guidebooks, progress reports, resource maps, and open-file reports. In addition, hundreds of articles have been published by staff members and by research associates in journals of professional and scientific societies, and staff members have made many scientific and technical presentations to state, national, and international organizations. NMBMMR's program of geologic and mineral resources studies has contributed significantly to New Mexico's position as a leading producer of energy and mineral materials.

In 1981 the value of minerals extracted in New Mexico totaled $7.24 billion. Payments from the U.S. Bureau of Land Management and compensatory reimbursement in lieu of taxes totaled $128 million. State severance and other taxes collected on minerals extracted in New Mexico during 1981, plus bonus and royalties were almost $1.1 billion. Thus, New Mexico's mineral industry is one of the major contributors to the state's economy.

The Bureau's operations extend into every corner of the state and cover most of the facets of geology and mineral resources. Examples are John Hawley's and David Love's oversight of the WIPP project in southeast New Mexico and examination of the geologic features of the state as related to areas which could accommodate sites for the disposal of low-level radioactive waste.

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

Geology and mineral resources

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

The scientific and technical literature generated by the Bureau contributes greatly to mineral exploration. Sales of Bureau publications totaled $69,002 this fiscal year; approximately 8,800 copies of the new publications were issued free to state officials, libraries, and scientific organizations. Sales performance of a particular publication, however, does not necessarily reflect its ultimate worth to New Mexico; any report or map may contain the clue that leads to the discovery of a huge orebody or a million-barrel oil pool.

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

Most of our geologic work comprises "ground truth" investigations, as demonstrated by the more than 272,000 mi logged by Bureau field vehicles during the fiscal year.

Basic services

Citizens of New Mexico and elsewhere, including geologists, engineers, landowners, prospectors, legislators, students, industry personnel, and tourists, sought technical advice from Bureau staff this year. Our records show that 12,440 letters and 11,290 telephone inquiries were answered, and 9,630 office visitors were counseled. Many adults and school children toured the Bureau's mineral museum. More than 3,200 analytical reports were prepared on mineral, ore, metallurgical, and water samples. Staff mineralogists identified hundreds of hand specimens of rocks and minerals brought or mailed to the Bureau.

Direct services to petroleum exploration included making available records of many of the more than 80,000 test wells drilled in New Mexico, including cuttings from selected wells and a variety of borehole logs such as electric, radioactive, and sonic. Up-to-date petroleum exploration maps for most counties are maintained and available.

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

ACKNOWLEDGMENTS—Editing and much of the compilation was by Marla D. Adkins-Heljeson, aided by Deborah A. Shaw (compilation of publications, articles, talks, and activities lists) and by Judy M. Vaiza and Jeanette Chavez (compilation of project lists). Drafting and drawings were by Michael W. Wooldridge. Special appreciation is owed to authors of the technical articles. All staff members aided in providing data on projects and services.

—Frank E. Kottlowski, Director

Laboratories

Analytical

The analytical laboratory is a service laboratory for the Bureau. We also perform analyses on up to three samples a year, free of charge, for New Mexico citizens on samples from New Mexico. This year the laboratory ran 3,204 analyses on 1,287 samples. The types of tests ranged from major, minor, and trace elements in water and rock samples to analyses of metallurgical leach solutions. Included in the total were many fire assays for gold and silver, a perennial favorite.

—Lynn Brandvold, Chemist

Chemical Microbiology

The chemical microbiology laboratory of the New Mexico Bureau of Mines and Mineral Resources is an applied-research facility engaged in projects sponsored by federal, state, and industrial contracts and grants. Projects researched during 1981–

82 included: 1) Pretreatment methodology for silver and gold recovery by cyanidation; 2) Microbial extraction of tungsten from wolframite; 3) Investigation of microbially induced permeability loss during in situ leaching; 4) Microbial flocculation of phosphate and potash slimes; 5) Contamination of ground and surface waters by uranium mining and milling; 6) Biological methods to remove selected pollutants from uranium mine waste water; 7) Trace elements in oil shale; 8) Application of bacterial leaching technology to deep-solution mining conditions; and 9) Application of bacterial leaching technology to deep-solution mining conditions of uranium extraction.

—*Corale L. Brierley, Chemical Microbiologist*

New Mexico Library of Subsurface Data

This year the staff aided 427 visitors and received 830 telephone calls and 402 letter inquiries. During the year 496 driller's logs and 1,155 petroleum-exploration maps were distributed, and 549 mechanical logs and 150 well-cuttings sets were loaned. In addition, 4,539 well records were copied.

Data added to the files during the year include 603 driller's logs (11,233 on file), 3,128 mechanical logs (over 53,000 on file) from 1,980 wells (25,199 on file), and 412 boxes of cuttings (37,184 on file) from 122 wells (11,006 on file). In addition, 2,867 new well records (over 80,000 on file) were added.

The library is an important source of information regarding exploration for petroleum, coal, uranium, and carbon dioxide. It is used by industry and graduate students as well as by Bureau geologists. Data items on file in the petroleum section include well cuttings, well records, driller's logs, sample descriptions and logs, mechanical logs, geologic maps, petroleum-exploration maps, production data, petroleum-geologic publications, and field and pool definitions and data.

—*Robert A. Bieberman, Senior Petroleum Geologist*

X-ray

The New Mexico Institute of Mining and Technology made a significant commitment to the x-ray analytical laboratory in 1980–81 with the purchase of a modern x-ray fluorescence spectrometer, an x-ray diffractometer, and dedicated computer equipment. The lab is managed by the New Mexico Bureau of Mines and Mineral Resources and is used by many members of its professional staff and by graduate students supported by the Bureau. The geoscience department of New Mexico Tech also uses the equipment extensively and contributes to its financial support. Researchers and students from the metallurgy and chemistry departments, the Petroleum Recovery Research Center, and from outside the Institute often take advantage of the facility.

The Rigaku 3064 x-ray fluorescence spectrometer has components that permit qualitative and quantitative analysis of rock powders for many elements of scientific and economic interest to geoscientists. The x-ray lab routinely performs accurate, precise, and rapid analyses of silicate rocks for 10 major oxides and a selected group of trace elements. A DEC PDP 11/23 computer is used to control the spectrometer and to collect, to store, and to process data. A great deal of effort has been directed toward developing the specialized software required to obtain high quality results automatically for the most requested elemental analyses. Purchased "Fundamental Parameters" software is also available for XRF data processing and is especially useful for specialized problems such as the analysis of ores.

The XRF spectrometer is a major tool in such current Bureau-sponsored research projects as the geochemical characterization of the Española Basin and of the Cenozoic volcanic rocks of the Datil–Mogollon volcanic field. The equipment also has been utilized in other Bureau projects including studies of coals, clays, carbonatites, Precambrian rocks, and uranium and tin ores. Upon request by state residents or organizations, analyses have been performed, free of charge, to help with specific technical questions and problems. Several x-ray analysts from other institutions have visited the lab to study our XRF methods for the analysis of geological materials.

The Rigaku Geigerflex x-ray diffractometer is used to identify the crystalline phases present in a wide variety of geologic materials. The unit can be operated under the control of its own microprocessor or of the PDP 11/23. With use of the computer and manufacturer-supplied "search-match" software, the diffraction pattern of a sample can be collected and stored, and its crystalline components can be identified after comparison with JCPDS reference patterns stored on disk. In addition to the new Rigaku diffractometer, older Philips diffraction equipment is available for use.

The Bureau routinely performs qualitative scans for the identification of mineral phases in samples submitted by staff members or the public. The x-ray diffraction equipment has been used as a research tool by Bureau staff members for such projects as the mineralogical characterization of the Española Basin, the clay content in adobe bricks, and the development of quantitative diffraction methods. A turbine-drive sample spinner has been designed and built which enables superb diffraction patterns to be obtained from less than 20 mg of sample. The new spinner also permits good patterns to be obtained from samples such as polished ore specimens which are normally too coarse grained for x-ray diffraction.

Because of the great increase in the use of the x-ray lab since the acquisition of the Rigaku instruments, the x-ray sample preparation facilities were necessarily modernized and expanded with the remodeling of laboratory space and the purchase of a programmable ashing furnace, efficient rock grinding equipment, and suitable lab furniture.

—K. Babette Faris, X-ray Lab. Manager

Mineral museum

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

During the last year, 20 groups, totaling over 800 people, arranged for special museum tours. Both students and geologists took advantage of the study collection. Fifteen new specimens were purchased at a cost of $1,376,00. The museum received 33 donated specimens worth approximately $2,000.00.

The "Minerals for sale" case in the museum generated $228.40, which was used to purchase new specimens for the display collection.

—Robert M. North, Mineralogist

TABLE OF ORGANIZATION

June 30, 1982

Administration & information
Kottlowski, Director, Sr. Geologist
Austin, Deputy Director, Geologist
Vaiza, Executive Secretary
Chavez, J., Administrative Secretary I
Lindsey, Staff Secretary
Baca, A., Technician II
Crespin, Mechanic

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

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

Environmental geology
Hawley, Senior Environmental Geologist
Love, Environmental Geologist

Geophysics
Reiter, Senior Geophysicist
Broadwell, Lab Technician I

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

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

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

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

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

Oil and gas
Bieberman, Senior Petroleum Geologist
Thompson, Senior Petroleum Geologist
Broadhead, Petroleum Geologist
Howell, Staff Secretary

Paleontology
Wolberg, Paleontologist
Flower, Sr. Emeritus Paleontologist

(P) Secondary assignment

Geology and resource projects

The object of the Bureau's program of investigations is to provide statewide evaluations of mineral resources and geology, to study key areas in detail, and to recommend guidelines for exploration, development, metallurgical extraction, and conservation of New Mexico resources. Completed and continuing projects, wholly or partly funded by the Bureau, are listed in this section. An index map of field projects is shown on pages 10 and 11. A list of part-time research associates on contract to the Bureau appears on pages 16 and 17. Bureau staff employed during the fiscal year is listed on pages 32–36.

Oil and gas

1. Austin, Myers, Bieberman, Chavez, R., Reiter, Siemers, Tabet, and Frost—Energy-resources map of New Mexico (in cooperation with U.S. Geological Survey; U.S. Geological Survey Misc. Inv. Series, Map I–1327)
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. Broadhead—Gas production and sedimentology of tight gas-producing sandstones of Abo Formation in east-central New Mexico
6. Broadhead—Oil and gas discovery wells in New Mexico in 1981
7. Broadhead—Oil and gas discovery wells in New Mexico in 1982
8. Christiansen—History of oil and gas exploration and production in New Mexico
9. Harder (King)—Oil and gas potential of Tularosa Basin–Otero platform area, south-central New Mexico (thesis available)
10. King—Petroleum potential of Otero Mesa region, south-central New Mexico
11. Thompson—Petroleum geology of southwestern New Mexico
12. Thompson—Analyses of petroleum source and reservoir rocks in southwestern New Mexico (in cooperation with New Mexico Energy Research and Development Institute; Open-file Report 153)
13. Thompson—Subsurface geology of the Cockrell No. 1 Playas well, Hidalgo County
14. Thompson—Subsurface geology of the Humble No. 1 State BA well, Hidalgo County
15. Thompson—Oil and gas exploration wells in southwestern New Mexico
16. Thompson and Jacka—Cambrian–Mississippian stratigraphy, petrography, and petroleum geology of the Mescal Canyon section, Hidalgo County
17. Thompson and Jacka—Guidebook to Middle Permian depositional and diagenetic features, Guadalupe Mountains, New Mexico and Texas

Industrial minerals and coal

1. Anderson—Geology and coal resources of Cantaralo Spring quadrangle (Open-file Report 142)
2. Anderson—Geology and coal resources of Venadito Camp quadrangle (Open-file Report 163)
3. Anderson—Geology and coal resources of Atarque Lake quadrangle
4. Anderson—Geology and coal resources of Mesita de Yeso quadrangle
5. Anderson—Geology and coal resources of Shoemaker Canyon SE quadrangle (in cooperation with U.S. Geological Survey)
6. Anderson—Geology and coal resources of Upper Gallistina Canyon quadrangle (in cooperation with U.S. Geological Survey)
7. Anderson, Campbell, and Hook—Coal resources of the Salt Lake and Zuni coal fields (in cooperation with U.S. Geological Survey)
8. Anderson and Frost—Geology and coal resources of Twentytwo Spring quadrangle (Open-file Report 143)
9. Arkell (Smith)—Coal geology of southwestern Sierra Blanca coal field
10. Austin—Shale and clay resources of New Mexico

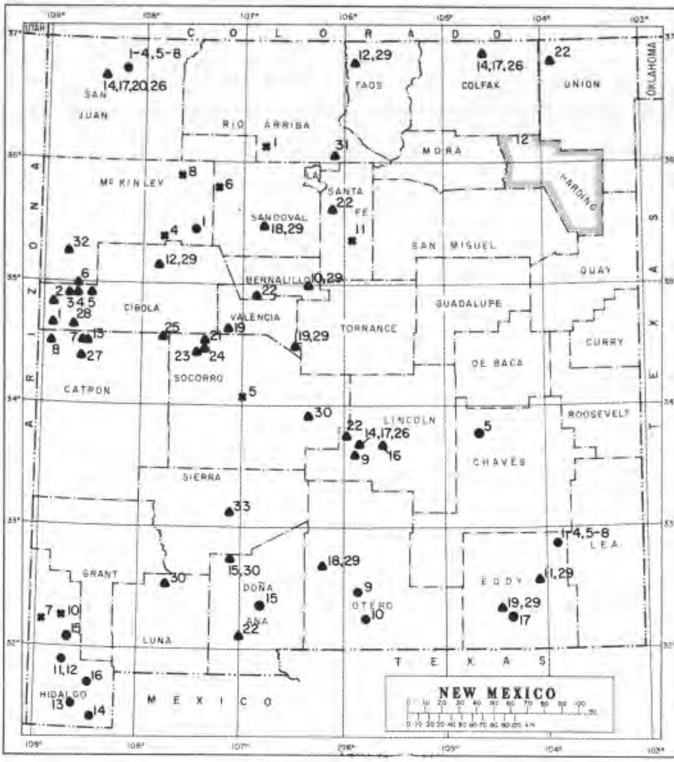
11. Austin, Logsdon, Siemers, and Weber—1981 forum on the geology of industrial minerals (Circular 182)
12. Austin and Weber—Perlite deposits of New Mexico (Circular 182)
13. Campbell—Coal resources of Cerro Prieto and The Dyke quadrangles (Open-file Report 144)
14. Campbell and Roybal—Coal resources map of New Mexico (ongoing revision of Resource Map 10)
15. Filsinger (Clark and Logsdon)—Barite deposits of Palm Park, Caballo Mountains, Doña Ana County
16. Jensen (MacMillan)—Depositional environments of Mesaverde Group in Capitan coal field
17. Kottlowski, Campbell, Roybal, and Martinez—New Mexico coal seams (1982 Keystone Coal Industry Manual)
18. Logsdon—Gypsum resources of New Mexico
19. Logsdon—Geology and industrial potential of limestone in New Mexico
20. Nickelson—History of coal mining in New Mexico
21. Osburn, J.—Geology and coal resources of Pueblo Viejo Mesa quadrangle
22. Osburn, J.—Scoria resources of New Mexico (Circular 182)
23. Osburn, J.—Coal geology of Alamo Band Navajo Reservation (Open-file Report 160)
24. Osburn, J.—Geology and coal resources of the central Datil Mountains coal field (in cooperation with U.S. Geological Survey; Open-file Report 164)
25. Osburn, J.—Coal geology of the Pasture Canyon and Wildhorse Canyon quadrangles
26. Roybal—Computerization of point-source coal data for New Mexico (in cooperation with U.S. Geological Survey)
27. Roybal—Geology and coal resources of Tejana Mesa quadrangle
28. Roybal and Campbell—Stratigraphic sequence and drilling data from Fence Lake area (Open-file Report 145)
29. Siemers, Austin, and Kottlowski—Industrial minerals of New Mexico (AIME Transactions)
30. Smith, T. J.—Barite deposits of New Mexico (revision of Circular 76)
31. Smith, E. W.—Sources of adobe bricks in New Mexico (Circular 188)
32. Tabet, Massingill, and Campbell—Coal geology of the Pinehaven quadrangle (in cooperation with U.S. Geological Survey; Open-file Report 154)
33. Wallin (MacMillan)—Stratigraphy and paleoenvironments of the Engle coal field

Water and geothermal resources

1. Anderholm and Stone—Hydrogeology and water resources of Cuba 15-min quadrangle (Hydrogeologic Sheet 3, in preparation)
2. Brandvold—Water Quality Control Commission projects (continuing update)
3. Brandvold—Water analyses file (continuing update)
4. Brod and Stone—Hydrogeology and water resources of the Ambrosia Lake–San Mateo area (Hydrogeologic Sheet 2)
5. Chapin—Socorro Peak KGRA geology
6. Craigg and Stone—Hydrogeology and water resources of the Arroyo Chico–Torreon Wash area (Hydrogeologic Sheet 4, in preparation)
7. Fleischhauer and Stone—Quaternary geology of Lake Animas, Hidalgo County (Circular 174)
8. Stone and others—Hydrologic and water resources of San Juan Basin, New Mexico (in cooperation with U.S. Geological Survey and New Mexico State Engineer; Hydrologic Report 6, in press)
9. Stone—Recharge and ground-water contributions to the salinity of River Murray, South Australia (sabbatical leave research in cooperation with CSIRO–Division of Soils, Adelaide, South Australia)
10. O'Brien and Stone—Hydrogeology of Animas Valley, Hidalgo County (in cooperation with U.S. Geological Survey; Open-file Reports 130, 131, and 132)
11. Summers—Hydrology of Galisteo River drainage basin in Santa Fe County
12. Roybal and Pinkston—Ground-water resources and geologic map of Harding County (in cooperation with U.S. Geological Survey)

Metallic ores and mining districts

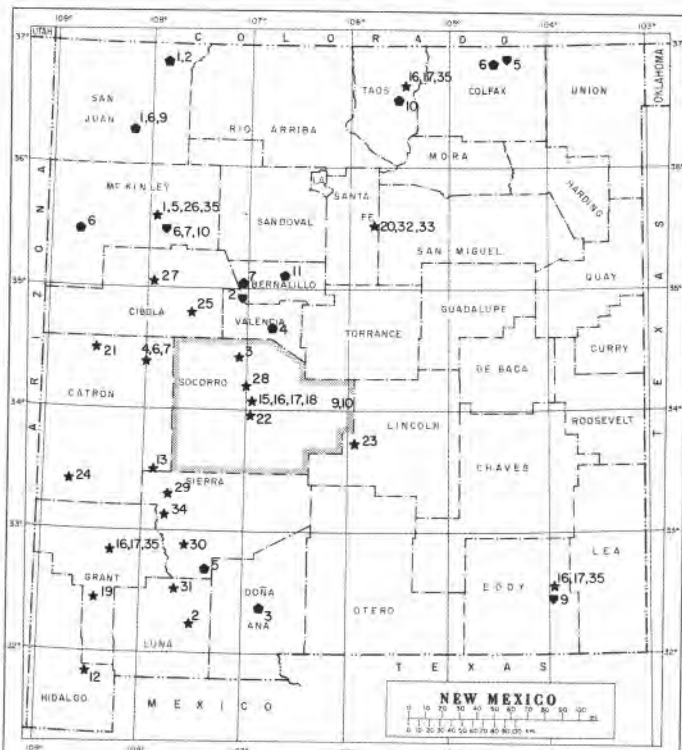
1. Anderson—Abandoned or inactive uranium mines in New Mexico (in cooperation with New Mexico Bureau of Surface Mining and U.S. Office of Surface Mining; Open-file Report 148)
2. Brown, G. (Clemons)—Mineralization of Mahoney mines and Gym Peak area, Florida Mountains (thesis available)
3. Chamberlin—Resource analysis of Sierra Ladron wilderness study area



▲ Industrial minerals and coal

● Oil and gas

✱ Water resources and geothermal

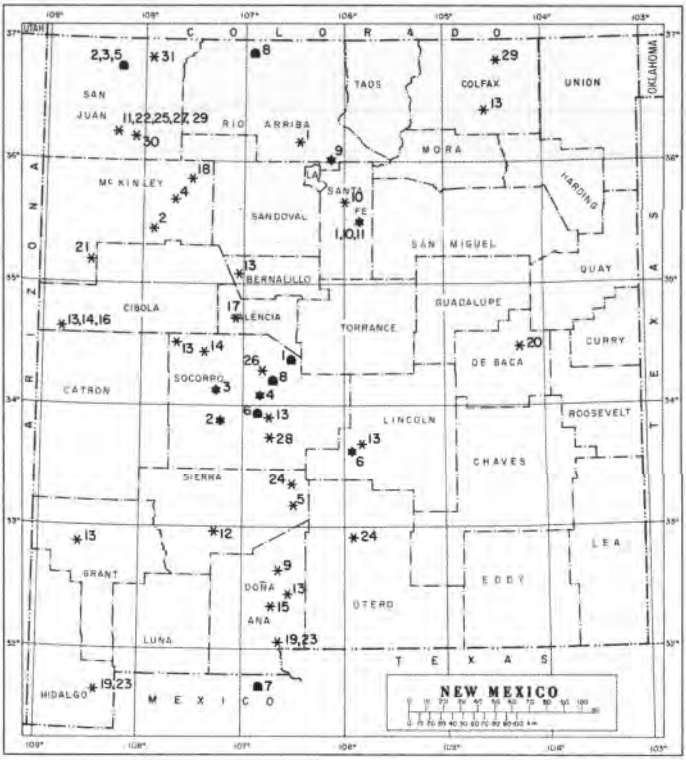


● Environmental geology

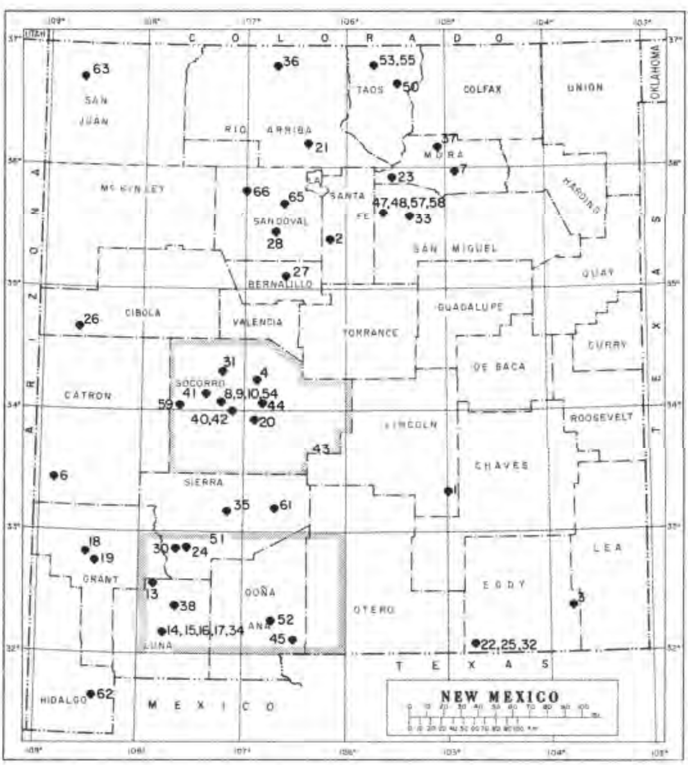
★ Metallic ores and mining districts

♥ Metallurgy and chemistry

INDEX MAPS OF BUREAU FIELD PROJECTS.



* Mineralogy, petrology and geochemistry
● Geophysics
* Paleontology



● Geology

geologic mapping, stratigraphy, and special projects

INDEX MAPS OF BUREAU FIELD PROJECTS.

4. Chamberlin—Uranium potential of Datil Mountains–Pie Town area, Catron County (Open-file Report 138)
5. Chamberlin—Monitor uranium exploration in New Mexico (continuing update)
6. Chamberlin—Geologic map and uranium occurrences in Datil Mountains–Pie Town area, phase II
7. Chamberlin—Distribution of uranium-bearing, lateritic-weathering profile of Paleocene(?) age in central and southern New Mexico
8. Chapin—Subsurface stratigraphy and ore controls of the Hansen orebody, Tallahassee Creek uranium district, Colorado (in cooperation with Rampart Exploration Co. and Cyprus Mine Corp.)
9. Chapin—Geology and mineral resources of the southeast Colorado Plateau margin
10. Chapin and Osburn, G.—Geology and mineral resources of Socorro–Magdalena–Datil area
11. Chapin and Osburn, G.—Data bank of radiometric dates, isotopic analyses, and chemical analyses of igneous rocks in New Mexico (continuing update)
12. Edwards (Annis)—Mineralization of Sylvanite–Bager area, Little Hatchet Mountains
13. Eggleston, T. (Norman)—Genesis of Taylor Creek tin deposits
14. Eveleth—New Mexico's mining railroads (continuing update)
15. Eveleth—Billing smelter, its role in the territorial mining industry of New Mexico
16. Eveleth and Bieberman—Mineral and mineral-fuel production activities in New Mexico during 1981 (in this report)
17. Eveleth and Menzie—Computerization of mineral-resources information for CRIB (in cooperation with U.S. Geological Survey)
18. Eveleth and North—Mines, prospects, and mineral potential of Socorro Peak mining district, Socorro County
19. Eveleth and North—Mines, prospects, and mineral potential of Gold Hill mining district, Grant County
20. Fulp (Woodward, Robertson)—Precambrian geology and mineralization in Dalton Canyon area (thesis available)
21. Guilinger (Chamberlin)—Uranium potential of Tejana Mesa–Hubbell Draw area, Catron County
22. Jahns—Manganese deposits of Luis Lopez district, Lincoln County
23. Jahns—Gold deposits of White Oaks mining district, Lincoln County
24. Kent, G. (Robertson)—Mineralization in the Mogollon mining district
25. Logsdon—Evaluation of mineral resources potential of Petaca Pinta Wilderness study area, Cibola County (Open-file Report 161)
26. McLemore—Radioactive occurrences in New Mexico
27. McLemore—Radioactive occurrences in veins and igneous and metamorphic rocks of New Mexico (Open-file Report 155 and U.S. Department of Energy Open-file Report GJBX-100[82])
28. McLemore—Carbonatites in Lemitar Mountains (Open-file Report 158)
29. McMillan and Jahns—Structure, petrology, and ore deposits of Chise quadrangle in southern Sierra Cuchillo, Sierra County
30. North, Eveleth, and McLemore—Gold mining and occurrences in New Mexico (continuing update)
31. Proctor—Trace base metals in Cooke's Peak stock
32. Robertson—Wall-rock alteration associated with massive sulfide deposits in Pecos greenstone belt
33. Robertson—Precambrian rocks and mineral deposits of Doctor Creek area, Santa Fe County
34. Sanders (Giordano, Seager)—Black Colt mine in Kingston mining district
35. Ward and Eveleth—The mineral industry in New Mexico (1981; *in* Minerals Yearbook, v. II, p. 345–356, U.S. Bureau of Mines)

Metallurgy and chemistry

1. Brandvold—Transport mechanisms in sediment-rich streams (in cooperation with Office of Water Research and Technology)
2. Brandvold—Speciation of uranium in organic-rich, high-uranium stream sediment from NURE Project
3. Brandvold—Water analyses (continuing update)
4. Brandvold—Rock and ore analyses (continuing)
5. Brandvold, L., Brandvold, D., and Popp—Acid rain in New Mexico (continuing)
6. Brierley and Brierley—Biological methods to remove selected pollutants from uranium-mine waste water (in cooperation with New Mexico Water Resources Research Institute; published)
7. Brierley and Brierley—Contamination of ground and surface waters by uranium mining and milling (in cooperation with U.S. Bureau of Mines and University of Colorado; published)

8. Brierley and Brierley—Trace elements in oil shale (in cooperation with U.S. Department of Energy and University of Colorado)
9. Brierley and Lanza—Microbiological flocculation of phosphate and potash slimes (in cooperation with U.S. Bureau of Mines and University of Texas at Dallas)
10. Brierley, Torma, and Brierley—Application of bacterial-leaching technology to deep-solution mining of uranium (in cooperation with New Mexico Energy and Minerals Department; published)
11. Brierley, Torma, and Brierley—Application of bacterial-leaching technology to deep-solution mining conditions (in cooperation with National Science Foundation)
12. Dondero—Flotation of chrysocolla
13. Dondero—Flotation of coal from coal waste

Environmental geology

1. Beaumont—Badlands in the San Juan Basin
2. Gillam (Hawley, Love)—Age and climatic effects on soil development in lower Animas River valley, San Juan County
3. Hawley, Gile, and Grossman—Soils and geomorphology in a Basin and Range area of southern New Mexico (Memoir 39)
4. Hawley and Love—Lower Hidden Mountain dam site, Late Quaternary stratigraphy, sedimentation, and geomorphology (with Human Systems Research, Inc.)
5. Hawley—Low-level radioactive waste disposal site selection (with Environmental Improvement Division)
6. Hawley, Love, and Hobbs—Alluvial valley floors in coal surface-mine areas (in cooperation with New Mexico Bureau of Surface Mining)
7. Hawley, Love, and Popp—Radionuclide and heavy-metal distribution in recent sediments of major streams in Grants mineral belt
8. Hawley and Love—Quaternary geology of New Mexico (in cooperation with U.S. Geological Survey)
9. Hawley, Love, Weber, O'Brien, Eveleth, Kottlowski, and others—Review and critique of Environmental Impact Statements and mining and reclamation plans (for example, Con Paso mine of Consolidation Coal Co.; EIS of Waste Isolation Pilot Plant)
10. Hawley, Love, and Kottlowski—Geologic hazards designations: landslides, earthquakes, volcanic eruptions, flood-prone areas, rock falls, and subsidence (part of National Hazards Information System, in cooperation with Office of Civil Emergency Preparedness and Linda Kehoe, Governor's office)
11. Hawley, Lambert, and Wells—Environmental geology of Albuquerque (in cooperation with New Mexico Geological Society)

Mineralogy, petrology, and geochemistry

1. Bowring—Ages and isotopic geochemistry of Precambrian rocks in northern and central New Mexico
2. Chapin—Hydrothermal alteration of ash-flow tuffs
3. Lindley (Chapin)—Geochemistry of potassium metasomatism in volcanic rocks of the Socorro area (in cooperation with University of North Carolina)
4. North—Guide to New Mexico Bureau of Mines and Mineral Resources Mineral Museum (published)
5. Renault—Thermoluminescence studies of quartz (continuing)
6. Renault—Geochemistry of New Mexico basalts (continuing)
7. Renault—Rapid determination of coal chemistry by x-ray fluorescence spectroscopy (continuing)
8. Renault—X-ray diffraction profile analysis of silica (continuing)
9. Renault—Geochemistry of Española Basin drill cuttings
10. Robertson—Petrography and geochemistry of Precambrian volcanic and subvolcanic rocks from Pecos greenstone belt
11. Robertson—Geochronology of volcanism and plutonism in Pecos greenstone belt
12. Robertson and Rose—Major and minor element geochemistry of Precambrian volcanic rocks of Portage Lake volcanics, Michigan

Geophysics

1. Chapin—COCORP seismic reflection profiles
2. Clarkson (Reiter)—Characteristics of thermal anomaly under the San Juan volcanic field

3. Eggleston, R. (Reiter)—Deep temperature-data study in the Colorado Plateau and eastern Basin and Range Province
4. McIntosh (Chapin)—Paleomagnetic study of Socorro potassium anomaly and ash-flow tuff stratigraphy
5. Reiter—Geothermal studies in the San Juan Basin: a) terrestrial heat-flow measurements, b) paleotemperatures, coalification, and petroleum genesis, and c) steady-state model of thermal source of heat flow
6. Reiter and Eggleston, R.—Deep heat-flow data along Rio Grande rift
7. Reiter and Tovar R.—Heat-flow analysis in northern Chihuahua, Mexico
8. Sanford—Statewide seismic monitoring (done mainly by New Mexico Tech Geoscience Department in cooperation with U.S. Geological Survey)

Paleontology

1. Berman—Early Permian vertebrates of north-central New Mexico
2. Brown, T. (Flessa)—*Crassostrea* reefs, Crevasse Canyon Formation, Borrego Pass area
3. Cobban and Hook—Paleontology of the Late Cretaceous "Cephalopod Zone" of Herrick (1900) (published in 1980–81 Annual Report)
4. Cross, Taggart, and Jameossanaie—Paleobotanical study of Menefee Formation in south Hospah area (in cooperation with Chaco Energy Co.)
5. DeKeyser—Conodonts in Lake Valley Formation of San Andres Mountains
6. Flower—Ordovician correlations (in preparation)
7. Flower—Faunas of New Mexico Devonian
8. Flower—Studies of Endoceratida and Tarphyceratida
9. Flower and LeMone—Faunal and petrographic studies of Bliss Sandstone, El Paso Group and Montoya Group
10. Galusha—Catalog of American Museum of Natural History records of collections from north-central New Mexico
11. Hartman—Cretaceous–Tertiary freshwater mollusks in San Juan Basin
12. Hook and Cobban—Stratigraphy and paleontology of Cretaceous rocks of Cooke's Range
13. Hook and Cobban—Stratigraphy and paleontology of Upper Cretaceous of a) Silver City area, b) Fence Lake area, c) southern San Andres Mountains, d) Carthage, e) Carrizozo–Capitan area, f) Rio Puerco area, g) Riley–Puertecito area, h) Springer area, and i) trans-Pecos Texas
14. Hook, Cobban, and Molenaar—Stratigraphy, paleontology, sedimentology, and regional relationships of Upper Cretaceous Tres Hermanos Sandstone
15. King—Fusulinids of the Hueco Formation in the Las Cruces area
16. Kelley, K. (Cross)—Palynology of Upper Cretaceous rocks in Fence Lake area (in cooperation with U.S. Geological Survey)
17. Kukalova-Peck—Late Paleozoic fossil insects of Carrizo Arroyo region
18. Leipzig (Wolberg)—Stratigraphy and depositional environments of Fruitland Formation and Kirtland Shale in Star Lake area (report available)
19. LeMone and Simpson—Wolfcampian megafauna and biostratigraphy of Franklin and Big Hatchet Mountains
20. Leonard and Frye—Stratigraphy and paleontology of Ogallala Formation in New Mexico (includes Circular 175)
21. Molenaar, Hook, and Cobban—Stratigraphy, paleontology, and regional correlations of the upper Cenomanian through lower Coniacian (Upper Cretaceous) strata of western New Mexico
22. Robison, Hunt, and Wolberg—Paleobotany and stratigraphy of Late Cretaceous leaf locality in lower Kirtland Shale
23. Simpson—Permian brachiopods of southwest New Mexico and far west Texas
24. Sorauf—Devonian corals from south-central New Mexico
25. Wolberg—Reptiles and elasmobranchs in the Fruitland and Kirtland formations
26. Wolberg and Baker—Late Cretaceous vertebrates from Atarque Member, Tres Hermanos Sandstone, near La Joya
27. Wolberg and Hunt—Paleontology and stratigraphy of Late Cretaceous rocks in the Hunter Wash area
28. Wolberg, Hunt, and Lucas—Eocene titanothere from Baca Formation near Carthage
29. Wolberg, Payne, and Hunt—Paleontology, stratigraphy, and magnetostratigraphy compared with iridium levels in San Juan and Raton Basins
30. Wolberg, Rigby, Hunt, Robison, and Hartman—Paleontology and stratigraphy of a Late Cretaceous fossil stump field in the San Juan Basin near Split Lip Flats

31. Wolberg, Rigby, and Schiebout—A Torrejonian faunule from Nacimiento Formation in Bohannan Canyon

Geology, geologic mapping, stratigraphy, and special projects

1. Allen, J., Kottlowski, Spence, and Pendleton—Revision of Scenic Trip No. 3, Roswell–Capitan–Ruidoso
2. Atkinson, Odlund, and Lee—Mineralogy of cores from San Pedro mining district (report available)
3. Bachman—Ochoan evaporites, Delaware Basin
4. Baker, B. (Wolberg)—Geology and depositional environments of Upper Cretaceous rocks in Sevilleta Grant, Socorro County (thesis available)
5. Balk—Stratigraphic nomenclature of New Mexico
6. Bikerman—Age-dating volcanic rocks in Mogollon area
7. Boyd (Campbell)—Geology of Turkey Mountains, Mora County
8. Cather (Chapin)—Petrology and volcano-sedimentary evolution of the Oligocene Spears Formation
9. Chapin—Origin and evolution of the Rio Grande rift
10. Chapin and Osburn, G.—Cenozoic stratigraphy of the Socorro–Magdalena–Datil area (Stratigraphic Chart 1, in preparation)
11. Chapin—Hydrothermal alteration of ash-flow tuffs
12. Chapin and Cather—Eocene tectonics and sedimentation in southern Cordillera
13. Clemons—Geology and mineral resources of Massacre Peak quadrangle (Geologic Map 51)
14. Clemons—Geology of Florida Gap region (Geologic Map 52)
15. Clemons—Geology of Capitol Dome quadrangle (Geologic Map 56, in preparation)
16. Clemons—Geology of west half of Gym Peak quadrangle (Geologic Map 58, in preparation)
17. Clemons—East half of South Peak quadrangle, Florida Mountains (Geologic Map 59, in preparation)
18. Cunningham—Circle Mesa quadrangle
19. Cunningham—Revision of geologic map of Silver City $7^1/_2$-min quadrangle
20. Eggleston, T. (Chapin)—Geology of the central Chupadera Mountains
21. Eberth—Sedimentology of Lower Permian red beds of north-central New Mexico
22. Franseen (Pray)—Sedimentology of the Grayburg (Getaway) bank of the Guadalupe Mountains escarpment
23. Grambling—Precambrian geology of Gascon area
24. Gutierrez (Seager)—Volcanic stratigraphy of area between Hillsboro and Kingston, Sierra County
25. Harris (Pray)—Geologic study of Cutoff Formation of southern Guadalupe Mountains (thesis available)
26. Hawley, Anderson, and Love—Investigations of "Fence Lake gravels" and Bidahochi Formation in western New Mexico
27. Hawley, Love, Broadhead, and others—Geologic road logs for Albuquerque Country 1982 guidebook of New Mexico Geological Society
28. Hawley, Tedford, Galusha, Barghoorn, and Love—Upper Cenozoic biostratigraphy of northern Albuquerque Basin (in cooperation with American Museum of Natural History)
29. Heljeson and Holts—Bibliography of New Mexico geology and mineral technology, 1976 through 1980 (Bulletin 109, in preparation)
30. Ilchik (Clemons)—Geology of eastern edge of Emery cauldron (thesis pending)
31. Johansen (Chapin)—Petrology of Mesaverde Group in Rio Salado valley
32. Kirkby (Pray)—Study of rocks beneath Cutoff Formation in southern Guadalupe Mountains
33. Klich (Robertson)—Precambrian geology of Elk Mountain–Spring Mountain area, San Miguel County
34. Saranyo Lemley (Clemons, Mack)—Lobo Formation and lithologically similar units in Luna and southwest Doña Ana Counties (thesis pending)
35. Lozinsky (Hawley)—Geology of Elephant Butte area
36. Muehlberger and Muehlberger—Scenic Trip No. 13 to Española–Chama–Taos
37. Nielsen—Ocate volcanic field, north-central New Mexico
38. North—Geologic map of Goat Ridge quadrangle
39. North—Small-size geologic map of New Mexico (in preparation)
40. Osburn, G.—Geology of Molino Peak quadrangle (Open-file Report 139a)
41. Osburn, G.—Geology of Lion Mountain quadrangle (Open-file Report 139b)
42. Osburn, G.—Geology of northern San Mateo Mountains
43. Osburn, G.—Compilation of Socorro County geology on 1:100,000 scale

44. Osburn, G.—Geology of northern Jornada del Muerto volcanic area
45. Ottensman—Sedimentation of the Bliss Formation
46. Owen and Siemers, C.—Dakota units in southeast San Juan Basin between Laguna and La Ventana
47. Renshaw (Woodward, Callender, Robertson)—Precambrian geology of Wild Horse Canyon area, southern Sangre de Cristo Mountains
48. Robertson—Geochronology of volcanism and plutonism in Pecos greenstone belt
49. Schilling—*Isochron/West*, a periodic journal of isotopic geochronology
50. Schilling, Taggart, and Pendleton—Revision of Scenic Trip No. 2, Taos–Red River–Eagle Nest
51. Seager, Clemons, Hawley, and Kelley, R.—Geology of northwest part of Las Cruces 1° × 2° sheet, scale 1:125,000 (Geologic Map 53)
52. Seager, Kottlowski, Hawley, and King—Geology of Robledo Mountains
53. Stoll (Dungan)—Intermediate to silicic volcanic rocks of Taos Plateau
54. Sumner, Bowring, Kent (Chapin)—Compilation of Precambrian geology in Socorro area for New Mexico Geological Society guidebook
55. Thompson, R. (Dungan)—Studies of early rift-age volcanic rocks, Taos Plateau
56. Thompson and Slaczka—A revision of the fluxoturbidite concept based on type examples in the Polish Carpathian flysch (published)
57. Wakefield (Robertson)—Precambrian geology of Glorieta Baldy–Ruiz Canyon area, Santa Fe County
58. Ward (Grambling)—Geochronology of Ortega quartzites in Truchas Range and Rio Mora areas
59. Weber, R.—Geology of Plains of San Agustin
60. Weber, R.—Petrographic and chemical characteristics of nine new meteorites from New Mexico
61. Weber, L. (Johnson, Kottlowski)—Facies analysis of Pennsylvanian carbonate rocks in Rhode Canyon area, San Andres Mountains
62. Weise (LeMone)—Carbonate petrology of U-Bar Limestone in Big Hatchet Mountains
63. West, C. (Flessa)—Paleoenvironment of Dakota–Mancos transition beds in western San Juan Basin
64. Wolberg and Kottlowski—Correlation of stratigraphic units in southwest New Mexico and westernmost Texas (COSUNA project)
65. Woodward—Geology of the Nacimiento Mountains
66. Wright (Anderson)—Facies of Mancos and lower Mesaverde Group near La Ventana

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Publishing group

Funds for printing totaled an all-time high of $175,054, approximately 9.6% of the Bureau's overall budget. One-fourth of the printing funds were expended in keeping selected older publications in print to meet the demand for information pertinent to intensified mineral exploration activities in New Mexico.

Most of the Bureau's printing production continued to be handled by the University of New Mexico Printing Plant in Albuquerque. The only jobs printed elsewhere were: 1) Sheet no. 1 in *Geologic Map 53*, compiled and printed by the Williams and Heintz Map Corporation, Capitol Heights, Maryland, and 2) the trimonthly journal *Isochron/West* compiled and composed by the Nevada Bureau of Mines and Geology and printed by the New Mexico Tech Print Plant.

By the close of the fiscal year, *New Mexico Geology* was midway in its fourth annual volume (February and May numbers already released, August and November numbers to come in next fiscal year). Paid annual subscriptions appear to have leveled off for the year at a total of 822. Total distribution is approximately 1,100 copies per issue. Subscribers are mostly professional earth scientists in New Mexico and the Southwest, although a number of copies are mailed throughout the country and overseas.

Twenty-six publications, 8 reissued publications, 34 open-file reports, and 6 announcement cards were released. Included in the new publications were 10 large-scale color sheets (three in book reports, seven in map reports). Nine other large-scale color sheets were reprinted in reissued publications. At the close of the fiscal year, 28 manuscripts were in review or pending while 23 others were in edit or at press.

Pages printed in new publications totaled 1,212 (948—scientific, 60—price-lists, 198—popular, 6—announcement cards). Pages printed in reissued publications totaled 883 (767—scientific, 116—popular).

Publishing staff, at close of fiscal year, was composed of a geologist-editor, a chief scientific illustrator (head of drafting), four drafters (three permanent, one temporary), one student drafting technician (part-time), three assistant editors, one editorial technician, one student bibliographer (part-time) and one student proofreader (part-time). In May the geologist-editor, in charge of the publishing group since May 1971, submitted retirement notice effective September 1, 1982; search for a successor was initiated.

New publications

Memoir 39—SOIL AND GEOMORPHOLOGY IN THE BASIN AND RANGE AREA OF SOUTHERN NEW MEXICO—GUIDEBOOK TO THE DESERT PROJECT, by L. H. Gile, J. W. Hawley, and R. B. Grossman, 1981, 212 p., 79 tables, 98 figs., 2 oversize sheets, $18.00

This book is intended primarily for use in field-study tours of the Desert–Soil Geomorphology Project of the U.S. Soil Conservation Service in Doña Ana County, southern New Mexico. Main purposes are to illustrate major soils and landscapes of the project area, to illustrate principles of soil and landscape evolution in a basin-and-range geomorphic setting, to show the landscape positions in which the soils are most likely to occur, to describe soil development, and to illustrate the United States system of soil taxonomy as it applies to desert soils of the region.

Circular 174—QUATERNARY GEOLOGY OF LAKE ANIMAS, HIDALGO COUNTY, NEW MEXICO, by H. L. Fleischhauer, Jr., and W. J. Stone, 1982, 25 p., 4 tables, 12 figs., $6.50

This study describes the geomorphology, soil stratigraphy, and ages for Lake Animas in Hidalgo County, New Mexico. The mapping of shoreline features in the lower Animas Valley indicates three stages for Lake Animas.

Circular 175—WESTERN EXTENT OF OGALLALA FORMATION IN NEW MEXICO, by J. C. Frye, A. B. Leonard, and H. D. Glass, 1982, 41 p., 10 figs., $6.00

This study defines the western limits of the Ogallala Formation (Upper Tertiary) west of the Pecos River and documents the late Cenozoic geology of the region, including fragmentary deposits of early Pleistocene age and molluscan faunas of Wisconsinan and Holocene age. Included are 10 figs. and an appendix containing clay-mineral analyses and measured stratigraphic sections.

Circular 179—POROSITY OF LOWER PART OF SAN ANDRES FORMATION, EAST-CENTRAL NEW MEXICO, by W. D. Pitt and G. L. Scott, 1981, 20 p., $4.00

This report is concerned with the lithologic variations within the lower part of the San Andres Formation in east-central New Mexico and the relationships of these variations to the potential occurrence of oil and gas.

Circular 182—INDUSTRIAL ROCKS AND MINERALS OF THE SOUTHWEST, compiled by G. S. Austin, 1982, 111 p., $13.00

On May 13–15, 1981,in Albuquerque, New Mexico, the 17th Annual Forum on the Geology of Industrial Minerals was held. This volume contains 18 expanded papers from the Forum, along with 2 abstracts of papers given at the Forum but not presented for publication.

In addition to technical papers on the major industrial minerals of New Mexico and adjoining states, Circular 182 contains articles on "Potash in Libya" and "Perlite in El Salvador."

Circular 188—ADOBE BRICKS IN NEW MEXICO, by E. W. Smith, 1982, 89 p., 9 tables, 102 figs., $4.50

Includes a history of adobe-brick making, soil geology and mineralogy, and a listing of 48 adobe producers active in the state in 1980, as well as their production totals and prices. Also includes 149 black-and-white photographs illustrating old and contemporary adobe architecture and production methods across the state, as well as 16 architectural drawings showing construction details.

Scenic Trip 3—ROSWELL–RUIDOSO–VALLEY OF FIRES INCLUDING TRIPS TO LINCOLN, TULAROSA, AND BOTTOMLESS LAKES STATE PARK, by J. E. Allen and F. E. Kottlowski, 1981, 96 p., 3 tables, 22 figs., 39 photos (7 in color), geologic map, $5.00

These revised scenic trip road logs and their descriptions of the geology, history and scenery cover the main routes from Roswell westward through Hondo, Lincoln (site of the Lincoln County Wars), Capitan, and Carrizozo, to the Valley of Fires State Park; then south along the flanks of towering Sierra Blanca through Nogal to Ruidoso, Mescalero, and Tularosa; and eastward past Ruidoso Downs returning to Roswell. An eastern side trip is to Bottomless Lakes State Park.

Scenic Trip 13—ESPAÑOLA–CHAMA–TAOS—A CLIMB THROUGH TIME, by W. R. Muehlberger and Sally Muehlberger, 1982, 97 p., 69 illustrations and maps, 16 color photos, $4.50

This guidebook was written for either one long trip or two shorter trips beginning in historic Santa Fe, the capital of New Mexico. At Española, the traveler can choose to take a longer loop through Abiquiu, Tierra Amarilla, and Chama or a shorter loop through Ojo Caliente and Tres Piedras. At Tierra Amarilla, the road log turns east and crosses the Tusas Mountains. The route reenters Carson National Forest and continues southeast to Taos, at the base of the Sangre de Cristo Mountains. The final leg of this loop follows the Rio Grande south and returns to Española.

Hydrogeologic Sheet 2—HYDROGEOLOGY OF AMBROSIA LAKE–SAN MATEO AREA, McKINLEY AND CIBOLA COUNTIES, NEW MEXICO, by R. C. Brod and W. J. Stone, 1981, 1 sheet (scale 1:62,500), 5 tables, 10 figs., $3.50

Covers Ambrosia Lake, San Lucas Dam, Dos Lomas, and San Mateo 7½-min quadrangles; shows hydrogeology and major aquifers in the heart of the Grants uranium region, 10 mi north of Grants.

Geologic Map 46—GEOLOGY OF REGINA QUADRANGLE, RIO ARRIBA AND SANDOVAL COUNTIES, NEW MEXICO, by M. A. Merrick and L. A. Woodward, 1982, 1 sheet with text, scale 1:24,000, $3.00

Regina quadrangle is located in Rio Arriba and Sandoval Counties in north-central New Mexico. The two major tectonic features in the quadrangle are the San Juan Basin on the west and the Nacimiento uplift on the east.

Geologic Map 51—GEOLOGY OF MASSACRE PEAK QUADRANGLE, LUNA COUNTY, NEW MEXICO, by R. E. Clemons, 1982, 1 sheet with text, scale 1:24,000, $3.50

Massacre Peak quadrangle is in north-central Luna County approximately 8 mi north-northeast of Deming. The southern Cooke's Range crosses the quadrangle from northwest to southeast, covering approximately half the area.

Geologic Map 52—GEOLOGY OF FLORIDA GAP QUADRANGLE, LUNA COUNTY, NEW MEXICO, by R. E. Clemons, 1982, 1 sheet, text, $3.50

Florida Gap quadrangle is in east-central Luna County, approximately 6 mi east-southeast of Deming. The quadrangle covers the Lewis Flats area of the Mimbres Basin, Rock Hound State Park, and Florida Gap which separates the Little Florida Mountains from the Florida Mountains. This map is the first phase of a comprehensive geologic and mineral-resource investigation of the Florida Mountains.

Geologic Map 53—GEOLOGY OF NORTHWEST PART OF LAS CRUCES 1° × 2° SHEET, NEW MEXICO, by W. R. Seager, R. E. Clemons, J. W. Hawley, and R. E. Kelley, 1982, 3 sheets, scale 1:125,000, $10.00

This is the first of a series of maps that will cover the Las Cruces 1° × 2° area. The 3 sheets include a geologic map, cross sections, and Bouguer gravity map. GM-54 will cover the Anthony quadrangle in the southern part, and GM-57, scheduled for publication in 1983, will cover the eastern part.

Isochron/West–Nos. 31, 32, 33, edited by J. H. Schilling, 33 p., 31 p., and 32 p. Available by subscription (6 issues for $12.00). Back numbers are available at $2.00 per issue.

A serial journal of isotopic geochronology.

Annual Report—ANNUAL REPORT FOR THE FISCAL YEAR JULY 1, 1980, TO JUNE 30, 1981, by F. E. Kottlowski and staff, 1982, 72 p., $2.00

Includes articles on Cretaceous fossils, reminiscences of a former director, uranium severance taxes, "tight" Abo gas sands, coal-paleontology workshop, and mineral production.

Pricelist 16—PUBLICATIONS AVAILABLE FROM NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, MARCH 1982. FREE

Comprehensive listing of geologic and mineral reports and maps.

Open-file List 1—OPEN-FILE REPORTS AVAILABLE FROM NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES, FEBRUARY 1982. FREE

Open-file reports are available at 20¢ per page.

Magazine—NEW MEXICO GEOLOGY, VOLUME 3, NUMBER 3, August 1981, 16 p.

Articles: Precambrian metallic mineralization in New Mexico; A mosasaur from the Lewis Shale (Upper Cretaceous), northwestern New Mexico; Modifications of stratigraphic nomenclature in New Mexico for 1980; new publications, abstracts, and announcements. Available by subscription (1979, 1980—$3.00; 1981—$4.00; 1982—$5.00; 1983—$6.00)

NEW MEXICO GEOLOGY, VOLUME 3, NUMBER 4, November 1981, 16 p.

Articles: Cañas Gypsum Member of Yeso Formation (Permian) in New Mexico; Early Tertiary(?) strata penetrated in Jornada del Muerto; Uranium resources in New Mexico—discussion of the NURE program; Oliver Lee Memorial; index to Volume 3, new publications, open-file reports, new projects, and abstracts.

NEW MEXICO GEOLOGY, VOLUME 4, NUMBER 1, February 1982, 16 p.

Articles: Lacustrine sediments of Baca Formation (Eocene), western Socorro County, New Mexico; Palomas volcanic field, southern New Mexico and northern Chihuahua, Mexico; Compilation index to satellite photomap of New Mexico; Elephant Butte; USGS topographic map coverage of New Mexico (as of November 1981); new publications, open-file reports, abstracts, and new projects.

NEW MEXICO GEOLOGY, VOLUME 4, NUMBER 2, May 1982, 16 p.

Articles: Oil and gas discovery wells drilled in New Mexico in 1981; Origin of gypsum deposits in Carlsbad Caverns, New Mexico; Occurrence of Bishop Ash near Grama, New Mexico; Living Desert; Aeromagnetic and aeroradiometric maps and profiles; announcements, new publications, open-file reports, and abstracts.

Mineral Land Assessment Program—EVALUATION OF CURRENT AND FUTURE MINERAL LAND ASSESSMENT PROGRAM OF U.S. BUREAU OF MINES, compiled by F. E. Kottlowski, 1982, 30 p.

A main evaluation of minerals on "locked-up" federal lands.

Leaflet—SCENIC TRIPS TO THE GEOLOGIC PAST, 1982, FREE

Describes the series of 13 publications exploring New Mexico's roadside geology, landscape, and history and includes a map showing the routes followed by each book and a convenient order form.

Bibliography—BIBLIOGRAPHY AND INDEX OF NEW MEXICO GEOLOGY, by Ghassan N. Rassam, ed., 1982, 122 p., $5.00

This edition, issued in cooperation with the American Geological Institute and GeoRef Information System and containing approximately 750 references, represents published and unpublished material that was added to the GeoRef database in 1981. The Bureau did not participate in collecting or in formating the references for this volume.

Announcement cards 24–29—New publications or special announcements, September 1981–May 1982

Re-issued publications

Bulletin 63—GEOLOGIC STUDIES OF UNION COUNTY, NEW MEXICO, by Brewster Baldwin and W. R. Muehlberger, 1959, 171 p., 17 plates, 28 figs., $15.00

Memoir 29—GEOLOGY OF SANDIA MOUNTAINS AND VICINITY, NEW MEXICO, by V. C. Kelley and S. A. Northrop, 1975, 136 p., 4 tables, 92 figs., 4 maps, 2 appendices, $12.50

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

Scenic Trip 6—TRAILGUIDE TO GEOLOGY OF THE UPPER PECOS, by P. K. Sutherland and Arthur Montgomery, 1975, 116 p., 8 plates, 51 photos, 27 figs., 1 map, $4.00

Scenic Trip 8—MOSAIC OF NEW MEXICO'S SCENERY, ROCKS, AND HISTORY, by P. W. Christiansen and F. E. Kottlowski, 1972, 170 p., 64 illustrations and maps, 6 color photos, $4.00

Resource Map 3—THE FUTURE OF NEW MEXICO'S OIL AND GAS RESOURCES, by R. W. Foster and P. R. Grant, Jr., 1974, scale 1:1,287,000, $1.50

New Mexico Geology article—Adobe brick production in New Mexico, by Edward W. Smith, *in* New Mexico Geology, v. 3, no. 2 (May 1981), 6 p.

Annual Report article—Paleocurrents of Bliss Sandstone (Cambrian–Ordovician), southwestern New Mexico and western Texas, by Sam Thompson III and Paul E. Potter, *in* Annual report for the fiscal year July 1, 1979, to June 30, 1980, 16 p.

Open-file reports

OF–127—HYDROCARBON SOURCE-ROCK EVALUATION STUDY, ORGANIC GEOCHEMICAL ANALYSES OF DRY-WELL CUTTINGS, EXXON CORP. PRISOR UNIT FED. #1 WELL, SIERRA COUNTY, NEW MEXICO, by P. J. Cernock, GeoChem Laboratories, Inc., (1977), 27 p., $5.40

OF–130—WATER-LEVEL DATA COMPILED FOR HYDROGEOLOGIC STUDY OF ANIMAS VALLEY, HIDALGO COUNTY, NEW MEXICO, by K. O'Brien and W. J. Stone, 66 p., $13.20

OF–131—WATER-QUALITY DATA COMPILED FOR HYDROGEOLOGIC STUDY OF ANIMAS VALLEY, HIDALGO COUNTY, NEW MEXICO, by K. O'Brien and W. J. Stone, 27 p., 4 maps, $11.40

OF–132—DRILL-HOLE AND TESTING DATA COMPILED FOR HYDROGEOLOGIC STUDY OF ANIMAS VALLEY, HIDALGO COUNTY, NEW MEXICO, by K. O'Brien and W. J. Stone, 81 p., 1 map, $21.75

OF–138—URANIUM POTENTIAL OF THE DATIL MOUNTAINS–PIE TOWN AREA, CATRON COUNTY, NEW MEXICO, by R. M. Chamberlin, 58 p., $11.60

OF–139a—GEOLOGY OF THE MOLINO PEAK QUADRANGLE, by G. R. Osburn, D. M. Petty, and C. E. Chapin, 24 p., 2 maps, $7.80

OF–139b—GEOLOGY OF THE LION MOUNTAIN QUADRANGLE, by G. R. Osburn and T. M. Larache, 40 p., 2 maps, $11.00

OF–140—HYDROCARBON SOURCE-ROCK EVALUATION STUDY, HACHITA DOME, INC. NO. 1 TIDBALL–BERRY FEDERAL WELL, HIDALGO COUNTY, NEW MEXICO, by L. P. Tybor, GeoChem Laboratories, Inc., 14 p., $2.80

OF–141—GEOLOGY OF THE CENTRAL CHUPADERA MOUNTAINS, SOCORRO COUNTY, NEW MEXICO, by T. L. Eggleston, 162 p., 2 maps, $35.40

OF–142—GEOLOGY AND COAL RESOURCES OF CANTARALO SPRING 7½-MIN QUADRANGLE, by O. J. Anderson, 13 p., 2 maps, $5.60

OF–143—GEOLOGY AND COAL RESOURCES OF TWENTY-TWO SPRING QUADRANGLE, by S. J. Frost, revised by O. J. Anderson, 6 p., 3 figs., $2.70

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OF–148—ABANDONED OR INACTIVE URANIUM MINES IN NEW MEXICO, by O. J. Anderson (reports sold by individual county at individual price)

OF–149—HYDROCARBON SOURCE-ROCK EVALUATION STUDY, COCKRELL CORP. NO. 1 COYOTE STATE WELL, GRANT COUNTY, NEW MEXICO, by L. P. Tybor, GeoChem Laboratories, Inc., 18 p., $3.60

OF-150—FACIES MOSAIC OF THE UPPER YATES AND LOWER TANSILL FORMATIONS (UPPER PERMIAN), RATTLESNAKE CANYON, GUADALUPE MOUNTAINS, NEW MEXICO, by A. H. Schwartz, 162 p., $32.40

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OF-153—PETROLEUM SOURCE ROCKS IN EXPLORATION WELLS DRILLED TO PALEOZOIC OR MESOZOIC UNITS, HIDALGO AND GRANT COUNTIES, NEW MEXICO, by Sam Thompson III, 126 p. (New Mexico residents—free; out-of-state residents—$4.50)

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OF-156—HYDROCARBON SOURCE-ROCK EVALUATION STUDY, PETROLEOS MEXICANOS NO. 1 CHINOS WELL, CHIHUAHUA, MEXICO, by P. J. Cernock and J. A. Haykus, GeoChem Laboratories, Inc., (1979), 25 p., $5.00

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Eveleth, R. W., Bieberman, R. A., Campbell, F. W., and Roybal, G. H., 1982, Mineral and mineral-fuel production activities in New Mexico during 1980: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1980–81, pp. 63–72.

Hook, S. C., and Cobban, W. A., 1982, *Spathites puercoensis* (Herrick and Johnson)—common Upper Cretaceous guide fossil in Rio Puerco valley, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1980–81, pp. 36–39.

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

———, 1982, Elephant Butte (State Park): New Mexico Geology, v. 4, no. 1, pp. 10–11.

Kottlowski, F. E., 1981, Oliver Lee Memorial State Park: New Mexico Geology, v. 3, no. 4, pp. 59–60, 63.

Logsdon, M. J., 1982, Gypsum resources of New Mexico, *in* Austin, G. S. (compiler), Industrial Rocks and Minerals of the Southwest: New Mexico Bureau of Mines and Mineral Resources, Circular 182, pp. 43–48.

McLemore, V. T., 1981, Uranium resources in New Mexico—discussion of the NURE program: New Mexico Geology, v. 3, no. 4, pp. 54–58.

Osburn, J. C., 1982, Scoria exploration and utilization in New Mexico, *in* Austin, G. S. (compiler), Industrial Rocks and Minerals of the Southwest: New Mexico Bureau of Mines and Mineral Resources, Circular 182, pp. 57–59.

Robison, C., Hunt, A., and Wolberg, D. L., 1982, A new Lower Kirtland Shale (Upper Cretaceous) leaf locality, San Juan Basin, New Mexico: New Mexico Geology, v. 4, no. 3, pp. 42–45, 48.

Ward, A. E., and Eveleth, R. W., 1982, The Mineral Industry of New Mexico: U.S. Bureau of Mines, Minerals Yearbook for 1981, pp. 345–356.

Weber, R. H., and Austin, G. S., 1982, Perlite in New Mexico, *in* Austin, G. S. (compiler), Industrial Rocks and Minerals of the Southwest: New Mexico Bureau of Mines and Mineral Resources, Circular 182, pp. 97–101.

Wolberg, D. L., 1982, Development of coal resources and paleontology—summary of a conference workshop: New Mexico Bureau of Mines and Mineral Resources, Annual Report 1980–81, pp. 49–53.

Oral presentations

Austin, G. S., "The New Mexico Bureau of Mines and Mineral Resources and its role in the study of industrial minerals," to Southeast New Mexico Section of AIME, Carlsbad, New Mexico, February.

———, "The New Mexico Bureau of Mines and Mineral Resources," to Southwest New Mexico Section of AIME, Silver City, New Mexico, April.

———, "The Bureau and State Geological Surveys," to NMIMT Mining 100 class, Socorro, New Mexico, October.

Austin, G. S., and Weber, R. H., "Perlite in New Mexico," to 17th Annual Forum on the Geology of Industrial Minerals, Albuquerque, New Mexico, August.

Brierley, C. L., "Microbial processes for removal of clay from phosphatic clay wastes," to W. R. Grace Company, Columbia, Maryland, August.

———, "Geomicrobiology and its application to industrial problems," to International Minerals and Chemicals Corporation, Terre Haute, Indiana, August.

———, "Molybdenum transformation mediated by *Sulfololus* species," to American Society for Microbiology, New Mexico Branch, Albuquerque, New Mexico, October.

———, "Biotechnology as applied to mining," to New Mexico Institute of Mining and Technology, Socorro, New Mexico, November.

——, "Biotechnology and its application to the mining industry," to University of Georgia, Athens, Georgia, February.

———, "The prospects for using biotechnology for cobalt and nickel recovery from copper ores and solid waste materials," to American Institute of Mining Engineers Annual Meeting, Dallas, Texas, February.

———, "Biomining: a new dimension in biotechnology?" to 1982 New Mexico Science Fair, Socorro, New Mexico, April.

———, "Investigation of microbially induced permeability loss during in situ leaching," to U.S. Bureau of Mines Twin Cities Research Center, Minneapolis, Minnesota, April.

———, "Potential for application of microorganisms to mining," to U.S. Department of Agriculture, Eastern Regional Research Center, Philadelphia, Pennsylvania, May.

———, "An overview of the mining and metals leaching industry," to Battelle Memorial Genetic Engineering Conference, San Francisco, California, June.

Brandvold, L. A., "Possible local effects of coal burning on precipitation in New Mexico," to Pacific Conference on Chemistry, Anaheim, California, October.

Chamberlin, R. M., "Geologic control of ground-water flow in the Water Canyon–Socorro Spring area," to NMIMT Hydrology 411 Class, Socorro, New Mexico, November.

———, "Uranium deposits in a tropical weathering profile of Paleocene(?) age, west-central New Mexico," to NMIMT Geoscience Seminar, Socorro, New Mexico, December.

———, "Techniques of mineral resource 'inventory' for wilderness study areas," to U.S. Bureau of Land Management, New Mexico Minerals Conference, Socorro, New Mexico, January.

———, "Development of rift structures in the Lemitar Mountains, central New Mexico," to New Mexico State University Geology Department Seminar, Las Cruces, New Mexico, February.

Chapin, C. E., "Eocene tectonics and sedimentation in the Colorado Plateau–Rocky Mountain area," to Albuquerque Geologic Society, Albuquerque, New Mexico, January.

———, "Tectonic evolution of the Socorro area," to University of North Carolina Geology Department, Chapel Hill, North Carolina, February.

Chapin, C. E., D'Andrea–Dinkelman, J. F., Lindley, J. I., and Osburn, G. R., "The Socorro K_2O anomaly: a fossil geothermal system in the Rio Grande rift, New Mexico," to Cornell Program for Study of the Continents, Ithaca, New York, May.

Dondero, A., "An introduction to ore treatment and mineral recovery," to Socorro Public Library, Socorro, New Mexico, March.

———, "Hydrometallurgy of gold and silver," to NMIMT Geoscience–Bureau Seminars, Socorro, New Mexico, February and July.

———, "The mechanism of gold and silver adsorption on activated charcoal, part 2," to NMIMT Brownbag Seminar in Extractive Metallurgy, Socorro, New Mexico, July.

———, "Laboratory demonstrations in extractive metallurgy," to Seventh Annual Women's Science and Engineering Conference, Socorro, New Mexico, December; and to Native American Mineral, Engineering, and Science Program, Socorro, New Mexico, July.

Eveleth, R. W., "The mining law of 1872—is it really obsolete," to Energy Seminar, New Mexico Highlands University, Las Vegas, New Mexico, September.

———, "Government regulations and their effect on our minerals industry and mining laws," to NMIMT Cooney Mining Club, Socorro, New Mexico, December.

Hawley, J. W., "Site identification for low-level radioactive waste disposal," to State Legislative Committee Hearing on Low-Level Waste Site Selection, Santa Fe, New Mexico, July.

Kottlowski, F. E., "Potential of strategic minerals in New Mexico," to U.S. Senate Science, Technology, and Space Committee, Albuquerque, New Mexico, July.

———, "Recommendations of National Academy of Sciences committee on the disposal of excess spoil," to Interior and Insular Affairs Committee, Subcommittee on Energy and the Environment, Washington, D.C., September.

———, "Projects and plans of New Mexico Bureau of Mines and Mineral Resources," to AASG–USGS Cluster Meeting, Snowbird, Utah, October.

———, "How we utilize your tax dollars—services of New Mexico Bureau of Mines and Mineral Resources, Socorro Rotary, Socorro, New Mexico, November.

———, "Coal resources of the San Juan Basin," to New Mexico Senate Corporation and Conservation Committees, Joint Session, Santa Fe, New Mexico, February.

———, "Mineral resource assessment by U.S. Bureau of Land Management," to Workshop on Bureau of Land Management Mineral Assessment, National Academy of Sciences, Denver, Colorado, April.

Logsdon, M. J., "An introduction to industrial minerals," to NMIMT Geology 510 Class, Socorro, New Mexico, October.

———, "Inventory techniques in mineral resource evaluations," to Bureau of Land Management, Socorro, New Mexico, January.

Logsdon, M. J., and Landis, G. P., "Aqueous geochemistry of the Lightning Dock geothermal area, New Mexico," to Gordon Research Conference, New London, New Hampshire, August; and to Geological Society of America Annual Meeting, Cincinnati, Ohio, November.

McLemore, V. T., "Regional implications of carbonatites in the Lemitar Mountains, Socorro County, New Mexico," to NMIMT Brownbag Seminar, Socorro, New Mexico, October.

North, R. M., "Minerals of New Mexico," to Albuquerque Gem and Mineral Club, Albuquerque, New Mexico, July.

O'Brien, K. M., "The feasibility of artificial ground-water recharge in Massachusetts," to Geoscience–Bureau Seminar, Socorro, New Mexico, November.

Popp, C. J., Brandvold, D. K., Brandvold, L. A., and Ohline, R. W., "Atmospheric particulates in central and northern New Mexico," to Division of Environmental Chemistry, American Chemical Society, Las Vegas, Nevada, August.

———, "Distribution and nature of acid precipitation in central and northern New Mexico," to Division of Environmental Chemistry, American Chemical Society, Las Vegas, Nevada, March.

Reiter, M. A., "Geothermal studies in the southwestern United States," to Earth Physics Branch Seminar, Ottawa, Canada, October.

———, "Geothermal investigation along offshore Atlantic Canada," to Division of Seismology and Geothermal Studies Seminar, Ottawa, Canada, November.

Renault, J., "Diffractometer alignment," to Denver X-ray Conference, Denver, Colorado, August.

Robertson, J. M., "Precambrian geology of New Mexico," to NMIMT Geoscience 510 Class, Socorro, New Mexico, October.

Stone, W. J., "Hydrogeology of marine sandstone aquifers," to Commonwealth Scientific and Industrial Research Organization, Division of Land Resources Management, Perth, Western Australia, August.

———, "Natural recharge and ground-water contributions to River Murray salinity from environmental isotope and Cl studies," to Commonwealth Scientific and Industrial Research Organization, Division of Land Resources Management, Central Australia Laboratory, Alice Springs, Northern Territory, Australia, May.

———, "Water resources and mining in a large sedimentary basin in the arid American Southwest," to Central Australia Earth Sciences Group, Alice Springs, Northern Territory, Australia, May.

Thompson, S., III, "Petroleum exploration in the Pedregosa Basin, southwestern New Mexico," to Rocky Mountain Association of Geologists, Denver, Colorado, October.

Weber, R. H., "Lithic materials and lithic typology," to Archaeological Society of New Mexico, Gallup, New Mexico, July.

Wolberg, D. W., "Ancient animals of the world," to Torres Elementary School, September and November, and to Native American students, August.

Other activities

Participation in scientific and professional conferences

American Association of Petroleum Geologists: annual meeting, June
American Association of Petroleum Geologists: coal symposium, March
American Association of Petroleum Geologists: Southwest Section, annual meeting, February
American Chemical Society: international meeting, September
American Chemical Society: Pacific Conference on Chemistry, October
American Institute of Mining Engineers: annual meeting, February
American Institute of Mining Engineers: fall meeting, November
American Institute of Professional Geologists: 18th annual meeting, October
American Society for Microbiology, New Mexico Branch: annual meeting, October
Archaeological Society of New Mexico: annual meeting, April
Association of Earth Science Editors: annual meeting, October
Australian Conservation Foundation: future of arid lands, May
Australian Institute of Agricultural Science, South Australia Branch: symposium on River Murray, September
Australian Institute of Petroleum, South Australia Branch: coal gasification conference, March
Battelle Memorial Institute: Genetic Engineering Conference, June
Cornell Program for Study of the Continents (COPSTOC): May
Data Management Meeting: November
DEC Computer Class: November
Denver Conference on Applications of X-ray Analysis: August
El Paso Geological Society: annual field conference, March
Fifth International Conference on Geochronology, Cosmochronology, and Isotope Geology: Japan, June–July
Fifth Symposium on the Geology of Rocky Mountain Coal: May
Forum on Geology of Industrial Minerals: annual meeting, April
Friends of the Pleistocene Rocky Mountains: field trip, September
Geological Society of America: annual meeting, November
Geological Society of America: Cordilleran Section, April
Geological Society of Australia: 5th annual convention, August
Geological Society of New Zealand: annual conference, November
Gordon Research Conference: hydrothermal systems, August
International Association of Seismology and Physics of the Earth's Interior: general assembly, July
International Mineral and Chemical Corporation: seminar, August
Los Alamos Scientific Laboratory: Rio Grande Rift Workshop, March
Max-Planck Institut für Biochemie: Workshop on the Molecular Biology of Archaebacteria, July
McGraw-Hill Company: Biotechnology—Research to Reality, October
Natural History Museum of Arizona: symposium on geology and paleontology, August
New Mexico Archaeological Council: annual meeting, November
New Mexico Archaeological Council: Rio Grande Archaeology Workshop, December
New Mexico Geological Society: 32nd field conference, Western Slope, Colorado, October
New Mexico Mining Association: Education and Information Committee, August
New Mexico Mining Association: International Mining Days, October
New Mexico Mining Association: state meeting, January
New Mexico Mining and Mineral Division, Bureau of Land Management, and Office of Surface Mining: joint conference, August
New Mexico State Fair: display, August
New Mexico Water Resources Research Institute: State Water Conference, April
Orbit Computer Course: August
Paleontology/Government/Industry Mitigation Committee, October
Princeton University: Fundamental Concepts in Modeling Fluid Flow in Porous Media, January
Showcase of Technology: display, October
Sigma Xi: annual meeting, October
Society for Applied Spectroscopy: Pacific Conference on Chemistry, October
Society for Industrial Microbiology: annual meeting, August
Society for Industrial Microbiology: Board of Directors meeting, November and April
Society of Petroleum Engineers: Roswell Section, March
South Australia Department of Mines and Energy: field conference, October
South Australia Soil Science Society: annual field day, October

United States Conservation Service: Desert Project—Soils and Geomorphology of the Basin and Range in southern New Mexico, October
United States Geological Survey: state cluster, October
Varian Seminar: geochemistry, March
Waste Isolation Pilot Plant: site meeting, September
Western States Seismic Policy Council: May

Participation in committees and commissions

Austin—Sigma Xi, NMIMT Chapter Secretary; Sigma Xi Safety Committee; AIME–SME, Continuing Education Committee; AIME–SME, Technical Publications Committee; IndMd, Div. of AIME–SME, Technical Committee, chairman; IndMd, Div of AIME–SME, Publications Committee, chairman; NMIMT Geoscience Advisory Committee; NMIMT Institute Benefits Committee, chairman; NMIMT Research Committee; NMIMT Space Utilization and Campus Planning Committee and Safety Subcommittee, chairman; NMIMT Financial Aids Committee; NMIMT graduate student committees; NMIMT tenure committee; Forum on Geology of Industrial Minerals, executive committee; Clay Mineral Society, executive committee; Private Industrial Council of Alamo School Board.
Bieberman—AAPG House of Delegates; AAPG Committee on Preservation of Samples and Cores; AAPG Membership Committee; Petroleum Geologist Search Committee; NMIMT tenure committees, member and chairman.
Blodgett—NMIMT Word Processor Committee.
Brandvold—New Mexico Water Conference Advisory Board; New Mexico Water Quality Control Commission, director's representative; New Mexico Water Well Drillers Association, Technical Support Group; NMIMT Sigma Xi, Membership Committee; NMIMT Financial Aids Committee; NMIMT Safety Committee; NMIMT Affirmative Action Committee; NMIMT Association of Women in Science, advisor.
Brierley—Society for Industrial Microbiology, Program Committee, chairman; International symposium on Environmental Biogeochemistry, co-chairman; NMIMT Women's Science and Engineering Conference, co-chairman; NMIMT Campus Life Committee; Society for Environmental Toxicology and Chemistry, Journal Editorial Board; Battelle Memorial Institute Conference on Genetic Engineering, Advisory Board.
Chapin–Consortium for Rio Grande Rift Studies, Executive Committee, chairman.
Hawley—American Institute of Professional Geologists, Ad Hoc Committee on Hazardous Waste; Geological Society of America, Soil Science Society of America Interdisciplinary Committee; New Mexico Geological Society Guidebook Committee, road logs co-chairman; New Mexico Water Resources Research Institute, Advisory Committee; NMIMT Sigma Xi, Nominating Committee and Hazardous Waste Committee.
Eveleth—NMIMT Mineral Museum Advisory Group; Metallurgist Search Committee, chairman.
Kelley—NMIMT tenure committees.
Kottlowski—American Association of Petroleum Geologists, Stratigraphic Correlations Committee, Publications Committee (Associate Editor), Energy Minerals Division (Publication Councilor); American Commission on Stratigraphic Nomenclature, CODES Committee; Association of American State Geologists, AAPG Liaison; Geological Society of America, Executive Committee, Councilor and Chairman of Budget Committee; Geological Society of America, Councilor, Coal Geology Division; Cady Award Committee; New Mexico Coal Surface Mining Commission; New Mexico Energy Research and Development Review Board; New Mexico Mines Safety Advisory Board, chairman; New Mexico Mining Association, Board of Directors and Information and Education Committee; Potential Gas Committee; Regional Coordinator for COSUNA (Correlations of Stratigraphic Units of North America); National Research Council, CODES chairman; COMRE chairman; New Mexico State Land Office, mining representative on Advisory Council; San Juan River Regional Coal Team.
Logsdon—Sigma Xi, Hazardous Waste Committee; Petroleum Geologist Search Committee; Engineering Geologist Search Committee; Geoscience Seminar Program, co-organizer.
Love—Engineering Geologist Search Committee, chairman; New Mexico Geological Society Guidebook Committee, road logs co-chairman, Albuquerque Gem and Mineral Club, board member.
North—New Mexico Minerals Symposium Organization Committee, Mineral Museum Committee.
O'Brien—New Mexico Water Resources Research Institute, State Water Conference Advisory Committee, substitute member; New Mexico Environmental Improvement Division, Data Coordination Committee; Bureau of Reclamation, Advisory Group for Tularosa Basin Water and Energy Study.

Reiter—NMIMT Graduate Council; NMIMT Presidential Search Committee; NMIMT tenure committees.

Renault—NMIMT Computer Advisory Committee; NMIMT Performing Arts Series; NMIMT Honorary Degrees Committee; San Miguel School, school board member.

Robertson—New Mexico Geological Society, Publications Committee chairman; New Mexico Geological Society, Advertising Committee chairman; New Mexico Geological Society, Development Committee chairman; International Science and Engineering Fair, Tours Committee chairman; Sigma Xi Executive Committee, treasurer; NMIMT Institute Senate Budget Committee; NMIMT Graduate Council.

Thompson—NMIMT tenure committees.

Weber—New Mexico Natural History Museum Policy/Advisory Committee; NMIMT Mineral Museum Committee; Archaeological Society of New Mexico Board of Trustees, Certification Council, vice president; NMIMT tenure committees; NMIMT search committees.

Wolberg—New Mexico Coal Surface Mining Commission alternate; NMIMT Mineral Museum Committee; State Paleontology Mitigation Program Committee; New Mexico Natural History Museum Exhibits Committee; Liaison for: Socorro, Albuquerque, and Farmington BLM Offices on Paleontology, Utah State Paleontologist, Kansas City District Army Corps of Engineers on Paleontological Mitigation, U.S. Bureau of Reclamation on Paleontological Mitigation, Society of Vertebrate Paleontology and Federal Paleontological Regulations, New Mexico Mining and Minerals Division, and Navajo Nation Cultural Resources Management Program; Editor/Geologist Search Committee; graduate student committees.

Staff

New employees joining the Bureau were Albert Baca, Technician II, 7 June 1982; Ronald Broadhead, Petroleum Geologist, 21 September 1981; Jane Calvert, Assistant Editor, 1 August 1981; Jim Hale, Driller's Helper, 6 April 1982; Cindy Howell, Staff Secretary, 6 July 1981; Helen Limvorratre, Clerk Typist/Receptionist, 5 May 1982; Deborah Shaw, Editorial Technician, 23 June 1982; Betsy Wilson, Clerk Typist/Receptionist, 1 December 1981; and Russell Wood, Drafter, 26 April 1982.

Resignations during the fiscal year were Kathy Eden, Editorial Technician, 7 May 1982; Steve Frost, Field Geologist, 30 September 1981; Dana Heljeson, Editorial Technician, 14 August 1981; Stephen Hook, Paleontologist, 31 July 1981; Sue Ness, Staff Secretary, 30 November 1981; Joan Pendleton, Associate Editor, 10 July 1981; Jackie Smith, Technician IV, 15 April 1982; and Betsy Wilson, Editorial Technician, 15 June 1982.

Promotions were Arleen Lindsey to Staff Secretary, July 1981; Wess Mauldin, Jr., to Driller, September 1981; and Sue Ness to Staff Secretary, July 1981.

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6/7/82

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1/1/81

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3/21/81

Corale Brierley
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Petroleum Geologist
9/21/81

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

Jane A. Calvert
Assistant Editor
8/1/81

Frank Campbell
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Richard Chavez
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Mark Logsdon
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Russell Wood
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4/26/82

Michael W. Wooldridge
Chief Scientific Illus.
1/25/71

Pseudaspidoceras pseudonodosoides (Choffat)—common Upper Cretaceous guide fossil in southwest New Mexico

by William A. Cobban, *Paleontologist*, U.S. Geological Survey, Denver, Colorado
and Stephen C. Hook, *Geologist*, Getty Oil Company, Houston, Texas

This is the sixth article in a series documenting biostratigraphically important and readily identified fossil mollusks that are found in Upper Cretaceous rocks in New Mexico. Previous reports described and illustrated the oysters *Pycnodonte newberryi* (Stanton), *P.* aff. *P. kellumi* (Jones), and *P.* cf. *P. kellumi* (Jones) (Hook and Cobban, 1977); the ammonites *Prionocyclus novimexicanus* (Marcou) and *Scaphites whitfieldi* Cobban (Hook and Cobban, 1979); the bivalve *Inoceramus dimidius* White, the oyster *Lopha lugubris* (Conrad), and the ammonite *Prionocyclus macombi* Meek (Hook and Cobban, 1980); the oyster *Lopha sannionis* (White) (Hook and Cobban, 1981b); and the ammonite *Spathites puercoensis* (Herrick and Johnson) (Hook and Cobban, 1982).

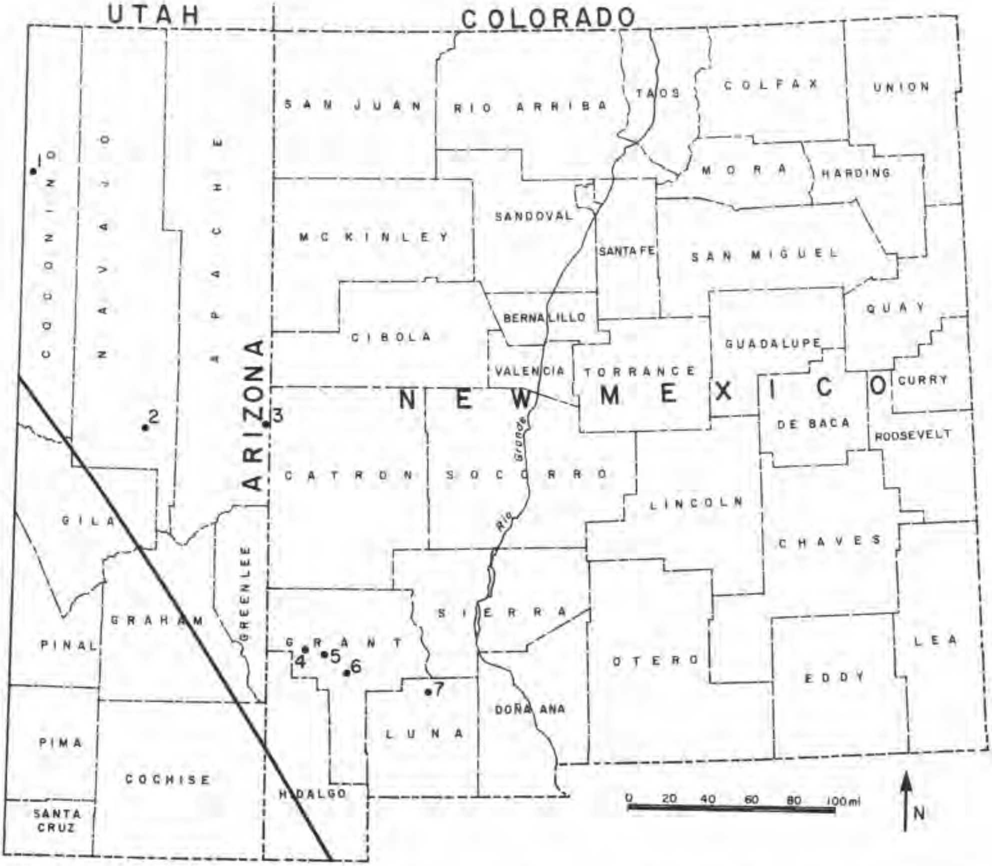

FIGURE 1—Map of New Mexico and part of Arizona showing localities (•) where *Pseudaspidoceras* has been collected and approximate position of Late Cretaceous shoreline (curved line) during *Pseudaspidoceras* time. Localities: **1**, west side of Black Mesa; **2**, Show Low area; **3**, Cottonwood Canyon; **4**, Red Rock Mountains; **5**, Big Burro Mountains; **6**, Little Burro Mountains; and **7**, Cooke's Range.

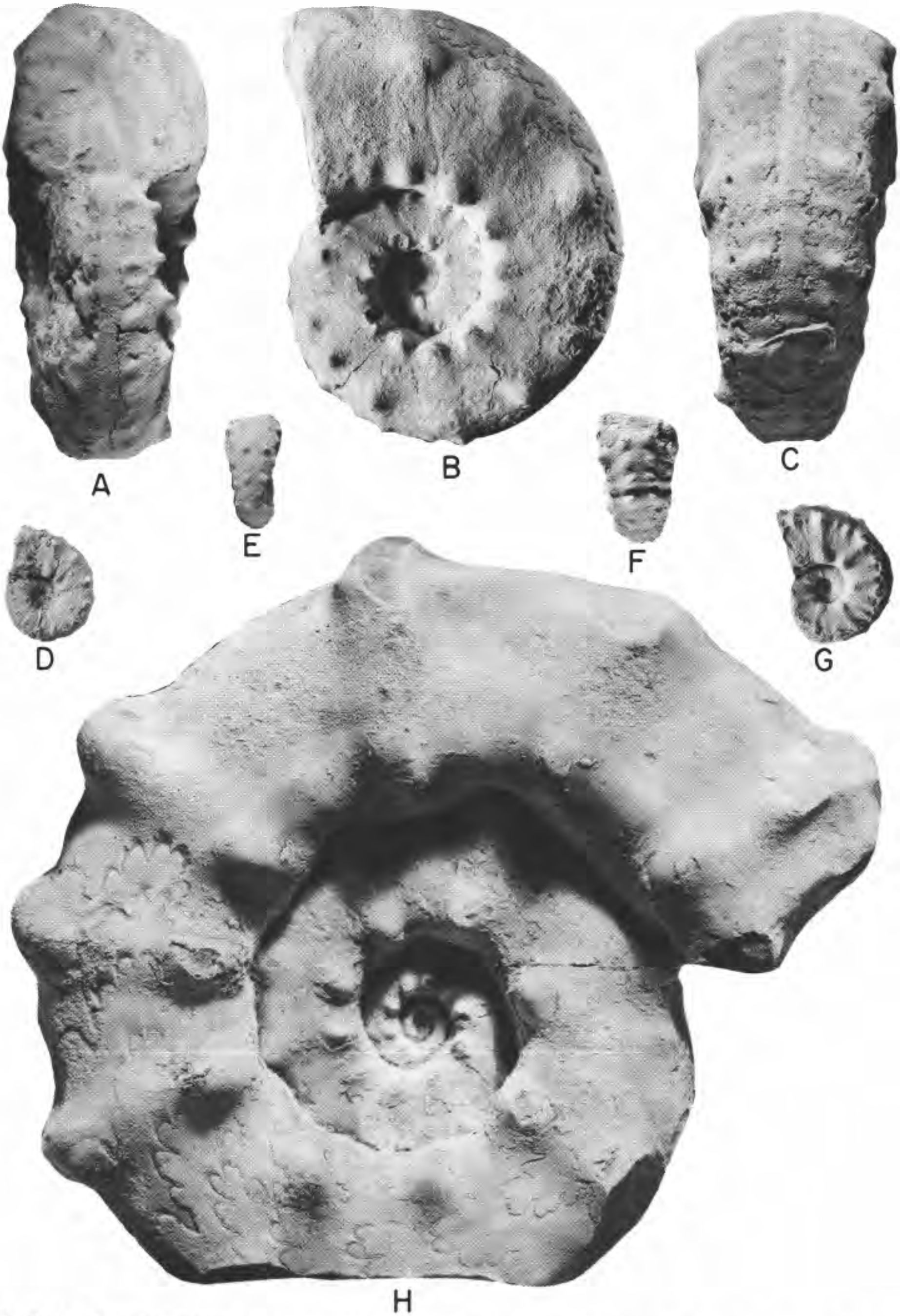

FIGURE 2—*PSEUDASPIDOCERAS PSEUDONODOSOIDES* (CHOFFAT), NATURAL SIZE, FROM COLORADO FORMATION. **A–C,** front, side, and rear views of hypotype USNM 337428, from USGS Mesozoic locality D10114 in NE1/4 sec. 13, T. 21 S., R. 9 W., Luna County, New Mexico; **D** and **E,** side and rear views of hypotype USNM 337429, from USGS Mesozoic locality D11460 in NW1/4 sec. 11, T. 18 S., R. 18 W., Grant County, New Mexico; **F** and **G,** rear and side views of hypotype USNM 337430, from USGS Mesozoic locality D10533 in N1/2 sec. 11, T. 18 S., R. 17 W., Grant County, New Mexico; and **H,** side view of hypotype USNM 307365, from same locality as A–C.

The genus *Pseudaspidoceras* is a moderately evolute to very evolute ammonite that has a square to rectangular whorl section and ornament of fairly wide-spaced ribs, umbilical tubercles, and inner and outer ventrolateral tubercles. Innermost whorls have periodic constrictions and/or periodic raised ribs; later juvenile whorls have more uniform tuberculate ribs, and adult whorls may lose much of their ribbing as well as the outer ventrolateral tubercles. The suture is characterized by its broad, bifid lateral lobe.

Pseudaspidoceras is abundant in southwest New Mexico, but outside that area, the genus is known from only a few localities (fig. 1). A few specimens have been found at the top of a thick sandstone unit in Cottonwood Canyon along the New Mexico–Arizona boundary east of St. Johns, Arizona, and a single specimen was collected from a calcareous concretion in sandstone farther west near Show Low, Arizona. Crushed specimens occur in limestone concretions near the base of the Mancos Shale in the Black Mesa area in northeast Arizona. In the Great Plains region, only a single specimen is known (Morrow, 1935, p. 469).

Pseudaspidoceras pseudonodosoides (fig. 2) is a moderate-sized evolute ammonite that was originally described as *Acanthoceras*(?) *pseudonodosoides* Choffat (1898, p. 65, pl. 16, figs. 5–8; pl. 22, figs. 32, 33). Choffat's specimens came from a bed of limestone at the mouth of the Rio Mondego in coastal Portugal. Choffat assigned the macrofossils from this bed to the Turonian, and recent studies of the microfauna suggest an early Turonian age (Lauverjat and Berthou, 1974).

Specimens that seem assignable to *Pseudaspidoceras pseudonodosoides* are fairly abundant in the lower part of the Colorado Formation in the Red Rock and Little and Big Burro Mountains in the Silver City area as well as at the top of the Bridge Creek Limestone Member of the Colorado Formation in the Cooke's Range near Deming. The species is especially abundant at a discontinuity surface near Rattlesnake Ridge 5 km (3 mi) south of Cooke's Peak in the NE$^1/_4$ NE$^1/_4$ sec. 13, T. 21 S., R. 9 W., Luna County (Hook and Cobban, 1981a). Specimens were first collected at this locality by N. H. Darton in 1910 and identified as *Prionotropis* sp. by T. W. Stanton (Darton, 1916, p. 45).

Pseudaspidoceras pseudonodosoides is easily identified by its stout whorls ornamented by large, nodate umbilical and inner ventrolateral tubercles and much weaker and smaller outer ventrolateral tubercles. Each umbilical tubercle usually is connected to an inner ventrolateral tubercle by a low, broad rib which is greatly weakened at mid-flank (fig. 2B and H). Outer ventrolateral tubercles generally weaken or disappear at some diameter between 60 and 70 mm, but they may persist to much larger diameters. On specimens that retain the outer tubercles to large diameters, both inner and outer ventrolateral tubercles are usually located on a short, thick rib that crosses part of the venter at a slight angle. The middle of the venter is smooth and forms a low area separating opposite ventrolateral tubercles. Early whorls of the species have periodic constrictions (fig. 2F). The suture (fig. 3) is typical of *Pseudaspidoceras* in having an unusually broad lateral lobe (L).

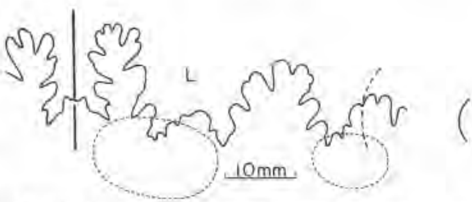

FIGURE 3—EXTERNAL SUTURE OF SPECIMEN OF *PSEUDASPIDOCERAS PSEUDONODOSOIDES* (CHOFFAT), SHOWN ON FIG. 2H. Heavy straight line marks middle of venter, L is lateral lobe, curved dashed line marks umbilical shoulder, solid curved line marks umbilical seam, and dotted ovals mark position of tubercles.

In southwest New Mexico, *P. pseudonodosoides* is associated with the densely ribbed ammonite *Neocardioceras juddii* (Barrois and Guerne) (Hook and Cobban, 1981a, pl. 1, figs. 6–8). The type specimens of *N. juddii* came from the Plenus Marls of the Paris Basin in France. Recent investigations of the rocks and fossils of the type Cenomanian and Turonian Stages of France suggest that the Plenus Marls are best assigned to the Cenomanian on historical grounds (Juignet and Kennedy, 1976; Hancock and Kennedy, 1980; Wright and Kennedy, 1981). Inasmuch as *P. pseudonodosoides* is considered early Turonian in Portugal, perhaps the Cenomanian–Turonian boundary there should be raised a bit higher than where placed by Lauverjat and Berthou (1974) in light of the faunal association in New Mexico.

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Reclamation of surface-mining areas in New Mexico

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Introduction

When surface mining in New Mexico is considered, coal strip mining immediately comes to mind—and for good reason. In addition to being a highly visible part of New Mexico's overall mining activity, coal mining accounts for a significant amount of the state's mineral production. New Mexico's 1981 production, the most recent year for which complete figures are available, amounted to $1.4 billion exclusive of oil and gas (Eveleth and Bieberman, 1983). Of that amount, 75% ($1.04 billion) was produced as a result of strip or open-pit mining methods. Strip-mined coal accounted for approximately one-third of that total. Other commodities mined by surface or open-pit methods include copper, gold, silver, molybdenum, and uranium (until 1982), as well as others.

Although small-scale surface mining has been conducted for perhaps the last 1,000 yrs or longer for such commodities as turquoise, gold, and silver, surface mining began in New Mexico on a commercial scale in late 1910 at Santa Rita in Grant County. The Santa Rita del Cobre property has been in nearly continuous operation since 1804, and has produced more than 10 billion lbs of copper (W. Ballmer, personal communication, 1982), most of it derived from surface mining. Additional open-pit copper mines have been developed since the early 1960's, including Phelps Dodge Corporation's Tyrone mine and Sharon Steel's Continental mine at Fierro.

Anaconda began open-pit uranium mining at the Jackpile mine near Laguna in 1952, and the mine was operated continuously until 1982. This mine produced approximately 100 million lbs of U_3O_8 during its 28-yr life and is probably the world's most productive uranium mine (Hatchell, 1981, p. 17).

Utah International began strip mining for coal in the Farmington area in 1962. Since then at least six other large-scale strip mines have opened, with more on the way.

Molycorp began open-pit mining for molybdenum in the Questa area during 1965 and operated continuously until August 1982. A new underground mine is currently under development.

Brief history of coal mining

The first records of state coal production were done by the Territorial Inspector of Mines in 1882 (New Mexico State Inspector of Mines, 1889–1980). Since that time annual coal production has fluctuated between a low of 116,656 tons as recently as 1958 to an all-time high in 1982 of over 20 million tons (K. Hatton, personal communication, 1983).

Historically, the Spanish used small amounts of coal several centuries ago, and anthracite was mined from the Cerrillos field as early as 1835. Mining began on a significant scale in 1861 when U.S. Army troops at Fort Craig opened a mine in the Carthage field.

Coal production exceeded a million tons for the first time in 1889 and was consumed primarily by the railroad and lead- and copper-smelting industries. Annual coal production topped 4 million tons in 1918, stimulated by the demands of the first World War. For the next 30 yrs, the smelting, manufacturing, and railroad industries still accounted for the majority of coal consumption. However, dieselization of the nation's railroads and the increased use of natural gas reduced annual production to under the one million ton mark in 1950. This downward trend continued until the previously mentioned low in 1958.

Coal surface mining

The turnaround in state coal production came in the early 1960's with the development of Utah International's mine in the Farmington area. The really large "boom," however, has come since the opening of other large-scale strip mines in both McKinley and San Juan Counties. The combination of inexpensive strippable coal and the increasing demand for electric power in Arizona, New Mexico, and California led to the opening of the McKinley strip mine near Gallup. Consolidated Coal's Con Paso mine near Burnham began strip mining operations in 1980 in the southwest corner of the Navajo field. Sunbelt Mining's De Na Zin mine has been active and producing coal since December 1980. The Gateway mine, operated by Sunbelt, began operations in October 1982, but is not currently in production. Santa Fe Coal Company's Lee Ranch mine began construction in 1982 and production is to begin in 1984. Black Diamond Coal Company is currently mining humate at their Black Diamond mine. Other operating mines in the San Juan Basin are San Juan Coal Company's mine northwest of Fruitland and Carbon Coal Company's Mentmore mine west of Gallup. Additionally, Kaiser Steel is operating a strip mine in West York Canyon near Raton.

Permits to strip mine coal have been obtained from the State of New Mexico for the Gallo Wash mine in the eastern Bisti area by Alamito Coal Company and for the South Hospah mine in the eastern Standing Rock area in central McKinley County by Chaco Energy. Permits in process for surface mining in New Mexico include the Carbon #2 mine near Gallup by Carbon Coal Company and La Plata mine in the northernmost Fruitland area by Utah International to be mined by San Juan Coal Company.

During 1982 total coal production amounted to 20,483,441 tons, up from the 1981 production figure of 18,793,666 tons (K. Hatton, personal communication, 1983). The 1982 production is 5% higher than the previous all-time high state coal production in 1980. Approximately 90% of this total was produced from strip mines.

Uses

New Mexico coal is used both within the state and throughout the western United States. Steam coal from the McKinley mine is shipped to the Cholla power plant of the Arizona Public Service Company near Joseph City, Arizona, while production from the Navajo and San Juan mines is used in the nearby Four Corners area power plants. Coal from the Mentmore mine travels by unit train to the Benson power plant of Arizona Power Co-op at Cochise. Coking coal, mined near Raton, is shipped by unit train to Kaiser Steel Corporation's mills at Fontana, California, and the Lone Star steel plant in Texas. Occasionally small amounts are shipped to the Colorado Fuel and Iron Company in Pueblo, Colorado.

Mining methods

Today, coal is mined and handled exclusively by large-scale mechanized equipment including draglines, shovels, and front-end loaders. At the San Juan mine, for example, two walking draglines of approximately 60 yd^3 capacity are used for overburden removal while at the neighboring Navajo mine, four draglines from 45 to 65 yd^3 capacity are in use. Carbon Coal Company uses two shovels with 13 to 15 yd^3 capacity instead of draglines.

The number of seams mined varies from two at the San Juan mine up to 11 at the Mentmore mine. After the blasting, the coal is loaded with shovels and front-end loaders and hauled to loading facilities on site in trucks or specialized loaders. The latter includes both WABCO and Euclid bottom dump rigs of 120 ton capacity. Truck and rail haulage, separately or in combination, are used to deliver coal to the mine mouth of off-site power plants (fig. 1).

Other surface mining

Surface mining is currently being done on a commercial scale for copper and gold. Molybdenum and uranium were mined commercially until 1982. Other commodities such as sand, gravel, stone, gypsum, and iron ore are mined by open pit instead of strip mining; they are mined in small-scale operations by comparison and will not be discussed here. Surface-mining methods are generally similar for all the "hardrock" minerals. Waste rock and ore are drilled with track- or truck-mounted hammer drills utilizing a drill and blasting pattern designed for optimum breakage and ore control. Overburden (or

FIGURE 1—HAULING COAL BY UNIT TRAIN AT THE NAVAJO MINE; Four Corners plant of Arizona Public Service Company is in background. Photo courtesy of Utah International, Inc.

waste) is removed in a series of horizontal cuts varying from 20 to 60 ft in thickness. As mining progresses downward, a system of benches is left surrounding the mined-out portion of the orebody. Unlike coal where the pay streak is defined by a bed or zone of rather definite thickness, a metalliferous orebody may continue downward for hundreds, perhaps thousands (as at Santa Rita) of ft; mining continues until the economic limits of the orebody have been reached. Older mined areas are therefore not backfilled as mining progresses because access to deeper ore would thus be cut off. Additionally, metalliferous deposits such as those at Santa Rita, Tyrone, and Questa are seldom "worked out" completely. What we consider waste today could well become the ore of tomorrow. Copper, for example, will doubtless be produced at Santa Rita for the next several hundred years and perhaps longer.

Here again, as with coal mining, specialized equipment is used to handle both ore and waste. Front-end loaders and shovels load diesel-electric haul trucks varying from 40 tons to 170 tons capacity. Waste and low-grade materials are taken to dump areas and the ore is taken to mill facilities.

Reclamation projects—coal

The most vigorous reclamation projects, because of strict federal and state regulations and the necessity of a reclamation plan before issuance of a mining permit, are those carried on by the various coal companies. As a result, reclamation of mined lands is an important part of any coal mine plan.

Coal surface mining in New Mexico is regulated by the Bureau of Mining and Minerals Division of the New Mexico Energy and Minerals Department. Mine plans submitted to the Bureau must include a detailed reclamation program, proposed timetable, and per-acre cost analysis of proposed reclamation procedures. Various topics addressed in the reclamation plan include backfilling, soil stabilization, and compacting and grading of the permit area. Removal, storage, and redistribution of topdressing, subsoil, and other overburden also are outlined in detail.

Revegetation plans, including a listing of plant species to be used and the amounts per acre, are discussed. Differences in climate, rainfall, and soils vary across the state; thus types of species used, as well as percentage of grasses to shrubs, may change from mine to mine. Methods of planting, seeding, and mulching as well as planting times and percentages of various seed types and mulches are governed by environment. Irrigation methods and types of pest and disease control, if these are necessary for vegetation, are discussed. Soil analysis may indicate how topdressing may best be handled for revegetation. Monitoring of the revegetation program also is a necessary part of the overall reclamation plan.

Other considerations are the protection of the hydrogeologic balance in the permit and surrounding areas and a discussion of the proposed use of the reclaimed land after mining. Surface and ground-water quality must be protected from adverse effects of coal surface-mining operations. The expected utility and capacity of reclaimed lands is addressed in some detail.

Several areas currently have ongoing coal surface-mining operations; these are generally confined to the San Juan and Raton Basins.

Reclamation in San Juan Basin

Utah International began actively reclaiming mined areas in 1966. At that time a test program was undertaken to level spoil spills. An undulating topography soon was determined to have greater resistance to both water and wind erosion. Utah International also began burying ash from the power plant at this time. The ash is backhauled to the mine and covered by spoil material.

Sunbelt Mining Company's De Na Zin mine in the Bisti area has been active since 1980, but with a projected mine life of only 3 yrs the mine is expected to disturb only 155 acres.

Reclamation is to follow the mining sequence as closely as possible with topsoil analysis being a year-round ongoing process. Topdressing removal is done in advance of overburden stripping and also is an ongoing process. Spoil regrading follows no more than four ungraded spoil ridges behind the dragline. Topdressing redistribution occurs at the time the topdressing is picked up if regraded spoil is available; otherwise the topdressing is placed in stockpiles. Fertilization, seeding, and mulching are done during May and June. Seeding is done with a disc drill (fig. 2) and mulching with a power mulching machine. Mulch is applied to areas

FIGURE 2—SEEDING NATIVE GRASSES AND SHRUBS AT THE NAVAJO MINE; photo courtesy of Utah International, Inc.

susceptible to erosion at a rate of up to 1,000 lb/acre. Mulch, consisting of grain straw or native material, is anchored to the soil by a mechanical crimper. All reseeded areas will receive irrigation from June through September for 2 yrs after reseeding. Estimated reclamation costs at the De Na Zin mine are \$4,979/acre (Sunbelt Mining Co., 1981b). Plant species to be used are Blue Grama, Western Wheatgrass, Streambank Wheatgrass, Indian Ricegrass, Galleta, Alkali Sacaton, Sand Dropseed, Fourwing Saltbush, Winterfat, and Shadscale.

A. J. Firchau's Arroyo No. 1 mine began operating in 1980 (Arroyo Mining Co., Inc., 1981); total production for that yr was just 15,000 tons. The area to be mined is 640 acres with a mine life of 11 yrs. The Arroyo No. 1 mine is located in La Ventana field in the southeast corner of the San Juan Basin.

The reclamation plan is similar to many others in New Mexico. Topsoil is removed by scraper or front-end loader and is stockpiled and stabilized. Soil materials are removed and directly applied to graded spoil material concurrently with mining to minimize wind and water erosion. The spoil material is reconstructed and graded to establish a topography similar to the premined landscape. Overburden is mixed to reduce potential of contamination of surface-water runoff and to eliminate phytotoxic effects of heavy-metal uptake by plants. Eighteen inches of topdressing is applied over the shaped and graded spoil piles. Discing from three to five inches deep loosens the compacted soil. Analyses of nutrient deficiencies of topdressing are done at the beginning of each season to determine fertilizer needs. Seeding takes place generally from July through September, the season of highest expected precipitation. Plant species used at Arroyo No. 1 mine are Crested Wheatgrass, Indian Ricegrass, Western Wheatgrass (cool season grasses), and Alkali Sacaton, Blue Grama, Galleta, and Sand Dropseed (warm season grasses). Shrubs used are Fourwing Saltbush and Winterfat.

Seeding is done with a rangeland drill except on higher relief areas where broadcast seeding is done. All areas will be mulched with native grass hay to prevent erosion (fig. 3). Two tons of mulch per acre, with nitrogen added, are spread by blower. Weed control for the first year will be done by mowing or clipping. Herbicides are to be applied only to noxious weeds.

Arroyo No. 1 does not plan to irrigate because of the average annual rainfall of 9.97 inches. Most of the rain (65%) falls from July through October.

Reclamation costs are held to a minimum by dumping to grade, thereby minimizing dozer work, and by returning topdressing from storage area by scraper. The estimated reclamation cost for the Arroyo No. 1 mine is \$762.93/acre. A total of 740,000 yd^3 of overburden will be moved during the life of the mine.

The Black Diamond mine, in the northern part of the San Juan Basin near the Colorado border, has a projected mine life of 3 yrs; mining began in 1982. Overall, 160 acres will be disturbed. Reclamation costs for the Black Diamond mine are broken down into costs for backfilling and revegetation. The total cost of backfilling is estimated at \$975,000; revegetation costs amount to \$850/acre (Black Diamond Coal Company, 1981).

The plan for removal of topsoil before mining is to move along the strike of the coal seam. Topsoil will be stockpiled directly

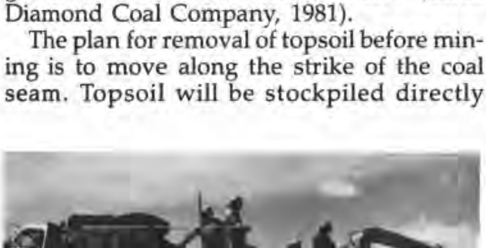

FIGURE 3—MULCHING WITH HAY AT THE NAVAJO MINE; photo courtesy of Utah International Inc.

northwest of the pit and maintained for 3 or more yrs. Crested Wheatgrass will be seeded on the stockpiles to prevent erosion.

Overburden will be excavated by scrapers, dozers, and rippers and also will be stockpiled into two piles. When coal in a particular area has been exhausted, overburden is to be returned by truck and compaction will be done by dozer. The filled pits will be graded to contour and plated with stockpiled topsoil by use of a scraper. Five inches of topsoil will be incorporated with an offset disc into overburden to a depth of four inches. A final seven inches of topdressing will then be applied to complete the amount of topsoil needed for the seed bed. Contour furrowing will follow to reduce runoff and hold moisture. Fertilizer rates will be based upon results of soil analyses and seeding is to be initiated by May 15 and completed before June 15 annually. Plant species to be used are Crested Wheatgrass and Western Wheatgrass (cool season grasses), and Alkali Sacaton, Blue Grama, Galleta, and Sand Dropseed (warm season grasses). Shrubs include Fourwing Saltbush and Winterfat.

Most seeding will be done with rangeland drill. However, broadcast seeding will be used on rocky slopes. The entire area will be mulched with native grass hay, tame grass hay, or small grass straw. Mulching will be done year round immediately after seeding and nitrogen is to be added to the mulch for fertilization. Irrigation is not planned in this mine area because of a mean annual precipitation of 11.21 inches.

Reclamation in Raton Basin

Kaiser Steel's West York Canyon strip mine has been mined since 1977 in the Raton coal field. Mine life is projected at 15–23 yrs with expected annual production of 500,000–700,000 tons (Kaiser Steel Mine Plan, 1980). The total disturbed area will be 13,211 acres and the total cost of reclamation over the life of the mine will be $9,494/acre.

Reclamation begins with topdressing removal and distribution after the clearing of trees and prior to the removal of overburden by dragline and/or shovel–truck fleet. After this phase and subsequent to backfilling and grading, topdressing is to be redistributed on the affected area. Regrading occurs no later than four dragline spoil rows behind the current dragline bench operation. Regrading will be done with bulldozers, and backfilling will be done by shovel–truck fleet. Fertilization and seed-bed preparation follow in the appropriate months. Seeding will be done by drilling (75%) and broadcasting (25%). Irrigation will be done where necessary after fertilization and seeding.

Grasses to be used at West York Canyon are: Blue Grama, Little Blue Stem, Sideoats, Big Blue Stem, Spike Muhly, Hairy Grama, Western Wheatgrass, Arizona Fescue, and Alkali Sacaton. Shrubs include Winterfat, Lewis Flax, Purple P. Clover, Fourwing Saltbush, mountain mahogany, Rubber Rabbitbrush, yucca, and piñon.

Reclamation costs, as shown in table 1, will obviously vary greatly depending upon climate, terrain, and other factors.

Reclamation successes and failures

Reclamation by coal surface mines in New Mexico has thus far been successful, but it must be realized that the success of reclaimed land can only be proven by time. Some of the earliest reclamation projects have had to be redone because of steepness of slopes, soil conditions, and other factors which were not taken into consideration. These problems have been solved by doing more analyses of the soils and by paying more attention to the topography of the area prior to mining. Therefore, the success rate in the last 4 yrs has been good for reclamation of surface mines in New Mexico.

Irrigation is an area of contention in reclamation. The areas that are irrigated do well, but some grasses planted do not survive after the irrigation has stopped. Areas that are not irrigated do no better or worse than areas that do have irrigation, but they are subject to the fluctuations in climate, such as a dry year or a wet year (J. Reynolds, personal communication, 1982).

Most mines operating at the present in the San Juan Basin have not been in reclamation long enough to evaluate their success. Utah International's Navajo mine (fig. 4) and Pittsburg and Midway's McKinley mine have been reclaiming mined areas since the 1970's, and they have a good success rate. The reclaimed mine areas of these two mines are considered to be significantly better for grazing than the surrounding grazing land (J. Reynolds, personal communication, 1982).

TABLE 1—RECLAMATION COSTS OF MINES (PROPOSED MINES) IN SAN JUAN BASIN AND ACRES DISTURBED ACCORDING TO MINE PLANS SUBMITTED TO THE STATE (Carbon Coal Company, 1981a, 1981b; Chaco Energy Company, 1980, 1981; Sunbelt Mining Co., Inc., 1981a; Western Coal Company, 1978).

Mine/ company	Mine life (yrs)	Cost/acre disturbed	Acres disturbed
Carbon #2 Carbon Coal	11	$4,700.00	321.7
Mentmore Carbon Coal	13	$ 762.93	4,337.6
South Hospah Chaco Energy	25	$3,945.00 1–3 yrs $5,445.00	550
Star Lake Chaco Energy	36	$3,945.00 1–4 yrs $5,445.00	2,837
Bisti Western Coal	25	$4,285.00–6,190.00	4,613
Gateway Project Sunbelt Mining	8	$1,306.00	1,802

Kaiser Steel's reclamation has been successful, although certain grasses such as Western Wheatgrass survive better than others (Blue Grama) after irrigation has stopped (B. Stockton, personal communication, 1982). The success of the reclaimed areas is indicated by the fact that wildlife graze on reclaimed land, although these areas are fenced and grazing is discouraged.

Other projects—noncoal

Reclamation projects on a smaller scale also are ongoing at three or more metal mines. These include Phelps Dodge Corporation's Tyrone mine, Gold Fields Corporation's Ortiz mine near Cerrillos, and Union/Molycorp's mine near Questa.

FIGURE 4—SECOND-YEAR VEGETATION OF THE NAVAJO MINE; New Mexico Bureau of Mines and Mineral Resources photo.

Phelps Dodge has had an active revegetation program at Tyrone for about 15 yrs. Revegetation projects have included plantings on borrow areas and waste dumps which will not be redisturbed. The largest project, however, resulted from a tailings spill that occurred in October 1980. Approximately 1½ million yds^3 of tailings covered 344 acres of ground in the Mangas Valley. Approximately 80% of this material was removed and returned to permanent tailings-storage areas. The entire area was then topdressed with 18 inches of material varying from a coarse, decomposed granite to a fine, sandy loam. Areas were then disced and seeded with a 10-species mix composed primarily of range grasses. Most areas were hydroseeded, although some were drilled. The hydroseeded mixture included 10–15 lbs of seed, 2,000 lbs of woodfiber mulch, 50 lbs of fertilizer, and 40 lbs of ammonium sulfate per acre. In addition to the area affected by the spill, borrow areas also were reclaimed. A total of 560 acres was reclaimed in a period of 87 days (J. T. Tysseling, personal communication, 1982).

Seeding and reclamation of disturbed construction areas began in the summer of 1980 at the Ortiz mine. These areas include those disturbed during construction of the initial access road and mine that would not be disturbed again. Gold Fields is experimenting with wildflowers in addition to grasses and shrubs. Wildflowers include, among others, Purple Aster, Calliopsis, Prairie Cornflower, and Lupine. Successful grasses include Crested Wheatgrass, Sand Dropseed, Annual Ryegrass, Sideoats Grama, Alkali Sacaton, Intermediate Wheatgrass, and Winter Rye. Shrubs include Fourwing Saltbush and Rubber Rabbitbrush (Hickson, 1982).

Experiments are ongoing to determine the best combination for use on leach-pile residues and waste piles. The Gold Fields project appears to be successful in those areas that have been reclaimed. The company is committed to a good-faith effort to leave the surface in as good a condition as possible.

Union Oil/Molycorp also has been experimenting with various revegetation projects. Hydrospraying a seed and fertilizer mixture is followed by application of wood-fiber mulch and water. Grasses yielding promising results are Sideoats Grama, Crownvetch, and Intermediate Wheatgrass. Molycorp and the U.S. Department of Agriculture have established test plots at various waste dumps and tailings sites. Twenty experimental studies covering 12 acres are to be evaluated over a 5-yr period which began in 1981 (Union/Molycorp, 1981). In addition to grasses and shrubs, Molycorp plants trees such as White Fir, Ponderosa Pine, Douglas Fir, and Blue Spruce.

Conclusion

Reclamation of mined lands is a relatively new agricultural science and an ongoing process. The expertise we have acquired is mostly a result of trial and error. While we may point to many successes, some notable failures also exist. For example, no one has yet found a way to induce vegetation to grow successfully on metal-mine tailings. However, many of our mining companies are dedicated to a good-faith effort toward finding acceptable answers to problems such as this. Given the caliber of scientists and engineers that are working today on these problems, certainly the future holds promise for many outstanding successes.

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Raton Basin magnetostratigraphy near Cretaceous–Tertiary boundary

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Introduction

The Raton Basin is a large sedimentary and structural basin in northeast New Mexico and southeast Colorado encompassing an area of approximately 10,000 km^2 (4,000 mi^2; fig. 1). The basin is bounded on the north by the Wet Mountains, on the west by the Sangre de Cristo Mountains, and on the east by the Sierra Grande–Las Animas arch (Johnson and others, 1966). A thick sequence of more than 3,700 m (12,000 ft) of sedimentary rocks of Late Cretaceous–Eocene age is present in the Raton Basin (Johnson and Wood, 1956; Baltz, 1965). Late Cretaceous sediments record the final regression of the Cretaceous epeiric seaway from the Western Interior of North

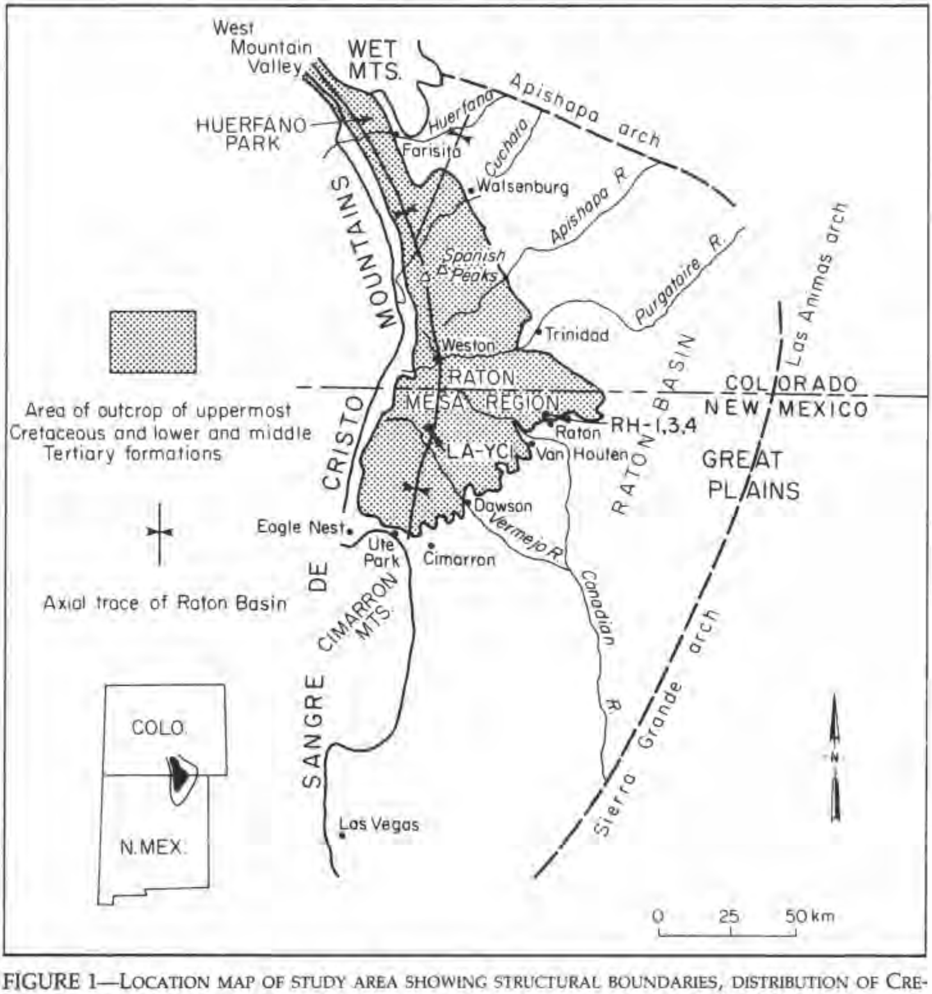

FIGURE 1—Location map of study area showing structural boundaries, distribution of Cretaceous and Tertiary rocks, and sampling localities for Raton core (LA–YCI) and exposures (RH–1,3,4); after Johnson and others, 1966.

America. The stratigraphic sequence of this regression from oldest to youngest consists of Trinidad Sandstone, Vermejo Formation, and Raton Formation.

The Raton Formation may be as much as 610 m (2,000 ft) thick (Pillmore, 1976) and contains the Cretaceous–Tertiary boundary. With the exception of paleobotanic materials (fossil leaves and pollen), fossils are poorly represented in the Late Cretaceous–Paleocene rock sequence. Leaf floras are known from the Trinidad Sandstone, the Vermejo Formation, and the Raton Formation (Ash and Tidwell, 1976). Brown (1943, 1962) considered the lower part of the Raton Formation to be Cretaceous in age and the upper part Paleocene. *Paleoaster inquirenda* Knowlton, a problematic plant fossil, occurs within the lowest 15 m (50 ft) of the Raton Formation and is not known to occur in the Tertiary. On the basis of core samples, Tschudy (1973) located the palynological Cretaceous–Tertiary boundary at 81 m (266 ft) and 88 m (289 ft) above the base of the Raton Formation. Tschudy (in Orth and others, 1981) reestablished the palynological Cretaceous–Tertiary boundary in a newly drilled core, . . . "within a 1 m interval between a coal bed centered at a depth of 255.7 m and a carbonaceous shale at 256.7 m." From data available to us, we cannot determine how far above the base of the Raton this boundary is situated. However, this palynological boundary occurs at the same stratigraphic position as an iridium abundance anomaly with concentrations of up to 5,000 ppt and is the first published record of an iridium anomaly in continental sediments.

Beyond the implication that anomalously high concentrations of iridium at the Cretaceous–Tertiary boundary might be the signature of a catastrophic, extraterrestrially derived event related to the demise of Late Cretaceous life forms, a number of useful stratigraphic implications also would result. First, when correlated with the paleomagnetic sequence, high concentrations of iridium would have far-reaching values for rock and time-stratigraphic correlation for geographically widely separated rock units. Depositional environments would be of no major consequence; marine and terrestrial units could be correlated given a continuous rock record. Similarly, anomalously high concentrations of iridium, when correlated with the paleomagnetic and paleontologic sequence could suggest a resolution of the controversy related to various proposed Cretaceous–Tertiary boundaries in the San Juan Basin. Butler and others (1977), Lindsay and others (1978), and Lindsay and others (1981) interpreted paleontologic/magnetostratigraphic data to indicate that in the San Juan Basin the Cretaceous–Tertiary boundary, based on the highest stratigraphic occurrence of dinosaurs, occurs within the normal polarity zone correlated with anomaly 29. Thus dinosaur extinction in the San Juan Basin occurred later than marine foraminiferal extinctions at Gubbio, Italy, where extinctions occurred high in the reversed magnetozone between anomalies 29 and 30 (Alvarez and others, 1977).

Finally, if an iridium anomaly represents a single simultaneous worldwide event at the Cretaceous–Tertiary boundary, the anomaly must occur within the same magnetic polarity zone. If continental extinctions and marine extinctions were simultaneous events at the Cretaceous–Tertiary boundary, they must occur within the same magnetic polarity zone.

To date, however, our efforts to locate a reproducible iridium anomaly in the San Juan Basin at or near various suggested Cretaceous–Tertiary boundaries have proved inconclusive. This is an unfortunate situation given the extant paleomagnetic/paleontologic documentation available. However, through the cooperation of Carl Orth, Los Alamos Laboratories, we were provided access to the 30.5-m (100-ft) Raton Basin core with a demonstrated iridium anomaly at the palynologic Cretaceous–Tertiary boundary. Samples also were taken at the Cretaceous–Tertiary boundary from surface exposures at Raton Park. Fig. 2 is a generalized representation of Raton Basin core showing dominant lithologies and paleomagnetic sampling intervals.

Experimental procedure

Samples of cylindrical plugs were taken from the Raton core at about 30-cm (1-ft) intervals (fig. 2b). Well-consolidated siltstones were cored and sliced wet to 2.5 cm (1 inch) cylinders. Friable shales had to be cut dry to fit $1.7 \times 2 \times 2$ mm plastic containers. Additionally, three oriented samples were collected in Raton Park. These samples were between 15 cm (6 inches) and 57 cm (22 inches) above the palynological Cretaceous–Tertiary boundary and iridium anomaly. Three spec-

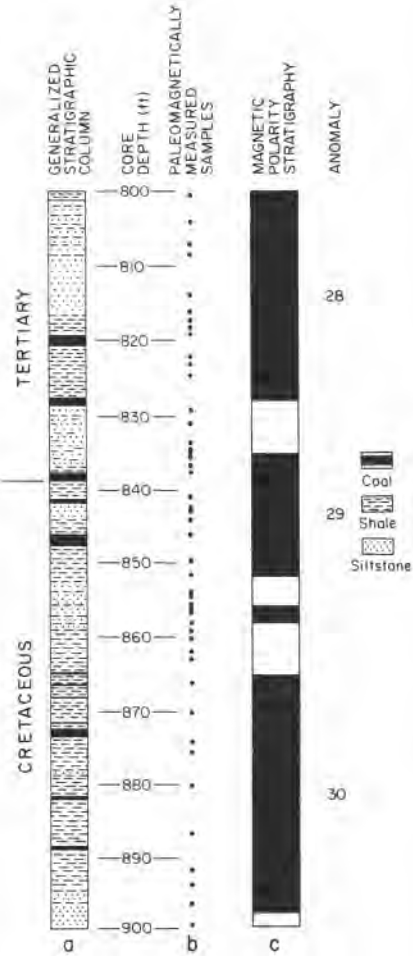

FIGURE 2—**a)** GRAPHIC REPRESENTATION OF RATON CORE LITHOSTRATIGRAPHY, **b)** PALEOMAGNETIC SAMPLING INTERVALS, **c)** MAGNETIC POLARITY ZONATION AND POSSIBLE MAGNETIC ANOMALY ASSIGNMENTS.

imens were taken from each sample and great care was taken to maintain vertical up for all specimens.

Initially a few of the cylindrical samples were measured on a Schonstedt SSM–1 spinner magnetometer interfaced with a North Star microcomputer. Specimens were demagnetized in 5 mT (*milliteslas*—measurement of magnetic intensity) steps using an in-house built alternating-field demagnetizer. The weakness of the magnetization precluded demagnetizing beyond 15 mT or 20 mT.

As a result of this problem, most of the measurements and further demagnetizations of the specimens, initially measured at New Mexico Institute of Mining & Technology, were made at the Paleomagnetics Laboratory at the University of Arizona (UA). At UA, an ScT two-axis cryogenic magnetometer, interfaced with a microprocessor, was used to make magnetization measurements. Demagnetizations were performed using a Schonstedt GSD–5 tumbling-specimen AF demagnetizer. At least one specimen from each sample was stepwise demagnetized fully in 10 mT increments to at least 40 mT. Natural remanent magnetization (NRM) and remaining magnetization after at least one demagnetization (generally 20 mT) were measured for each of the remaining specimens. Fisher statistics were applied to three specimens from each sample to obtain sample mean directions. Since declinations were arbitrary, declination for each specimen was first converted to zero.

Experimental results

Samples from the Raton core were, in general, very weakly magnetized. Typically, NRMs were on the order of a few times 10^{-9} A m^2 (10^{-4} A m^{-1}). Demagnetization to 20 mT generally decreased this by a factor of 2–5. Additionally, the median destructive field (MDF) for these samples was relatively low. MDFs were typically less than 20 mT; many MDFs were less than 10 mT. Usually this lowness indicates that the primary magnetic carrier is magnetite, which is assumed to be detrital. Fig. 3 shows a plot of the inclination of magnetically cleaned specimens as a function of core depth. Also plotted is the mean inclination for each sample. Since a certain degree of scatter was apparent in the data, a set of criteria was developed following Lerbekmo and others (1979). Since the inclination expected for a Cretaceous–Paleocene sample collected from the Raton Basin is approximately 60°, and the inclinations measured for normal-polarity San Juan Basin samples were on the order of 30°–50° (Lindsay and others, 1981), the range of possible inclinations was divided into three segments: $-90°$ to $-30°$ (designated reversed), $-30°$ to $+30°$ (indeterminate), and $+30°$ to $+90°$ (normal). A sample was designated reversed (R) polarity if one or more of its specimens were reversed and none were normal, if two were reversed and one normal, or if there were one specimen in each of the three segments. A sample was designated inde-

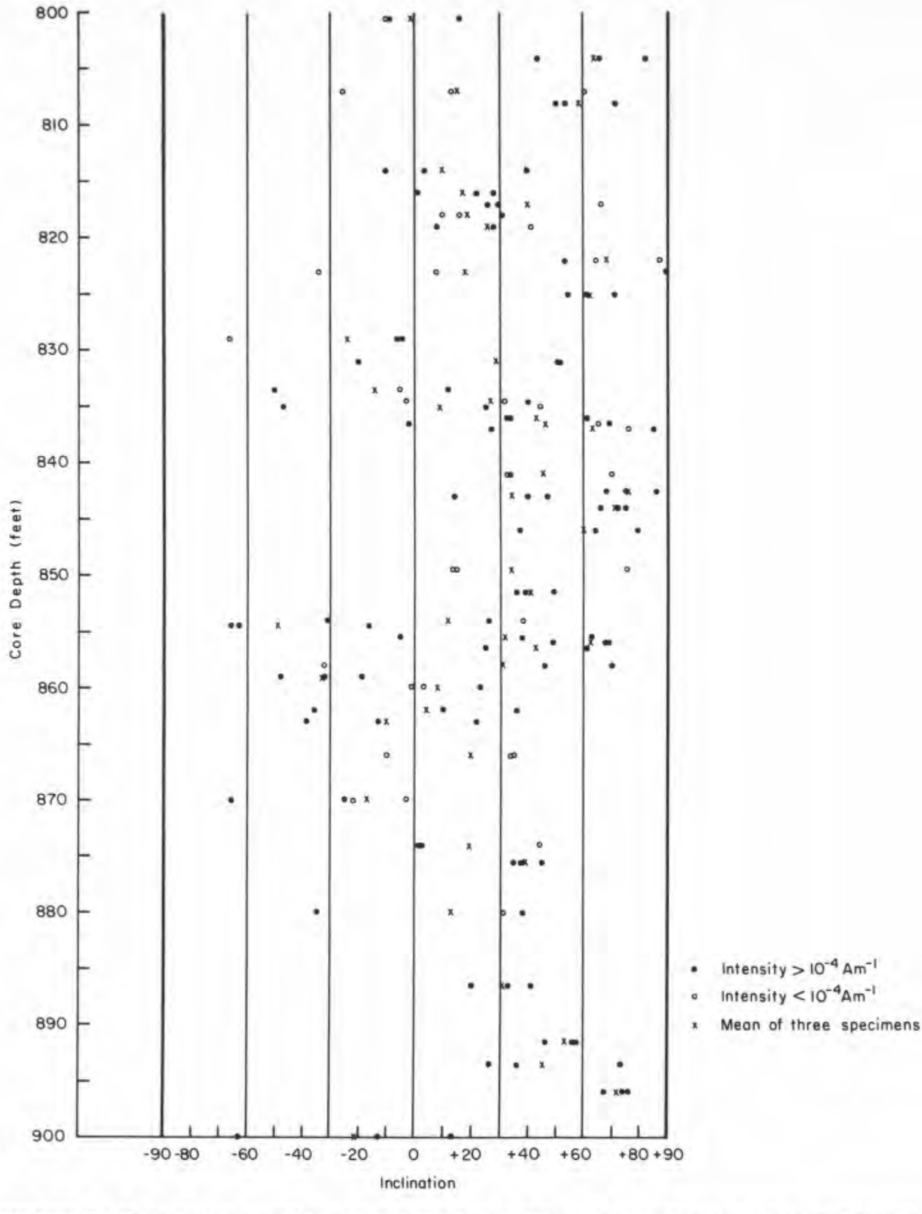

FIGURE 3—PLOT OF INCLINATIONS OF THREE SPECIMENS FROM EACH HORIZON AND MEAN INCLINATION OF EACH AS A FUNCTION OF CORE DEPTH.

terminate (I) if all three specimens were indeterminate, if two were indeterminate and one were normal, or if two were normal and one were reversed. A sample was designated normal (N) if all three specimens were normal or if two were normal and one were indeterminate. This procedure is biased in favor of reversed polarities because it assumes that overprinting is predominantly of a viscous nature acquired in the present Brunhes normal-polarity zone.

Sample behavior upon demagnetization is illustrated by two typical Zijderveld diagrams for: 1) the normal zone that includes the palynologic Cretaceous–Tertiary boundary (fig. 4) and 2) the reversed zone, approximately 6 m below the boundary (fig. 5).

Paleomagnetic zonation

The application of data from studies of geomagnetic field reversals to stratigraphy has been reviewed by Lowrie and Alvarez (1977) and Ness and others (1980). The polarity sequence for the last 4.5 m.y. was established in radiometrically dated volcanic rocks by Cox and others (1963, 1964). Opdyke and others (1966) tied paleomagnetism to deepsea sediments dated by paleontology.

Vine and Mathews (1963) suggested that seafloor magnetic anomalies are related to geomagnetic field reversals. Vine and Wilson (1965) demonstrated that the polarity sequence inferred from marine anomalies supported the observed volcanic sequence. They also employed radiometric ages of reversal boundaries to estimate an average rate of seafloor spreading.

Heirtzler and others (1968) interpreted marine magnetic anomalies from the Pacific, Indian, and Atlantic Oceans and provided a geomagnetic polarity time scale. Anomalies 31 and 32 were the oldest anomalies observed and were included in the Late Cretaceous. The Cretaceous–Tertiary boundary was placed between anomalies 26 and 27. Several subsequent refinements of the Heirtzler polarity time scale have been made (LaBrecque and others, 1977; Ness and others, 1980; Lowrie and Alvarez, 1981). The Late Cretaceous–Early Tertiary magnetostratigraphy of the San Juan Basin has been documented by Butler and others (1977), Lindsay and others (1978), and Lindsay and others (1981). Our paleomagnetic studies in the Raton Basin represent the first paleomagnetic work conducted in the Raton area.

Fig. 2c shows our interpretation of magnetic polarity zonation of the Raton core based on the criteria noted above. The 835–852 in-

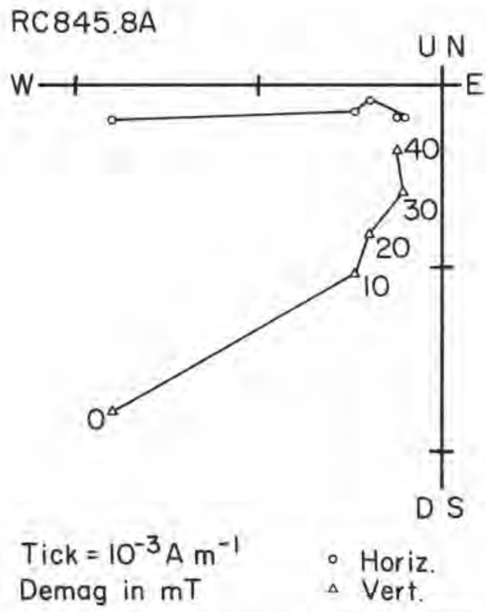

FIGURE 4—ZIJDERVELD DIAGRAM FROM NORMAL ZONE (LEVEL 845.8) THAT INCLUDES PALYNOLOGICAL CRETACEOUS–TERTIARY BOUNDARY.

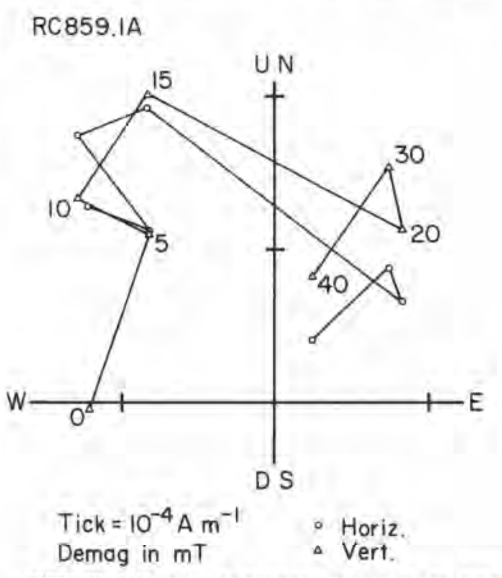

FIGURE 5—ZIJDERVELD DIAGRAM FROM REVERSED ZONE (LEVEL 859.1), APPROXIMATELY 6 M BELOW PALYNOLOGICAL CRETACEOUS–TERTIARY BOUNDARY.

FIGURE 6—EXPOSED SAMPLING RATON PARK, NEW MEXICO; CRETACEOUS–TERTIARY CONTACT IS AT BASE OF COAL.

terval is normal. This interval includes both the palynological Cretaceous–Tertiary boundary and the iridium abundance anomaly reported by Orth and others (1981) as occurring at 839. Within this interval, core data provide good, reliable normal inclinations. These results are verified by data from three surface samples collected from exposures at Raton Park, New Mexico (fig. 6) which also produced well-defined positive inclinations. After the samples were cleaned, measured inclinations for these surface samples were +73.6°, +49.0°, and +61.2° (mean of +61.3°); +32.9°, +39.5°, and +67.0° (mean of +46.4°); and +87.3°, −2.0°, and +26.5° (mean of +36.0°) for the samples 25 cm (10 inches) below, 10 cm (3.9 inches) below, and 75 cm (29.5 inches) above the palynological Cretaceous–Tertiary boundary, respectively.

Based upon palynological data and relative lengths of polarity zones, a tentative zonation for the Raton core has been attempted (fig. 2c). Our current view is that anomaly 28 is represented by the upper normal. The normal interval between 835 and 852 is anomaly 29; anomaly 30 is represented by the normal between 865 and 898. The restricted normal, seen in the interval between 856 and 858, can be correlated to the short normals found by Lerbekmo and others (1979) in the Red Deer Valley of Alberta.

From this interpretation, average sedimentation rate between the base of anomaly 28 and the base of anomaly 30 (a total of 2,130 cm) is 6 mm/1,000 yrs when correlated to the Ness and others (1980) time scale. Uniformity of the average sedimentation rate for each polarity zone is interesting and remarkable. This rate is seen to be 0.5 cm, 0.66 cm, 0.56 cm, and 0.55 cm per 1,000 yrs for the reversed intervals between anomalies 28 and 29, anomaly 29, the reversed interval between anomalies 29 and 30, and anomaly 30, respectively.

A less favored alternative zonation is possible by which the entire core would be within anomaly 29. In this case, minimum sedimentation rate would be about 3.8 cm/1,000 yrs, still a very low rate of sedimentation.

Interestingly enough, this low sedimentation rate may explain in part the lack of fossil vertebrates or invertebrates within the Raton Formation. Preservation of vertebrate material is in part dependent upon relatively rapid burial in order to prevent destruction by scavengers or decay. If sediments are not supplied quickly enough, animal carcasses will be exposed to destructive mechanisms. The lack of shelly invertebrate material in the Raton Formation may in part be a result of low sedimentation rates and low pH values in swampy environments that favored dissolution of calcium-carbonate shells.

Conclusions

Our results demonstrate that in the Raton Basin the Cretaceous–Tertiary palynological boundary and an iridium anomaly both occur within a normal polarity zone. Palynological data make it highly probable that this normal polarity zone is best correlated with magnetic anomaly 29 of the standard sections of Ness and others (1980) or Lowrie and Alvarez (1981). The conclusion that results from this placement is that the Cretaceous–Tertiary boundary is diachronous with respect to terrestrial and marine extinctions.

An anomalously high concentration of iridium without doubt occurs in this normal polarity zone. This is in sharp contrast to other occurrences of high iridium levels documented elsewhere and which occur in a zone of reversed polarity. A number of possibilities exist that would explain this result:

1) More than one iridium anomaly exists in the stratigraphic record.
2) The Raton Basin iridium occurrence is the product of other concentrating mechanisms not related to extraterrestrial impacts.
3) Anomalous iridium occurrences in continental sequences may not be as reliable as occurrences in marine sequences.

In our view, caution should be exercised in evaluating as "anomalous," concentrations of platinum-group metals, especially when related to rock sequences with coals. Nadkarni (1977) reported that National Bureau of Standards (NBS) Coal Standard SRM 1632 yielded an iridium value of 3.53 ± 0.52 ppb. Block and Dams (1975) reported iridium concentrations of 7–9 ppb in Belgian coals. Although Finkelman and Aruscavage (1981) suspected possible contamination of SRM–1632, they document that platinum-group concentrations in coals may be well above crustal averages. High values of platinum-group metals in coal may be a result of solution in fluvial or brackish waters (Stumpfl, 1974) and subsequent precipitation by organic matter (Goldschmidt, 1954). Finkelman and Aruscavage (1981) suggest that platinum-group metals concentration in coal is probably related to rocks in the source area. These rocks could have iridium concentrations as high as 4,300 ppb (Naldrett and Duke, 1980). McLean (1981, 1982) postulates that iridium enhancement in the Cretaceous–Tertiary "boundary" clay is related to volcanic origins and slow sedimentation rates. Increased Laramide volcanic activity would be expected to provide "anomalous"iridium in coal-forming depositional environments in the Raton Basin also with slow sedimentation rates.

Implications for San Juan Basin

Our results from the Raton Basin would tend to confirm data from the San Juan Basin. The Raton Cretaceous–Tertiary palynologic boundary and the San Juan Basin magneto/paleontologic Cretaceous–Tertiary boundary both occur within normal polarity zones. Additional palynologic work adjacent to and at the San Juan Cretaceous–Tertiary boundary magnetozones should yield pollen data to support or refute this line of reasoning.

Lerbekmo and others (1979) established that Cretaceous dinosaurs in the Red Deer Valley of Alberta became extinct within a reversed polarity zone correlated by them with the reversed zone between anomalies 29 and 30. This dinosaur extinction was followed, within a few meters, by a major palynofloral change. Thus, terminal Cretaceous extinctions possibly began earlier in the north than in the south where, as in the Raton and San Juan Basins, a major palynofloral change does not occur prior to magnetic anomaly 29. Similarly, dinosaur extinction may have preceded botanical derangements as indicated by palynologic data.

If the base of anomaly 29 is accepted as the worldwide Cretaceous–Tertiary boundary, as suggested by Lerbekmo and others (1979), or if the Cretaceous–Tertiary boundary is placed somewhat lower, within the 29–30 reversed polarity zone, the palynofloral change seen in the Raton Basin and the extinction of the dinosaurs in the San Juan Basin are Paleocene events. Extinction was not a synchronous, worldwide event. Catastrophic events at or near the Cretaceous–Tertiary boundary, as indicated by iridium abundance anomalies (Alvarez and others, 1980), did not result in the extinction of dinosaurs and Cretaceous floras everywhere.

ACKNOWLEDGMENTS—We thank Dr. Carl Orth, Los Alamos National Laboratories, for providing access to the Raton core and many interesting discussions; Charles Pilmore, U.S. Geological Survey, for field assistance at Raton Park; Dr. Robert Butler, University of Arizona, for his generous cooperation and for providing access to the paleomagnetism laboratory of the University of Arizona; Dr. Everett Lindsay, for his cooperation, suggestions, and frequent discussions; Dr. J. D. Archibald, Yale University, for his comments and suggestions; and Dr. F. E. Kottlowski, Director of the New Mexico Bureau of Mines and Mineral Resources, for his support without which this project could not have been undertaken. We absolve all of the above from any views expressed in this paper.

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Mineral and mineral-fuel production activities in New Mexico during 1981

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New Mexico mineral and mineral-fuel production values soared to an all-time high of 7.24 billion during 1981. This represents a 22% increase in total value over the previous year, but the percentage increase is misleading in that it tends to suggest an overall healthy minerals industry. However, this is not the case because nearly all of the increase was derived from the oil and gas sector.

While oil and gas production have steadily decreased for several yrs (see mineral fuels section), higher energy costs, a result of demand compounded by inflation, have resulted in large increases in dollar value—38% for crude petroleum and 19% for natural gas during the year. Values of commodities produced by the nonfossil fuel sector actually registered a net 8% decrease (table 1). Significant decreases were registered by copper (−14%) and potash (−10%). Coal production also decreased slightly but value was up nearly 32% over the production value for 1980, reflecting an increased demand particularly for steam coal shipped out of state. The coal

TABLE 1—Mineral and mineral-fuel production in New Mexico. Short tons unless noted. **NA**, not available; **XX**, not applicable; **W**, withheld to avoid disclosing individual company data; **P**, preliminary; subject to revision; **R**, revised; —, no production. Data sources: U.S. Bureau of Mines, 1982; U.S. Department of Energy, 1982; Oil Conservation Division, New Mexico Department of Energy and Minerals, personal communication, 1982; Oil and Gas Accounting Division and Property Tax Division, New Mexico Department of Taxation and Revenue, personal communication, 1982; Resource and Development Division, New Mexico Department of Energy and Minerals, personal communication, 1982; and Keystone coal industry manual (1981, 1982).

	1980		1981	
	Quantity	Value (thousand dollars)	Quantity	Value (thousand dollars)
Clays, excluding fireclay (thousand tons)	60	114	64	119
Coal (thousand tons)	19,481	260,037	18,794	342,035
Copper (tons)	164,679	337,328	169,881	289,204
Gem stones	NA	150	NA	200
Gold (troy oz)	15,787	9,670	65,749	30,221
Gypsum (thousand tons)	182	1,688	166	2,256
Manganiferous ore, 5–35% Mn (tons)	35,198R	W	12,741	W
Natural gas (million ft^3)	1,132,316	2,026,846	1,118,589	2,415,033
Natural gas liquids (thousand bbls)	43,003	733,948	53,867	958,837
Peat (tons)	2,000	40	—	—
Perlite (thousand tons)	539	14,404	489	14,983
Petroleum, crude (thousand bbls)	75,324	1,794,210	72,155	2,474,196
Potash (thousand tons)	2,060	289,011	1,765	261,200
Pumice, including cinder (thousand tons)	448	3,028	93	919
Sand and gravel (thousand tons)	7,050	17,676	7,300P	18,000P
Silver (thousand troy oz)	W	W	1,632	17,170
Stone, crushed (thousand tons)	2,217	7,259	4,162	12,485
Stone, dimension (thousand tons)	18	91	26	173
Uranium, recoverable U_3O_8 (thousand lbs)	15,500	371,018	12,420	356,454
Combined barite, CO_2, cement, fireclay, lead, lime, mica, molybdenum, salt, sulfur, vanadium, zinc, and tungsten	XX	87,845	XX	47,747
Totals	XX	5,954,363	XX	7,241,232

TABLE 2—NEW MEXICO PRODUCTION AND NATIONAL RANKING BY COMMODITY. Asterisk (*) denotes percent of total quantity produced, all others percent of total value produced. W, withheld to avoid disclosing individual company data. Sources: U.S. Bureau of Mines, personal communication, 1983; U.S. Department of Energy, personal communication, 1983.

Mineral commodity	1980 Rank of New Mexico	1980 Number of states producing	1980 Percent of total	1981 Rank of New Mexico	1981 Number of states producing	1981 Percent of total
Uranium	1	9	35	1	9	32
Perlite	1	7	87	1	7	83
Potash	1	3	82	1	3	83
Natural carbon dioxide	2	4	W	2	4	W
Manganese ores	2	3	20*	3	14	10
Copper	3	10	13	3	14	10
Pumice	3	5	20	3	8	19
Molybdenum	4	5	W	4	5	W
Natural gas	4	31	5.8*	4	31	5.6*
Natural gas liquids	4	21	7.9*	4	17	7.3*
Vanadium	5	5	W	5	6	W
Silver	7	13	W	8	20	4
Gold	7	11	2	5	14	5
Crude petroleum	7	31	2.3*	7	31	2.3*

industry was one of the few "bright spots" in the state's overall mining picture.

New Mexico continued to lead the nation in the production of uranium, perlite, and potash and was the third largest producer of copper and pumice. Gold production in the state rose to fifth place nationally, primarily as a result of Gold Fields, Ltd. operation at Cerrillos. However, for most commodities, New Mexico's share of total production is gradually decreasing (table 2).

Mineral fuels

OIL AND GAS

New Mexico oil production for 1981 decreased by 4.2% (3.1 million bbls) from 1980 production (table 3). The southeast part of New Mexico produced 5.7% or 3.9 million bbls less oil than in 1980, while the northwest part of the state produced 13.3% or 0.81 million bbls more oil than in 1980. Natural-gas production in New Mexico decreased by

TABLE 3—OIL AND GAS PRODUCTION, 1981. Source: Oil Conservation Division, New Mexico Department of Energy and Minerals, personal communication, 1982.

County and area	Crude oil (bbls) Production	Crude oil (bbls) Gain (+) or decline (−) from 1980	Natural gas (thousands ft³) Production	Natural gas (thousands ft³) Gain (+) or decline (−) from 1980
Chaves	2,487,797	+329,559	18,771,155	+7,190,216
Eddy	12,362,798	−3,633,349	221,274,411	+6,752,290
Lea	48,946,382	−588,678	315,160,737	−20,668,406
Roosevelt	1,431,849	−90,938	4,203,182	+182,719
Southeast totals	65,228,826	−3,983,406	559,409,485	−6,543,181
McKinley	846,768	−65,285	74,114	−7,721
Rio Arriba	2,478,822	+388,479	176,575,545	−6,617,477
Sandoval	537,714	+168,715	2,885,722	+656,834
San Juan	3,062,887	+322,849	379,643,721	−1,216,112
Northwest totals	6,926,191	+814,758	559,179,102	−7,184,476
State totals	72,155,017	−3,168,648	1,118,588,587	−13,727,657

1.21% or 13.7 billion ft³. A decline of 1.16% or 6.5 billion ft³ in natural-gas production was posted in southeast New Mexico, and production decreased by 7.2 billion ft or 1.27% in northwest New Mexico. The state ranked seventh in the nation in crude-oil production and fourth in natural-gas production.

In 1981 exploratory drilling and the rates of success in New Mexico increased over 1980 levels (table 4). The 294 wildcats drilled in 1981 had a success rate of 53.4% compared with 292 wildcats and a success rate of 48.6% in 1980. Slightly higher activity was reported in northwest New Mexico than in the southeast areas of the state in comparison to 1980.

TABLE 4—DRILLING STATISTICS FOR 1980 AND 1981 (American Petroleum Institute, 1981, 1982).

	1980	1981
Wildcats drilled	292	294
Southeast	207	193
Northwest	85	101
Oil	44	72
Southeast	35	42
Northwest	9	30
Gas	98	85
Southeast	73	58
Northwest	25	27
Success rate (percent)	48.6	53.4
Southeast	52.2	51.8
Northwest	40.0	56.4
New-field wildcats drilled	225	195
Southeast	172	142
Northwest	53	53
Oil	24	32
Southeast	22	22
Northwest	2	10
Gas	64	41
Southeast	58	34
Northwest	6	7
Success rate (percent)	39.1	37.4
Southeast	46.5	39.4
Northwest	15.1	32.1
Development wells drilled	1,643	2,077
Southeast	821	1,005
Northwest	822	1,072
Oil	627	752
Southeast	501	575
Northwest	126	177
Gas	898	1,161
Southeast	228	310
Northwest	670	851
Success rate (percent)	92.8	92.1
Southeast	88.8	88.1
Northwest	96.8	95.9

New-field wildcats, the best indicators of ıe level of exploration activity, posted decreases in the number of wells drilled and the percentage of discoveries. In 1981, 195 new-field wildcats were drilled with a success rate of 37.4% compared to the 225 wildcats drilled in 1980 with 39.1% discoveries.

Primary exploration targets in northwest New Mexico were sandstone reservoirs of Cretaceous age. Decreasing demand for natural gas caused some operators to shift from gas to oil exploration (Stevenson and Hayte, 1982). In southeast New Mexico, exploration continued at a high rate for gas in the Morrow in southern Eddy and Lea Counties (fig. 1) and for Abo dry gas in the shallow backreef area of northern Chaves County. Several discoveries from sandstone stratigraphic traps in the Abo were reported (Gaines and others, 1982).

The total number of development wells drilled in 1981 was 2,077; 752 produced oil and 1,161 produced natural gas, resulting in an overall success rate of 92.1%. The 1,005 development wells drilled in the southeast area represent a 22.4% increase over 1980, and the 1,072 wells drilled in the northwest area represent an increase of 30.4%. Development-well success rates were 88.1% in the southeast and 95.9% in the northwest. Development continued at a rapid rate in the Morrow trend of Eddy and Lea Counties and in the Abo trend of northern Chaves County. Infill, development, and step-out drilling in the natural-gas fields of northwest New Mexico slowed, not withstanding the fact that

FIGURE 1—AN IMPRESSIVE LINEUP OF HYDROFRACTURING EQUIPMENT IS ASSEMBLED AT A YATES GAS WELL 5 MI SOUTH OF ARTESIA, NEW MEXICO. Petroleum Recovery Research Center photo, courtesy of Dave Martin.

the San Juan Basin was the most active area in the Rocky Mountains.

Development of the Bravo Dome Carbon Dioxide Unit continued with the drilling of 60 wells in Harding County and 78 wells in Union County. The completed wells are shut in pending the completion of the pipe line to west Texas.

The addition to proved oil reserves in New Mexico from new-field discoveries was approximately 2 million bbls, which is equal to the 1980 contribution (table 5). Extensions of old reserves and discovery of new ones in old fields added an additional 15 million bbls to proved oil reserves, a decrease of 6.2% from the total proved oil reserves in 1980.

Contributions to proved natural-gas reserves from new-field discoveries increased 73.5% from the 1980 level to 118 billion ft³. Extension of existing reservoirs and discovery of new ones in old fields added 908 billion ft³, an increase of 27.5% over 1980.

Once again, production of crude oil and natural gas exceeded discoveries in 1981. However, the net effect of corrections, adjustments, and revisions of previously reported reserve figures was an approximate 1.5% increase in New Mexico's proved crude-oil reserves to approximately 555 million bbls and an increase of 4.4% in natural-gas reserves to approximately 13.87 trillion ft³.

TABLE 5—CONTRIBUTIONS TO PROVED RESERVES FROM DISCOVERIES IN 1980 AND 1981 (U.S. Department of Energy, 1982).

	1980	1981
Added new-field proved oil reserves (million 42-gal bbls)	2	2
Added oil-field extensions and new reservoirs proved oil reserves (million 42-gal bbls)	16	15
Added new-field proved natural-gas reserves (billion ft³)	68	118
Added old-field extensions and new reservoirs proved natural-gas reserves (billion ft³)	712	908
Total proved oil reserves (million 42-gal bbls)	547	555
Total proved natural-gas reserves (billion ft³)	13,287	13,870

COAL

Coal production declined slightly in 1981 to just under 19 million short tons although value rose 32% to $345 million. This disparity is accounted for in part by a 5% overall decrease in mine mouth usage and a 6% overall increase in steam coal shipped out of the state. The latter is generally produced at the newer mines and is thus sold at significantly higher prices than that consumed in mine-mouth power plants (at generally older and lower contract prices). Decreased production from the largest mines accounted for most of the decrease. Eight surface and two underground mines were active during the year (table 6).

TABLE 6—NEW MEXICO INDIVIDUAL COAL-MINE PRODUCTION. **U**, underground; all others, surface; **NA**, not available; **—**, no production. Sources: Keystone coal industry manual, 1982; New Mexico Energy and Minerals Department, personal communication, 1982.

Mine	Owner	Production (short tons) 1980	1981
Potato Canyon (U)	Kaiser Steel Corp.	5,505	27,878
York Canyon (U)	Kaiser Steel Corp.	900,000	763,000
West York Canyon	Kaiser Steel Corp.	600,000	510,000
McKinley	Pittsburg & Midway Coal Co.	4,658,154	4,936,900
Navajo	Utah International, Inc.	7,733,000	6,845,000
San Juan	San Juan Coal Co.	4,538,000	4,119,000
Burnham	Consolidation Coal Co.	39,652	48,000
De Na Zin	Sunbelt Mining Co., Inc.	13,177	211,145
Amcoal	Amcoal, Inc.	93,907	—
Mentmore	Carbon Coal Co.	973,980	NA
Arroyo No.1	A. J. Firchau	15,748	NA
	Total	19,480,820	18,793,666

Additionally five mines, Gallo Wash mine (Alamito Coal Co.), Black Diamond mine (Black Diamond Coal Co.), South Hospah mine (Chaco Energy), Lee Ranch mine (Santa Fe Coal Corp.), and La Plata mine (Western Coal Co.), had permits to operate but were not active. Operation of the South Hospah mine is dependent upon completion of the Star Lake Railroad and thus is not likely to begin operation soon. The other four are expected to begin operations during 1982 (New Mexico Energy and Minerals Department, written communication, 1981).

The average price of New Mexico coal during 1981 was $18.20 per ton, approximately 30% below the national average. Price in the state ranged from $10.27 to $44.42 per ton (Gretchen Roybal, personal communication, 1983).

Metallics

COPPER

Copper is New Mexico's number one metallic commodity. Since the record high value of production of over $337 million in 1980, however, the performance of copper has been "all down hill." The price of copper at the beginning of 1981 was just over $.90 per lb, barely above break-even price for many U.S. producers. From that time on, the price trend was a rather steady decrease to just under $.80 per lb by December 1981. This price level spelled trouble for New Mexico's mines. In an effort to cope with the situation, producers moved to curtail production by extended vacations, summer shutdowns, and layoffs. Production of copper began to taper off toward the year end, but near peak production during the first half of the year actually resulted in a slight overall increase to 170 thousand tons over the 1980 total of 165 thousand tons.

Early in March 1981, Sharon Steel Corporation, the number three copper producer in the state, began a series of layoffs that culminated in complete shutdown by January 1982. Sharon Steel, not surprisingly, reported a loss from its copper operations for the year (Sharon Steel Corp., 1982, p. 3).

Phelps Dodge extended its normal two-week summer shutdown to three weeks and imposed an additional 9-day furlough over the Christmas holiday season. These changes resulted in a combined production decrease of 26,000 tons of copper from the Tyrone and Morenci operations.

Chino Mines Company tried to maintain business as usual but finally announced at year end that layoffs were imminent early in 1982. The firm also reported a loss for 1981 (Standard Oil Co., 1982, p. 10). The Kennecott–Mitsubishi partnership (Chino Mines Company) became final in March 1981. For its one-third interest, the Japanese firm invested an initial $116 million and will contribute one-third of any excess amount incurred in Chino's modernization program. In return Mitsubishi will receive one-third of Chino's production. The $350-million program will include a new slurry pipeline for the delivery of concentrates to the smelter, a new concentrator near Santa Rita, and certain smelter modifications. Bechtel Corporation was awarded the contract for both design and construction of the concentrator. The new facilities should allow Chino to increase copper production by 60–70% (to 110,000 tons per year) while lowering costs per lb by 20 to 30 cents.

Fast on the heels of the Kennecott–Mitsubishi agreement, Sohio (Standard Oil Company of Ohio) rocked the domestic mining world with its announced takeover of Kennecott Corporation. Stockholders quickly approved the $1.77 billion merger which became final early in June 1981. Why would Kennecott, successful on its own at Chino since the 1930's, suddenly merge not once, but twice, with other corporations? Kennecott is faced with massive capital outlays both within the state and at other divisions for improvements and/or new milling and smelting plants that are projected to cost billions of dollars. Unlike copper, of which Kennecott has a surplus, cash is a scarce commodity. Thus, with the exception of Mitsubishi Corporation's one-third ownership of Chino, Sohio owns the mine.

Phelps Dodge Corporation was planning the construction of a new solvent extraction electro-winning plant at Tyrone and intended to let a contract late in 1981. The continued depressed market, however, apparently forced at least a temporary postponement. In addition to the new Tyrone plant, the firm will be expanding its El Paso, Texas, refinery. Eventual plans call for full recovery of all precious metals and other concentrates contained in Tyrone at the El Paso refinery. Currently slimes from the copper-refining process are shipped to another firm in New Jersey for processing (Phelps Dodge Corp., 1982, p. 7).

The company was hard at work during the first six months of 1981 cleaning up the tailings spilled in October 1980 along Mangas Creek. Phelps Dodge did an admirable job in reclaiming the area; approximately 1½ ft of topsoil was spread on the reclaimed ground followed by a liberal application of mulch and fertilizer. Reseeding was completed early in July 1981. Weather favored the project with heavier than average rainfall and the reclaimed area had produced a fine stand of grass by the end of the year.

Quintana Minerals vigorously pushed the construction of mine and mill at its Copper Flat project near Hillsboro, New Mexico. M. M. Sundt of Tucson, Arizona, is the general contractor. Everything was said to be on schedule and Quintana planned mill startup by early 1981 despite the dismal copper and molybdenum market situation.

Exxon Minerals announced in the early part of 1981 that they were pulling the pin on their Pinos Altos property after having invested some $11 million in exploration and development over the past 10 yrs. The property has proved reserves of 7 million metric tons grading 5% combined copper and zinc. While geologic evidence suggests additional possible reserves, the orebody is apparently not large enough for Exxon to mine it. Dozens of firms interested in purchase toured the property; late in 1981, the field had narrowed to two companies, both foreign. An operational arrangement appears to be more interesting to Exxon than an outright sale. In either case, Exxon is likely to retain a royalty interest on any possible production.

In another corporate merger, the largest in United States' history at $7.54 billion, Conoco was absorbed by the E. I. DuPont de Nemours Company in August 1981. Conoco has both base-metal and uranium holdings in New Mexico. What effect the merger will have on the development of these properties remains to be seen because DuPont is not a mining company. Conoco drilled their Jones Hill prospect near Terrero during the year but at a lesser pace, thus only six holes were completed. No announcements have been made by Conoco regarding size and grade of the deposit.

Anaconda was active in the Picuris district in Taos County; results, however, were said to be discouraging. Santa Fe Industries was considering an exploration program on Federal Resources' Lordsburg properties, idle since 1976.

LEAD/ZINC

Early in 1981, Asarco (American Smelting and Refining Co.) was looking for a partner in a possible joint venture at the Groundhog mine at Vanadium. Sale of the property also was considered. No satisfactory partnership or buy offers were tendered and Asarco closed the mine permanently during August, pulling the pumps and retrieving usable equipment.

Only small amounts of lead and zinc were produced during the year—all from the Steeple Rock district in western Grant County.

GOLD/SILVER

For many years most of New Mexico's precious-metal production has resulted from the mining of copper. However, a new primary gold producer, the Ortiz mine of Gold Fields Ltd., came on stream during 1981. When at full production, this mine will produce approximately 750,000 tons of ore per yr. During the part of 1981 that the mine was in operation, 27,035 oz of gold were produced, making the Ortiz New Mexico's largest gold producer (Gold Fields Ltd., 1981, p. 9).

Few people are aware that Tyrone is the state's largest silver producer; the mine is ranked eleventh in the nation, producing 1,211,896 oz during 1981 (Engineering and Mining Journal, 1982, p. 15). The Phelps Dodge property also produces a substantial amount of gold, sharing the Grant County production spotlight with Sharon Steel's Continental mine at Fierro. (Chino usually produces no precious-metal byproducts because its copper is generally not electrolytically refined.)

Goldfield Corporation (not to be confused with Gold Fields Ltd.) pushed development of their St. Cloud property in the Black Range district near Chloride. The firm has disclosed the discovery of 377,000 tons of reserves grading 11.4 oz silver and .03 oz gold per ton and a combined 4.6% copper, lead, and zinc (no payment made for the latter two). The ore, when developed, is to be shipped to the company's San Pedro mill near Golden, New Mexico. The mine is being developed with trackless diesel equipment (fig. 2). The

FIGURE 2—TRACKLESS DIESEL (L.H.D.) EQUIPMENT AT GOLDFIELD CORPORATION'S ST. CLOUD MINE NEAR CHLORIDE, SIERRA COUNTY, NEW MEXICO. The $-13^1/_4\%$ decline (just out of view to right) was collared September 1, 1981. New Mexico Bureau of Mines and Mineral Resources photo, courtesy of JoAnne Cima Osburn.

portal of the $-13^1/_4\%$ incline was collared September 1, 1981, and the vein was intersected 20 days later. Development will continue through early 1982; silver production for 1982 is projected at more than $^1/_2$ million oz (Goldfield Corporation, 1982), at which point Goldfield will become the state's number two producer of silver.

New Cinch Uranium Corporation completed hole no. 50 in February 1981 at their Orogrande prospect. Mineralization, although low in grade, is said to be fairly widespread. Gold averages .04–.05 oz per ton. The possibility of using cyanide heap-leaching techniques is still being investigated.

Exploration for precious metals was conducted, in varying degrees, in the Georgetown, Hopewell, Cerrillos, Hermosa, Hillsboro, Winston–Chloride, Gold Hill, and Pinos Altos districts.

MOLYBDENUM

This metal, like copper, suffered a dismal year economically. Three-fourths of molybdenum production goes to the iron and steel industry (U.S. Bureau of Mines, 1982). Because auto and construction industries were in recession, supplies greatly exceeded demand. This is reflected in the selling price which dropped twice in 1981 from \$9.70 per lb contained molybdenum to \$8.50 per lb by December. Worse, the spot (noncontract) price which had attained record highs of more than \$30/lb during 1979, fell below \$5.00 per lb by October 1981.

Despite the market situation, development of Union Oil/Molycorp's underground mine near Questa remained on schedule. Connection between service and development shafts was made in August 1981. The mill was scheduled for shutdown during the same month for renovation and improvement. Stripping of overburden began in February 1981 to develop approximately 3 million tons of ore which will be used to feed the mill after renovation and prior to the underground mine coming on stream early in 1983. Molybdenum production showed a drastic 51% decrease to 1,832,000 lb MoS_2 because of closure of the mill August 14, 1981, and falling grade as the last of the surface ore was mined (Union Oil Company of California [Molycorp], 1982, p. 38). Mining operations in the pit terminated on August 25, 1981.

The company has suffered more than its share of tailings spills, the latest of which occurred March 9, 1981. Because of topography, the firm's tailings disposal line runs along Red River and a fish hatchery downstream is particularly vulnerable to spills. As part of the renovation, a new tailings line is being constructed on the north side of NM–38, opposite the river (Union 76–Molycorp, 1981); the new location is hoped to effectively prevent tailings from entering the river.

The occurrence of widespread molybdenum mineralization in the South Fork Peak area approximately 10 mi south-southeast of Questa and possibly indicative of a "Questa-type" deposit was disclosed by the U.S. Geological Survey (Engineering and Mining Journal, 1981).

URANIUM

The uranium industry experienced one of the worst years (if not the worst) in its history and was marked by numerous mine closures and massive layoffs. Most distressing, the future held little prospect for immediate improvement. The continued slack in demand was brought about primarily for three reasons: environmental concerns of nuclear power safety and waste handling, subsequent delays or postponements of planned nuclear power plants, and perhaps most important, a world oversupply of yellowcake. Much of this surplus uranium is produced by "foreign" companies in South Africa, Australia, and Canada from higher grade deposits and without costly environmental controls. Their production costs are low enough that American mines cannot compete. The average selling price for uranium in 1981 was approximately $29.00 per lb, while average domestic mining and milling costs totaled approximately $40 per lb (U.S. Department of Energy, 1981, p. 80).

This disparity in price took its toll on the American uranium industry; producing mines were reduced in number to just 27 at the end of 1981, down from the already reduced 45 mines in 1980 (Hatchell and Wentz, 1982, p. 64, 65). Production in 1981 was down 20% from that of 1980 to 12.4 million lbs although dollar-value decreased just 4% during the same period reflecting the price improvement from the lower to upper $20 per lb range. However, the price improvement along with a severance tax reduction passed early in 1981 by the State legislature was not enough to help many New Mexico producers.

Bleak market projections also adversely affected exploratory drilling which was down 67% to just 1.51 million ft, the lowest rate in over 13 yrs (McLemore, 1983).

Perhaps the most startling news came with Anaconda's decision to close the historic Jackpile mine at the end of February 1982. Anaconda had earlier announced that operations would be phased out gradually during 1983, but market conditions were actually worse than anticipated. Approximately 800 employees at the mine and Bluewater mill were affected. Approximately 50 employees were retained for maintenance and security purposes.

Sohio Western closed its L–Bar mill in May for an indefinite period. The 1,500 ton-per-day facility obtained only part of its feed processing toll ore. The recent loss of toll-ore contracts as a result of mine closures reduced the daily feed to below peak efficiency thus forcing closure of the mill. The mine, however, is to continue in production, stockpiling ore for the future when prices may improve and new toll contracts are obtained.

Development of two underground mine projects in the Crownpoint area, Conoco and Phillips, was halted during the year. Additionally, Gulf Mineral Resources reduced its work force by 100 at Mount Taylor late in 1981. No shutdown plans were announced at Gulf but that company is doubtless feeling the economic pinch also. The Mount Taylor deposit is one of the largest known uranium deposits in North America with about 22% of known low-cost U.S. reserves (128 million lb U_3O_8). Development costs are high, however, because the deposits are more than 3,000 ft deep (Engineering and Mining Journal, 1981).

Two companies, Mobil and Exxon, still were considering plans for in situ mining of uranium near Crownpoint during 1981. In situ U_3O_8 is less costly to produce than uranium mined by conventional methods, but this process is still in the pilot-plant stage. Mobil was awaiting approval from the state engineer in June 1981. By April 1981 Exxon had decided to hold off on development of the project until the market situation improved. However, such improvement may take some time. According to predictions by the Department of Energy, no significant increase in demand for uranium will be seen until at least 1987.

Nonmetallics

Potash

Demand for potash was expected to remain high during 1981 and sales were up for the first six months as compared to the previous year. Sales turned sour in the last half of the year, however, resulting in an estimated 3% decrease in total production. Duval Corporation summed up the situation as accurately as possible: "The fertilizer market continues to be depressed because of continued high interest rates and low farm commodity prices. . . . Improvement in this picture is necessarily tied to an upturn in the farm economy both nationally and worldwide" (Pennzoil, 1982, p. 18).

At least part of the decrease, however, was due to a temporary shutdown by Amax, New Mexico's largest producer of potash, because of a fire in the mill. The mine was forced to close a few days later because of the ever-growing stockpile of ore.

Mergers and takeovers, commonplace in the metals industry, also have occurred in potash. Freeport Minerals Company announced in April that it had purchased the National Potash Company. National Potash Company was forced, late in 1981, to lay off approximately one-fourth of its work force in an effort to reduce inventory.

Other nonmetallics

Perlite production in 1981 was down 14% mainly because of the depressed housing in-

FIGURE 3—GENERAL REFRACTORIES COMPANY (GREFCO) PERLITE PLANT AT NO AGUA NEAR TRES PIEDRAS, TAOS COUNTY, NEW MEXICO; GREFCO operates a similar plant near Socorro, New Mexico. New Mexico Bureau of Mines and Mineral Resources photo, courtesy of George S. Austin.

dustry. Two firms in the Tres Piedras area, Manville and Grefco Corp., laid off part of their workforce beginning in August 1981 and continued layoffs through early 1982 (fig. 3).

Barite of America, in addition to producing mud-grade barite at its plant near Deming, had been custom milling 100 tons per day of lead silver ore during the early part of 1981. Western General Resources (Minopco) continued construction on their barite–lead–fluorspar mill at Hansonburg. Severe design problems became apparent, however, during a test run late in 1981.

Mathis and Mathis, operators of a lime kiln near Hanover in Grant County, lost their Phelps Dodge lime contract in 1981. The quarry remained in limited operation during the year producing crushed stone. The company hopes to negotiate a new contract with Kennecott when the Chino renovation is complete.

Western Gypsum closed their Rosario mine and plant in Santa Fe County in May 1981.

New scoria production from a deposit at Cerrito Pelado 10 mi west of Santa Fe may be forthcoming. U.S. government officials met in February 1981 to discuss sales, mining, and management of the deposit because scoria is a salable commodity and is not locatable under the general mining laws.

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Coal geology studies by New Mexico Bureau of Mines and Mineral Resources

by Gretchen H. Roybal, *Coal Geologist*, with introduction by Frank E. Kottlowski, *Director*, New Mexico Bureau of Mines and Mineral Resources

The New Mexico Bureau of Mines and Mineral Resources (NMBM&MR) has been involved in study of coal deposits in New Mexico, emphasizing various facets of stratigraphy, depositional environments of the sediments, coal resources, and economics of coal production, for most of the 55-yr life of NMBM&MR. Study of coal deposits was often incidental to the mapping and description of geology and mineral deposits of particular quadrangles. Major specific projects to report on coal stratigraphy and coal resources began in 1968 with the cooperative project, funded by the U.S. Environmental Improvement Agency, on the strippable coal resources of the San Juan Basin area, northwest New Mexico. Prior to that , NMBM&MR had monitored coal production and coal exploration with short articles reporting on the coal activities and summary articles for the Keystone Coal Industry Manual.

The present program of NMBM&MR is to work specifically in coal-bearing areas, mainly those for which a relatively small amount of previous data is available, such as west-central New Mexico. We cooperate with the U.S. Geological Survey and with the New Mexico Energy and Minerals Department, Mining and Minerals Division, in various coal projects and in monitoring of production, exploration, planning, and various research efforts. We have been involved with the U.S. Bureau of Land Management on the San Juan River Basin Coal Lease Team, as a legal entity on the New Mexico Coal Surface Mining Commission, and on various ad hoc committees and studies dealing with coal resources of the state. Active project work is concentrated at present in west-central New Mexico in the Fence Lake–Salt Lake coal field, Datil Mountains coal field, and the Zuni and southern Gallup coal field areas. In addition, we are supporting theses investigations and are doing reconnaissance work in essentially all of the other coal areas of the state with some emphasis on the Engle, Carthage, Jornada, Sierra Blanca, and Raton coal areas as well as most parts of the San Juan Basin coal region.

Our goal is to develop coal-stratigraphy and coal-resource data to be of aid to companies in exploring for and in producing coal for the various purposes that New Mexico's coal seams are useful. In addition, our environmental geologists and hydrogeologists are doing base studies which should help in reclamation of surface-mined lands, particularly in some of the areas that have not been strip mined as yet. The New Mexico Energy and Minerals Department, Mining and Minerals Division, collects the official statistics for coal production, and we cooperate with them in coal-reserve and coal-resource compilations.

As part of the Energy Resources Map of New Mexico, compiled in cooperation with the U.S. Geological Survey (USGS map I–1327, 1981), coal areas were plotted as were major active and abandoned coal mines. The most recent phase of our coal effort has been to assist in the Abandoned Mine Lands Program in which NMBM&MR provided the first preliminary inventory of abandoned coal mines and uranium mines in the state; this is the basic data being used by the Abandoned Mine Lands Section of the New Mexico Surface Mining Bureau of EMD in their reclamation efforts. Data concerning abandoned mines of all types, but with emphasis on coal mines, is made available from our AML Technical Information, Resources, and Service Center which has recently been set up as part of our facilities in Socorro. The Center already contains a considerable number of maps, reports, and various other types of data relating to coal mining in the state, but including all other types of mines. The center is being developed to make available to the AML Program and to all interested geologists, engineers, and private citizens, comprehensive files on geology, mineral resources, and mines, both active and abandoned, in New Mexico. Funding is chiefly from the U.S. Office of Surface Mining, via a cooperative grant to the New Mexico EMD's Mining and Minerals Division.

Coal data available

Under a matching contract with the U.S. Geological Survey (USGS) for the National Coal Resource Data System (NCRDS), a large amount of coal data (mainly point-source) has been collected and entered into the computerized NCRDS system, as well as into the computer at New Mexico Tech and the minicomputer at the NMBM&MR. Besides data for coal-resource calculation and coal-quality analyses, other types of material such as production figures for New Mexico are available. The following is a listing of coal information available to the public from NMBM&MR upon request to Gretchen Roybal and Frank Campbell.

COAL PRODUCTION—Three files with coal production figures for New Mexico are available. One file contains data from the U.S. Bureau of Mines Minerals Yearbooks for 1899 to 1977. These production figures are generally given by county and are compiled for a yearly state production figure. The U.S. Department of Energy (DOE) has reported coal production figures for the states from 1977 to the present. This data file has coal production for New Mexico and the United States for comparison on a yearly, and more recently, a monthly basis. The other file contains production figures from the State Mine Inspectors' reports from 1899 to 1932. This file has information on particular mines in operation during this time and includes production figures for those mines. This file can be searched on an individual mine basis.

COAL QUALITY ANALYSES—A file containing proximate, ultimate, and Btu analyses results has been compiled from published sources and from coal projects done at NMBM&MR. These coal analyses are limited to mine samples and samples from drilling; outcrop analyses are not included. From this file information for maximum, minimum, and standard deviation of the coal analyses parameters in a particular coal field or formation is available. The number of samples for each part of an analyses suite is specified to indicate how representative this compilation is of the area parameter chosen. Another file contains the data available on trace-element analyses for New Mexico coals. This data is based primarily on data from USGS coal laboratories. The type of information that can be obtained from this file is in the same statistical format that is used for the other quality analyses data file.

COAL RESOURCES—Coal-resource calculations are based on a compilation of point-source data from coal fields and formations in New Mexico. Coal-resource information can be defined by stripping ratios, depth categories, and minimum coal thicknesses. For a coal field or formation, the measured and indicated resources are reported in million tons with the average coal thickness and depth indicated. At the present time, coal partings also are dealt with to a limited extent for calculating resources.

GEOPHYSICAL LOG DATA—This file is a listing of geophysical logs from coal drilling done by NMBM&MR. The location of the drill hole and formation(s) drilled through along with coal thickness and depths are listed.

These information files are being updated continuously in conjunction with the NCRDS project and other coal projects at the NMBM&MR. Other programs are being developed to further delineate the coal beds in New Mexico.

Recent coal projects

Recent work in coal areas at the New Mexico Bureau of Mines and Mineral Resources has been mainly in the Datil Mountains and Salt Lake coal fields in west-central New Mexico. Joint investigations with the U.S. Geological Survey Branch of Coal Resources in the Salt Lake field began in 1978. The three staff coal geologists working in the Salt Lake area at present are Orin Anderson, Frank Campbell, and Gretchen Roybal.

The Salt Lake coal field is defined as the Mesaverde Group outcrop on the state geologic map (Dane and Bachman, 1965), south of the Bandera lava flow, and west of the Continental Divide extending to the Arizona border. The latest Cretaceous coal-bearing rocks of the Salt Lake area are defined as the Moreno Hill Formation by McLellan and others (1983). The Dakota Sandstone also occurs in this field with a few thin coals of poor quality visible in outcrop.

The Datil Mountains coal field is east of the Salt Lake coal field and in the upper drainage basin of Rio Salado between Riley on the east and Hickman on the west. The coal-bearing units of the Datil Mountains are in the lower part of the Mesaverde Group in the Gallup Sandstone and Crevasse Canyon Formation. JoAnne Osburn is working in the main Datil Mountains coal field area and Frank Campbell is working on the western edge of the field at present.

Quadrangles in which detailed mapping and coal-resource investigations have been carried out thus far by Orin Anderson are the Cantaralo Spring, Venadito Camp, and Atarque Lake quadrangles in the northwest part of the Salt Lake coal field. The Cantaralo Spring quadrangle (Anderson, 1981) encompasses the northwest end of the Zuni Plateau and contains outcrops of the Moreno Hill Formation and Dakota Sandstone coal-bearing Cretaceous units. The Venadito Camp quadrangle includes a small part of the Salt Lake coal field north of the basalt flow with outcrops of the coal-bearing Moreno Hill Formation (Anderson, 1982c). The Atarque Lake quadrangle is on the northern edge of the Salt Lake coal field with outcrops of the lower Moreno Hill Formation in the southwest corner of the quadrangle, bounded on the north by Triassic rocks and on the south by the Bandera lava flow.

In recent months, Anderson has been continuing coal resource investigations north and east of the Salt Lake coal field, into the Gallup–Zuni coal field. Investigations of the Mesita de Yeso quadrangle (Anderson, 1982a) and Shoemaker Canyon SE as a joint project with U.S. Geological Survey have been completed (Anderson and Mapel, 1983), and mapping and coal-resource evaluation in the Upper Gallestina Canyon and Plumasano Basin quadrangles in cooperation with the U.S. Geological Survey is in progress. Orin Anderson is involved in the compilation of the 1:100,000 geologic map of the Fence Lake area with Frank Campbell.

Frank Campbell has been mapping and overseeing the coal drilling for the past three years in the Salt Lake coal field, especially for the Cerro Prieto and The Dyke quadrangles. The compilation of the geology and coal resources of this area are in the NMBM&MR Open-file Report 144 (Campbell, 1981). From this geologic mapping and from mapping by the USGS and Orin Anderson, Gretchen Roybal and Campbell are compiling the Fence Lake 1:50,000 geologic map. This area is the southwest quarter of the 1:100,000 Fence Lake quadrangle being compiled jointly with Anderson.

A report on the Salt Lake field (NMBM&MR Open-file Report 145) evaluating the coal resources and subsurface stratigraphy in the area was co-authored by Gretchen Roybal and Frank Campbell (Roybal and Campbell, 1981). At the present time Frank Campbell and Gretchen Roybal are revising the Bureau's Resource Map 10 (Tabet and Frost, 1978) on the coal fields of New Mexico. Work is being done cooperatively by Frank Campbell, Gretchen Roybal, Frank Kottlowski, Fred Kuellmer (New Mexico Tech), Edward Beaumont (Albuquerque), Arthur Cohen and others (Los Alamos National Laboratory), and Eric Nuttall and Frank Williams (University of New Mexico) on coal quality of coals in New Mexico funded by the New Mexico Energy Research and Development Institute and NMBM&MR. Cores will be obtained from drilling beginning in the San Juan Basin for the analyses for this project.

A coal analytical laboratory has been developed by Frank Campbell with Nancy Blount as technician; this lab has the capabilities of running proximate, ultimate, and Btu analyses and is being expanded to handle sample analyses for the coal quality project supported by NMERDI. Campbell is also helping Gretchen Roybal with development of a computerized data base of coal information.

JoAnne Osburn has been working for three years in the Datil Mountains coal field region. She has mapped the Pueblo Viejo Mesa quadrangle in the central Datil coal field on a grant from the USGS Conservation Division, compiling the geology and coal potential of the area. With this quadrangle and two adjacent quadrangles (Table Mountain and Indian Spring Canyon), Osburn did a compilation geologic map for the central Datil Mountains coal field with an evaluation of coal potential and coal quality from 20 drill holes (Osburn, 1982a). Aided by a grant from the USGS Coal Branch, Osburn did a compilation map as part of a mineral resource study for the Bureau of Indian Affairs on the Alamo Reservation, northwest of Magdalena. The detailed geologic map was included in Open-file Report 160 (Osburn, 1982b) which included coal-resource potential and coal-quality information for the Alamo Reservation. Osburn also wrote an article for *New Mexico Geology* from the Alamo report (Osburn, 1983).

At present Osburn is completing a geologic map on Pasture Canyon in the Datil Mountains area emphasizing the coal resources and has mapped most of the adjoining Wildhorse Canyon quadrangle. As a by-product of these projects, she is investigating the regional correlations and depositional environments of the Crevasse Canyon Formation in the central Datil Mountains area, using both surface and subsurface data acquired in previous studies.

Gretchen Roybal is primarily involved in evaluating point-source coal data for New Mexico for the USGS cooperative project of the National Coal Resource Data System (NCRDS). This project includes collecting data for calculating resources and determining the quality of coals throughout New Mexico and involves developing a computerized data base of coal information for the New Mexico Bureau of Mines and Mineral Resources.

In addition to the coal-data project, Roybal has mapped the Tejana Mesa quadrangle in the southeast corner of the Salt Lake coal field with emphasis on the coal-bearing Cretaceous units and coal potential in the area (Roybal, 1982). The report includes results of NMBM&MR's coal drilling in the area. She is mapping the Lake Armijo quadrangle to the west of Tejana Mesa for further delineation of the coal-bearing Cretaceous units and, with Frank Campbell, compilation of Cretaceous outcrops is being done for the Quemado 1:100,000 quadrangle, in cooperation with USGS.

Roybal, with Frank Campbell and Frank Kottlowski, and with Lewis Martinez and Kay Hatton of the New Mexico Mining and Minerals Division of EMD, has co-authored the annual Keystone Coal Industry Manual article on New Mexico. Roybal also is involved in the coal-quality project funded by NMERDI.

Donald Wolberg, NMBM&MR vertebrate paleontologist, is involved in studies of stratigraphy, depositional environments, and paleontology of the Fruitland–Kirtland formations in the Bisti, De-Na-Zin and Ah-She-Sle-Pah badlands areas. Much of this work has been done with Adrian Hunt, New Mexico Tech graduate student, J. Hartman, molluscan paleontologist, and Coleman Robison, paleobotanist.

Wolberg has done a paleontological inventory of federal lands for the De-Na-Zin project for Sunbelt Mining and was one of the main participants in formulating a paleontology–coal mitigation plan for the State of New Mexico. He also has served as an alternate on the New Mexico Coal Surface-Mining Commission.

David Love, John Hawley, and T. C. Hobbs (1981) described alluvial valley floors in strippable coal areas of New Mexico, a cooperative project with New Mexico Energy and Minerals Department. In addition, Love and Hawley are involved in several base-line studies for coal areas of New Mexico, including the geomorphology of the Chaco River basin, by David Love and Steve Wells; a study of the runoff-sediment transport in the Puerco Basin, which is pertinent to the Torreon Wash region and the La Ventana coal field, by Love; and a compilation map of surficial deposits in New Mexico, by Hawley and Love.

Drilling program at NMBM&MR

For the past five years, NMBM&MR's drilling program principally has involved coal studies. The main drill rig used is a Failing C–15 with stem to drill to 1,000 ft and the capability to go to 1,500 ft. The rig has a core barrel for coal and soft sediments that is able to take a 10-ft core, 3 inches in diameter. The drill rig and support vehicles are operated and maintained by a three-man crew, generally working from April to December.

Over the course of the drilling program, stratigraphic coal-test holes have been drilled in the San Juan Basin, in the Engle coal field near Truth or Consequences, in the Jornada del Muerto field southeast of Socorro, and in the Datil Mountains and Salt Lake–Fence Lake coal areas west to the Arizona border. Generally, coal tests are to depths less than 300 ft and are a part of the NMBM&MR's study to determine the strippable coals in New Mexico. Drill cuttings are sampled every 5 ft for study by the geologists; holes are logged with geophysical probes to obtain logs pertinent to coal. These geophysical logs help to determine coal thickness and the lithology of the surrounding rock. With cuttings, along with cores and logs, as much information as possible is obtained from drilling.

The NMBM&MR drilling rig does not compete with private industry for coal projects but is merely used for stratigraphic tests involving coal and only in situations where the locations are pertinent to aid our coal studies.

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Financial statement

New Mexico Bureau of Mines and Mineral Resources
July 1, 1981 to June 30, 1982

Funds available			
Beginning balance July 1, 1981		$ 674	
State appropriation		1,785,400	
Publication receipts		50,829	
Reimbursements		22,388	$1,859,291
Expenditures			
Salaries:			
Scientists and engineers	$741,986		
Support staff	191,359		
Part-time staff (students)	97,936	$1,031,281	
Employee benefits		153,937	
Project contracts		140,097	
Travel & vehicles		68,621	
Scientific laboratories:			
Maintenance	$ 17,385		
Materials & supplies	33,177	$ 50,562	
Office supplies		11,436	
Postage & freight		12,150	
Printing		182,057	
Equipment		48,619	
General expenses:			
Telephone	$ 21,727		
Subscriptions & dues	4,052		
Computer service	10,111		
Overhead & audit	80,700		
Heat, water, electricity	33,740	$ 150,330	$1,849,090
Balance June 30, 1982			$ 10,201
Grants and contracts	$628,641		