A Preliminary Mineral-Resource Potential of Western Rio Arriba County, Northwestern New Mexico

by

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PREFACE

During the spring, 1985, the U.S. Bureau of Land Management (BLM) and the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) entered a cooperative agreement to prepare a preliminary mineral-resource inventory and assessment of northwestern New Mexico, including Valencia, Cibola, McKinley, San Juan, and western Rio Arriba Counties. This is the last of six reports describing the geology and mineral-resource potential of northwestern New Mexico. The first report describes the methodology and classification of mineral-resource potential used in this report and includes a summary of the mineral-resource potential of western Rio Arriba County.

These reports are based upon time consuming analyses of all available data, published and unpublished, by a group of geologists and technical support staff. Without this team effort this project would be impossible. In addition to the coauthors of the final report, many other people at the NMBMMR and BLM provided assistance, especially in reviewing the rough drafts.

This report is organized into a text, appendices (volume 2), and supporting figures, maps (scale 1:100,000), and tables. Known mineral occurrences, mines, and deposits, including material pits, are briefly described in Appendix 1 and plotted on 1:100,000 scale maps. Mineral-resource potential of various commodities is discussed in the text and also shown on 1:100,000 scale maps.

ABSTRACT

A preliminary mineral-resource potential assessment of western Rio Arriba County involves analyses of available published and unpublished geologic, geochemical, geophysical, and economic data and a brief reconnaissance. Mineral-resource potential is an assessment of the favorability that a commodity will occur in substantial concentrations in a given area that can be exploited under current or future economic conditions. A classification of high, moderate, low, very low, or unknown is assigned. A high mineral-resource potential exists in areas where geologic and economic data indicate an excellent probability that economic mineral deposits occur there. Moderate or low mineral-resource potential exists in areas where the data indicate a lesser probability that economic mineral deposits occur. A classification of very low potential is reserved for areas where sufficient information indicates that an area is unfavorable for economic deposits. A classification of unknown mineral-resource potential is assigned to areas where either necessary geologic, geochemical, geophysical, and economic data are inadequate to otherwise classify an area or where any other classification (high, moderate, low, or very low) would be misleading. Some areas have not been evaluated for specific commodities because of lack of useable data.

Oil and gas are currently being produced in western Rio Arriba County and the resource potential is high in Cretaceous, Jurassic, and upper Paleozoic rocks. Clay in the Mesa Prieta area has a moderate resource potential. There is a high resource

potential for crushed and dimension stone throughout the entire area. Limestone resource potential is high in the Todilto Limestone in southeastern Rio Arriba County.

A moderate resource potential exists for copper and silver in the Chinle Formation in the Nacimiento Mountains, deep coal in the Menefee and Fruitland Formations in the San Juan Basin, CO_2 and helium in the San Juan Basin, and limestone in the Madera Formation. An unknown resource potential exists for silica sand, zeolites, and barite.

Additional geologic mapping and geochemcial studies are required in areas with active claims, areas of aggregate resources, and along the Kirtland-Fruitland contact for barium resource potential. Isopach facies and structure-contour maps and additional petroleum tests are suggested to enhance evaluation of the petroleum resources. Detailed studies of the mineralogy and chemistry of clay deposits are required to fully assess their potential.

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INTRODUCTION

Purpose and Scope

The Federal Land Policy and Management Act (FLPMA) of 1976 charges the U.S. Bureau of Land Management (BLM) with responsibility for preparing a mineral-resource inventory and assessment of mineral-resource potential for all of the public lands they manage. These studies are essential to land-use planning and management and they are required prior to BLM actions such as disposal, withdrawal, exchange, or conveyance of land and wilderness designations. In order to meet this statutory requirement, the BLM and the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) entered a cooperative agreement to prepare a preliminary mineral-resource inventory and assessment for northwestern New Mexico, including Valencia, Cibola, McKinley, San Juan, and western Rio Arriba Counties (Fig. 1). NMBMMR staff were already actively involved with compilations and geologic studies of various commodities on all lands within New Mexico, so the requirements of both agencies were satisfied. McLemore (1984) and McLemore et al. (1984) previously evaluated the mineral-resource potential of Torrance County and Sandoval and Bernalillo Counties and adjacent parts of McKinley, Cibola, and Santa Fe Counties (Fig. 1).

This preliminary mineral-resource inventory and assessment is based on analysis of available published and unpublished geologic, geochemical, geophysical, and economic data and brief field reconnaissance as described by McLemore (1985) and McLemore et al. (1986a). A more rigorous and complete analysis of all available information and additional field work could expand the

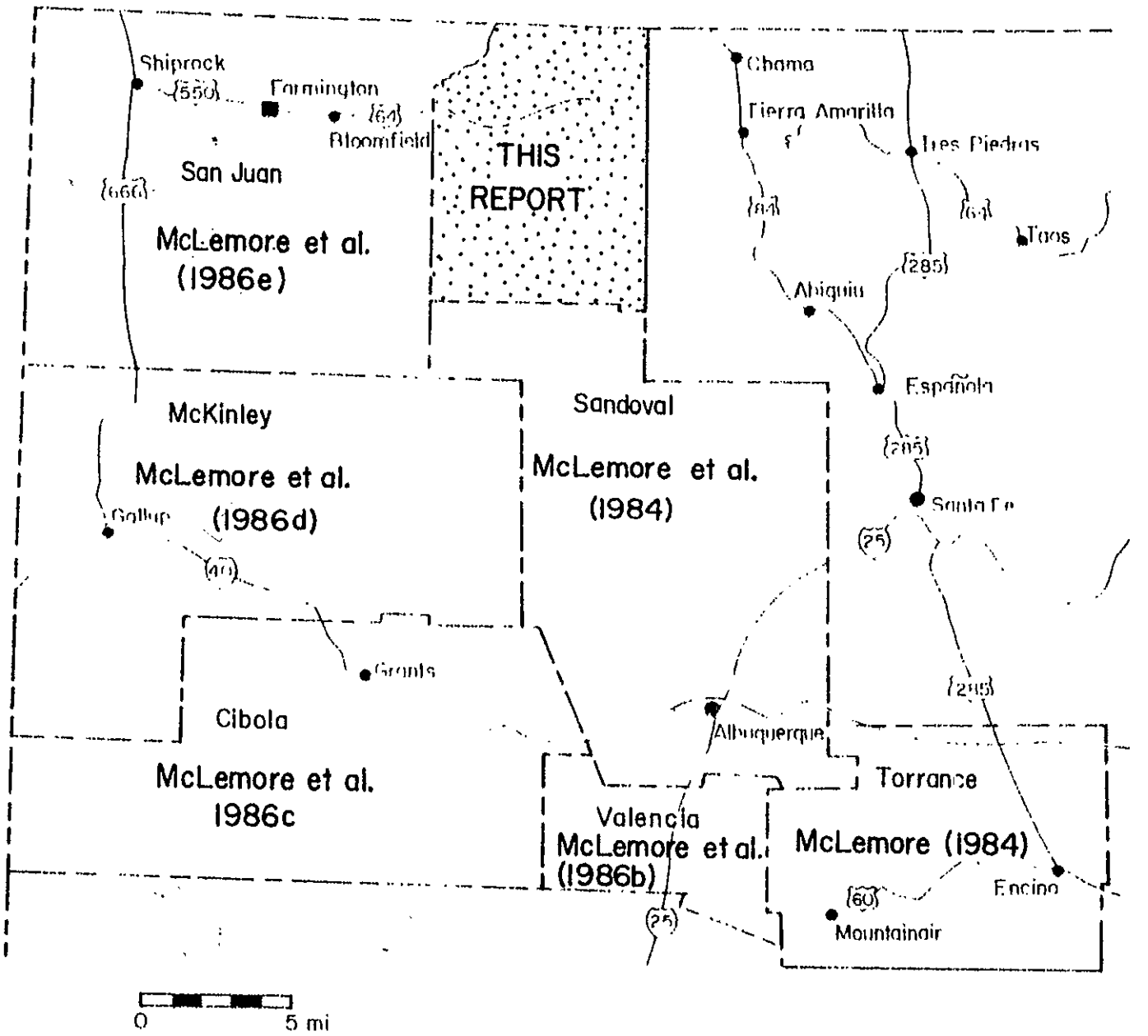


Figure 1. Areas assessed by New Mexico Bureau of Mines and Mineral Resources.

preliminary conclusions of this report.

This report is organized into a text, appendices, and supporting figures, maps, and tables. Known mineral occurrences, prospects, deposits, and mines, incuding material pits, are briefly described in Appendix 1 and generally described by deposit type in the text. Petroleum tests are tabulated in Appendix 2. Coal reserves, resources, and coal quality data are tabulated in Appendix 3. They are plotted on 1:100,000-scale maps; Figure 2 is an index to 1:100,000-scale topographic maps covering western Rio Arriba County. Mineral-resource potential of various commodities is discussed in the text and also shown on 1:100,000-scale maps.

Definitions

Mineral resources are the naturally occurring concentrations of materials (solid, gas, or liquid) in or on the earth's crust that can be extracted economically under current or foreseeable future economic conditions. Reports describing mineral resources vary from simple inventories of known mineral deposits to detailed, geologic investigations.

A mineral occurrence is any locality where a useful mineral or material occurs. A mineral prospect is any occurrence that has been developed by underground or above ground techniques or by subsurface drilling. These two terms do not have any resource or economic implications. A mineral deposit is a sufficiently large concentration of a valuable or useful mineral or material that may be extracted under current or future economic conditions. A mine is any prospect which produced or is

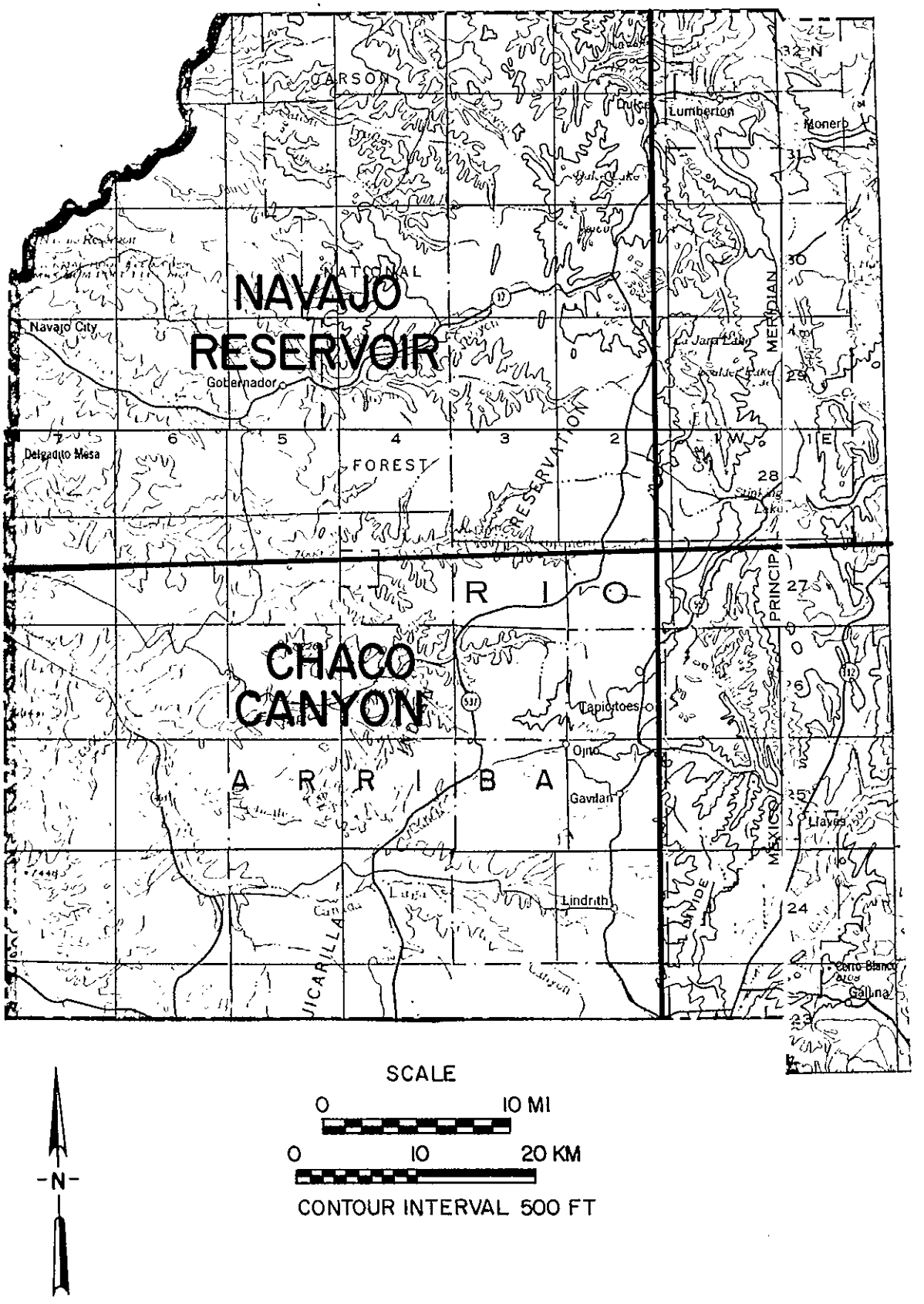


Figure 2. 1:100,000 scale topographic maps covering western Rio Arriba County, New Mexico.

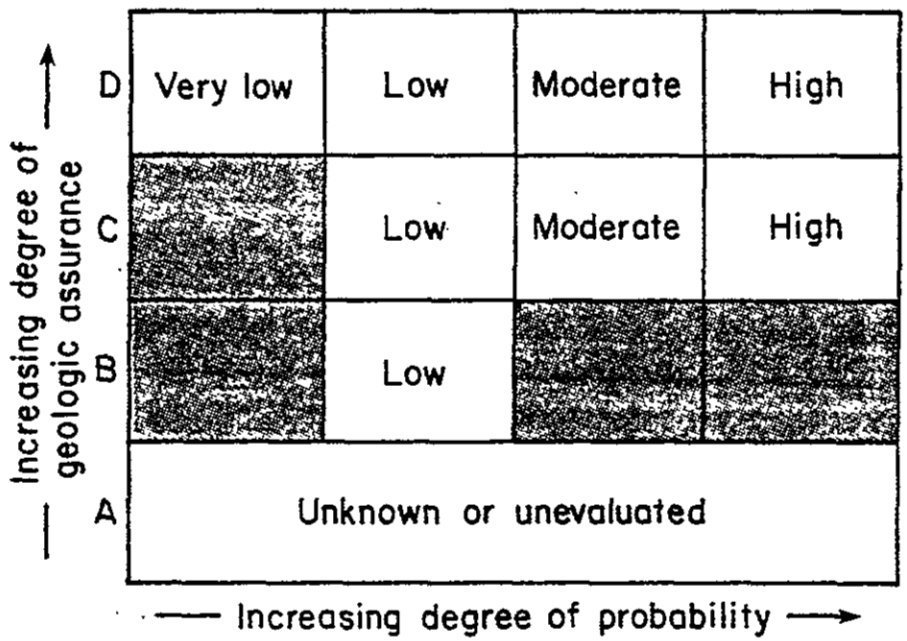


Figure 3–Classification of mineral-resource potential (modified from Taylor and others, 1984 and Goudarzi, 1984). A–D represent four levels of geologic assurance.

currently producing a useful mineral or material.

The mineral-resource potential of an area is the likelihood or probability that a mineral will occur in sufficient quantities so that it can be extracted economically under current or future conditions (Taylor and Steven, 1983). Mineral-resource potential is preferred in describing an area whereas mineral-resource favorability is used in describing a specific rock type or geologic environment (Goudarzi, 1984). The mineral-resource potential is not a measure of the quantities of the mineral resources, but is a measure of the potential of occurrence. Factors that could preclude development of the resources, such as the feasibility of extracting the minerals; land ownership; accessibility of the minerals, or cost of exploration, development, production, processing, or marketing, are not considered in assessing the resource potential; although these factors certainly affect the economics of extraction. Total evaluation of mineral-resource potential involves a complete understanding of the known and undiscovered mineral resources in a given area.

Classification of Mineral-Resource Potential

A simple subjective classification of mineral-resource potential is used for the purposes of this report. The potential is simply classified according to availability of geologic data and relative probability of occurrence as high, moderate, low, very low, or unknown (Fig. 3). More detailed descriptions of this classification scheme and evaluation process are by McLemore (1985) and McLemore et al. (1986a).

A high mineral-resource potential is assigned to areas where there are known mines or deposits or where the geologic, geochemical, or geophysical data indicate an excellent probability that mineral deposits occur. A moderate mineral-resource potential exists in areas where data suggest a reasonable possibility that undiscovered deposits occur in formations or geologic settings known to contain economic deposits in similar geologic settings elsewhere. A moderate to low mineral-resource potential exists in areas where data suggest a reasonable possibility that undiscovered mineralization occurs in an area, but the potential is not as good as moderate. Low mineral-resource potential exists in areas where available data imply the occurrence of mineralization, but indicate a low possibility for the occurrence of a deposit. A classification of very low mineral-resource potential is reserved for areas where sufficient information indicates that an area is unfavorable for economic deposits. Use of the very low classification requires a high level of geologic assurrance.

A classification of unknown mineral-resource potential is reserved for areas where necessary geologic, geochemical, and geophysical data are inadequate to otherwise classify an area. This assessment is assigned to areas where the degree of geologic assurance is low and any other classification (high, moderate, low, or very low) would be misleading. These areas should receive high priority for additional study.

The mineral-resource potential of some areas can not be assessed because of lack of useful data. Detailed geologic mapping at a scale of 1:24,000 may be required before the

mineral-resource potential can be assessed. The lack of data does not imply a very low mineral-resource potential. The difference between an unknown resource potential and unevaluated area is that some data exists in an area of unknown resource potential which implies the possiblity of the occurrence of resources.

In addition to evaluation of the mineral-resource potential, the potential for development is assessed. The potential for development is classified simply as high, moderate, or low and takes into account such factors as grade, tonnage, current market conditions, and status, and similar economic factors. High potential for development indicates that the area is currently producing a commodity or economic conditions suggest that production of the deposit is economically feasible currently or in the near future. Moderate potential for development exists in areas where production of the deposit would occur if certain geologic or economic conditions became favorable. Low potential for development indicates only a slight possibility, if any, for production of the deposit. The potential for development classification is also a highly subjective judgment, but it does offer an evaluation of the economic feasibility of an area.

Previous Geologic Investigations

The geology of western Rio Arriba County is described as part of numerous regional geologic reports on the Colorado Plateau. Many of these reports are cited where appropriate. Much of the county is covered by geologic maps of various scales

(Figs. 4, 5). Two state geologic maps and one regional map (Dane and Bachman, 1957, 1965; New Mexico Geological Society and NMBMMR, 1983) also include western Rio Arriba County. Geologic mapping at 1:250,000 scale of the Aztec 1- by 2-degree quadrangle is by NURE (National Uranium Resource Evaluation).

Specific reports describing the mineral resources in Rio Arriba County are numerous, especially concerning petroleum, uranium, and coal resources. The best source describing all mineral resources in New Mexico is a compilation prepared by the U.S. Geological Survey (1965) in cooperation with various state and federal government agencies. Various reports on uranium resources include Anderson (1957), Siemers and Austin (1979a, b), U.S. Geological Survey and NMBMMR (1981), Anderson (1981), and McLemore, V. T. (1983). Schilling (1975) and McLemore, V. T. (1983) include bibliographies of additional citations concerning uranium resources. Various reports on coal resources include numerous geologic maps (Figs. 4, 5), Shomaker et al. (1971), U.S. Geological Survey and NMBMMR (1981), and Nickelson (in press). Other mineral reports include Jones (1904), Talmage and Wootton (1937), Bieberman and Weber (1969), Foster and Grant (1974), Logsdon (1982), Austin (1982), Barker et al. (1984), and North and McLemore (1984, 1986). Additional commodity reports concerning this area are cited where appropriate. Production statistics are from various file data, U.S. Geological Survey (1903-1931), U.S. Bureau of Mines (1932-1984), and New Mexico State Mine Inspector (1903-1983). A leaseable mineral-land classification map has been prepared by DeCicco et al. (1978). As part of the U.S. Department of Energy's NURE, much of western

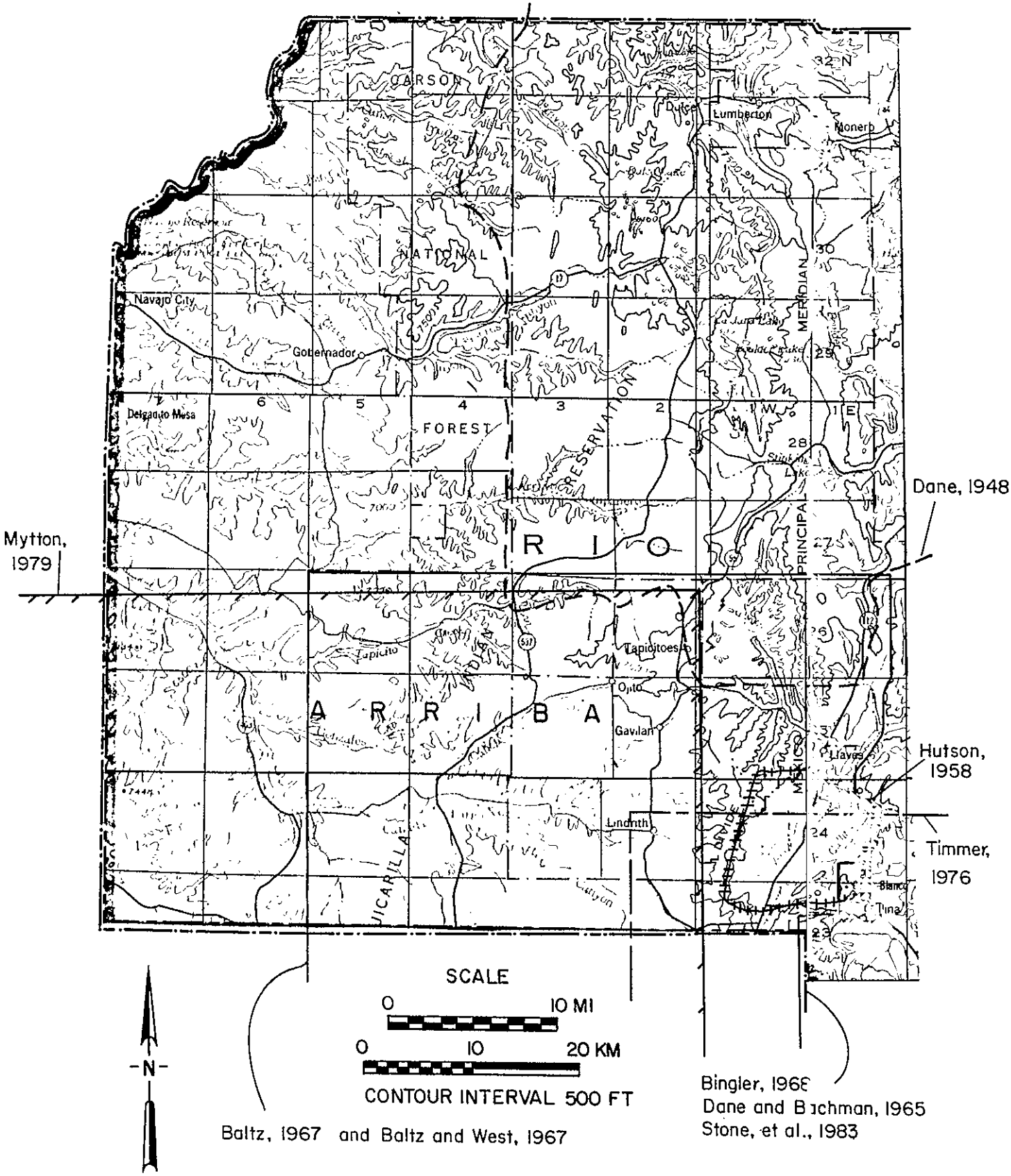


Figure 4. Index of geologic mapping at scales smaller than 1:24,000.

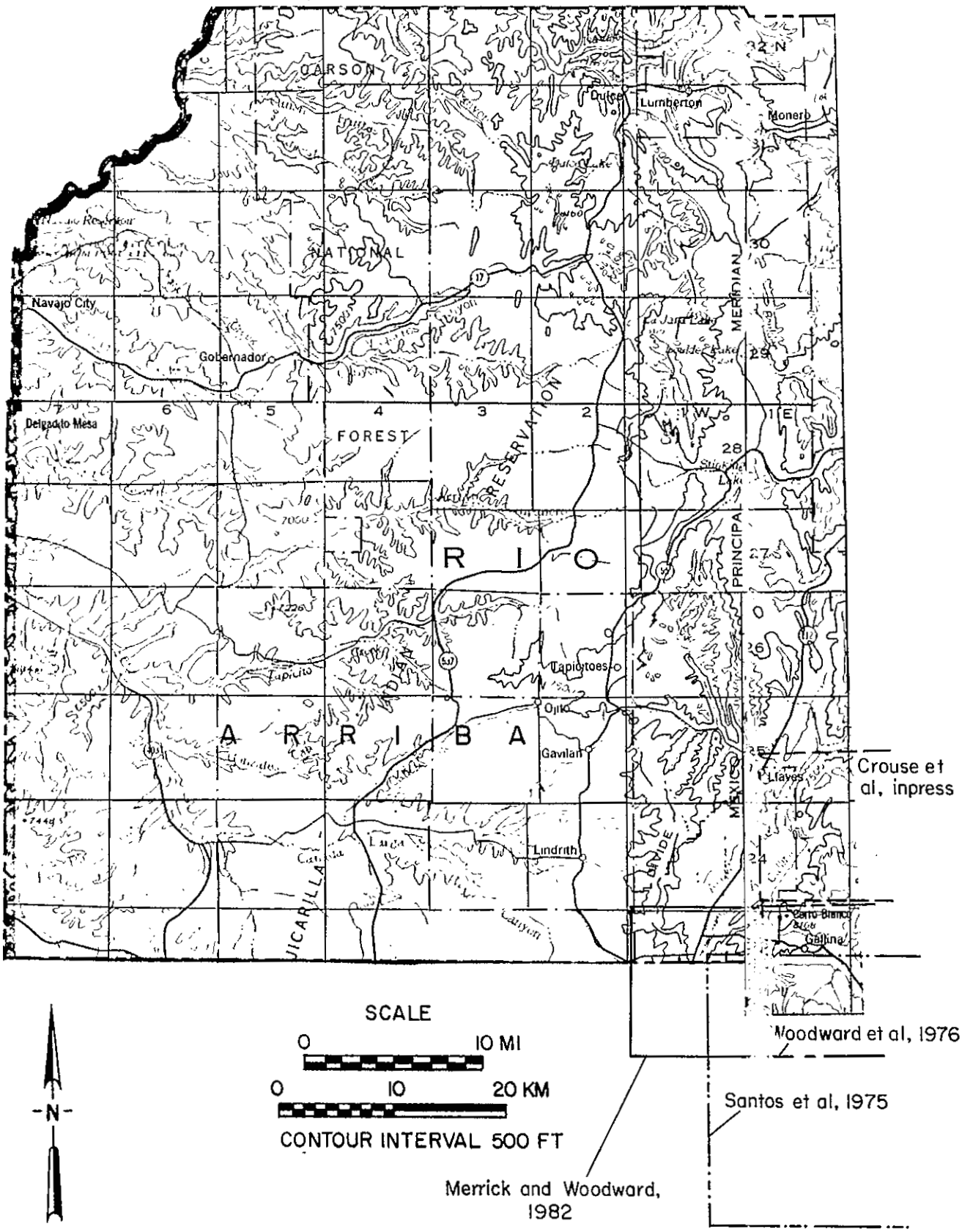


Figure 5. Index of geologic mapping at a scale of 1:24,000.

Rio Arriba County was examined (Green et al., 1982a, b).

Acknowledgments

This project was completed under a cooperative agreement between the Bureau of Land Management (BLM) and the NMBMMR. The coordinators for the BLM include Henry Wilson, William Jonas, Carl Yost, and Pat Hester who provided some of the data needed to evaluate the mineral-resource potential. Warren Bennett, New Mexico State Highway Department, provided data on aggregate resources. Many people on the NMBMMR staff in addition to the coauthors assisted greatly in preparing this report. Lynn Brandvold and associates provided chemical analyses. Cherie Pelletier, Cindie Salisbury, Kris Klein, and Lori Baker drafted most of the figures and Lynne McNeil typed the manuscript. This manuscript benefited from critical reviews by George Austin, Sam Thompson, Robert Bieberman, Pat Hester, and Robert North. Finally, Brian Christiansen, Kris Klein, Linda Frank, Karen Brown, Jose Manrique, Kent Anderson, Shawn Leppert, and Lori Baker assisted in copying, proofreading, compiling the bibliography, compiling the mineral occurrences, compiling the geochemical anomaly maps, and compiling the index to geologic mapping.

PHYSIOGRAPHY AND GEOLOGY

(by V. T. McLemore, R. F. Broadhead, and G. Roybal)

Western Rio Arriba County lies in the Colorado Plateau physiographic province and is dominated by the San Juan Basin. Lithologic units range from Paleozoic to Recent (Fig. 6) and many of the stratigraphic intervals contain mineral deposits (Table 1). A brief synopsis of the stratigraphy and history follows; for more detailed information the reader is referred to the references cited.

Paleozoic Stratigraphy

(by R. F. Broadhead)

The oldest rocks exposed in northwest New Mexico are Paleozoic and belong to the Ignacio Formation (Cambrian; Fig. 7). The Ignacio occurs in western San Juan County as erosional remnants in block-faulted grabens (Stevenson and Baars, 1977). It has a maximum thickness of 100 ft. The Ignacio consists of friable to well-indurated, quartzose sandstones with local shale lenses. It is a transgressive marine deposit.

The Aneth Formation (Devonian) unconformably overlies the Ignacio Formation (Fig. 7). Where the Ignacio has been removed by erosion, the Aneth Formation rests unconformably on Precambrian basement. The Aneth occurs in western San Juan County as erosional remnants in grabens (similar to the occurrence of the Ignacio Formation; Stevenson and Baars, 1977). It has a maximum thickness of approximately 75 ft. The Aneth Formation consists of dark resinous limestones, argillaceous dolostones, black shales, and dark siltstones. It is a basal

TABLE 1 - Stratigraphic units and associated economic commodities in Rio Arriba.

Age	Unit or Formation	Description	Potential economic commodities present
Quaternary	alluvium and eolian deposits	unconsolidated sand and silt	sand and gravel
	terrace and pediment deposits	surficial veneer of poorly consolidated gravel and sand	sand and gravel
Tertiary	intrusive igneous rocks	a series of dikes (northeast) and plugs (west) of lamphophyre and associated alkalic rocks.	gravel
	Chuska Sandstone	light brown to white crossbedded eolian sandstone	crushed and dimension stone
	San Jose Formation	massive sandstone and conglomeratic sandstone interbedded with shale	sand
Tertiary-Cretaceous	Nacimiento Formation, Ojo Alamo Sandstone, and Animas Formation	shale interbedded with medium to fine grained sandstone and conglomeratic sandstone	petroleum
Cretaceous	Kirtland Shale and Fruitland Formation	shale, fine grained sandstone, and coal	coal, petroleum, uranium
	Pictured Cliffs Sandstone	tan crossbedded to massive fine- to medium-grained sandstone	petroleum
	Lewis Shale	dark gray shale with concretionary limestone beds and sandstone (unit is not always present)	
	Cliff House Sandstone	tan to gray crossbedded sandstone with minor interbedded shale	clay, crushed and dimension
	Menefee Formation Point Lookout Sandstone	alternating beds of tan and brown sandstone and gray shale	petroleum, coal
	Mancos Shale	light to dark gray marine shale with subordinate fine grained sandstone, siltstone, and bedded or concretionary limestone	petroleum
	Dakota Sandstone	tan sandstone and conglomeratic sandstone with lenses of shale and coal	petroleum
Jurassic	Morrison Formation	fluvial and floodplain deposits with minor lacustrine and eolian deposits consisting of alternating shale, sandstone, conglomeratic sandstone, and siltstone	uranium
	Summerville Formation	claystone, siltstone, and sandstone	
	Todilto Formation	thin bedded limestone with minor sandy intervals in lower part, thick gypsum deposits in center of basin	building stone
	Entrada Sandstone	reddish-brown, fine- to medium-grained crossbedded eolian sandstone	petroleum
Triassic	Chinle Formation		uranium
	-----	sandstone, carbonates, and shales	petroleum, CO_2, He
Permian	Cutler Formation	sandstones, shales, and carbonates	uranium
Pennsylvanian, Mississippian, and Devonian	-----	sandstone carbonates shales	
Precambrian	-----	granite, metamorphic rocks	mica

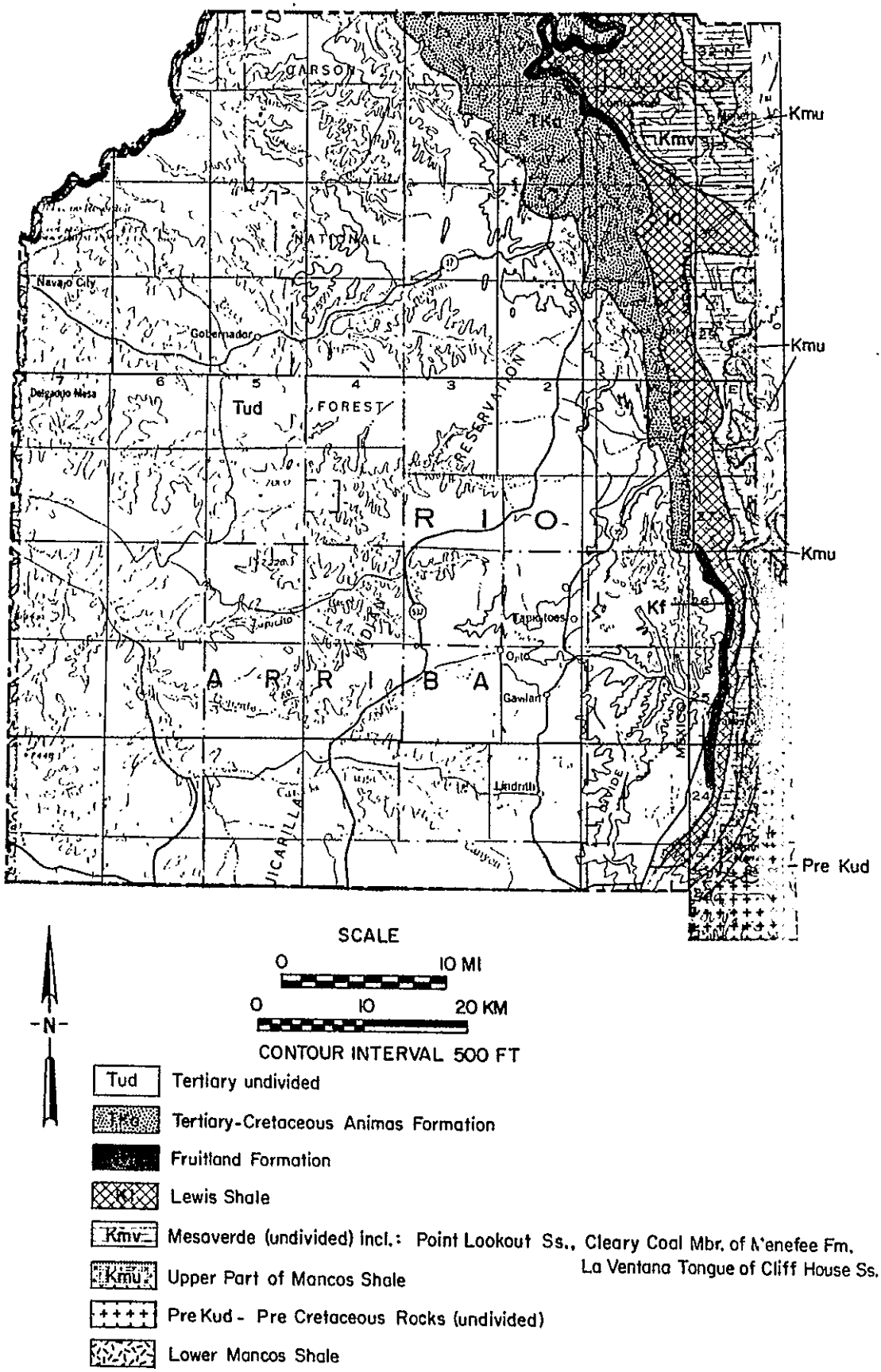


Figure 6. Simplified geologic map of western Rio Arriba County, New Mexico (adapted from Bingler, 1968).

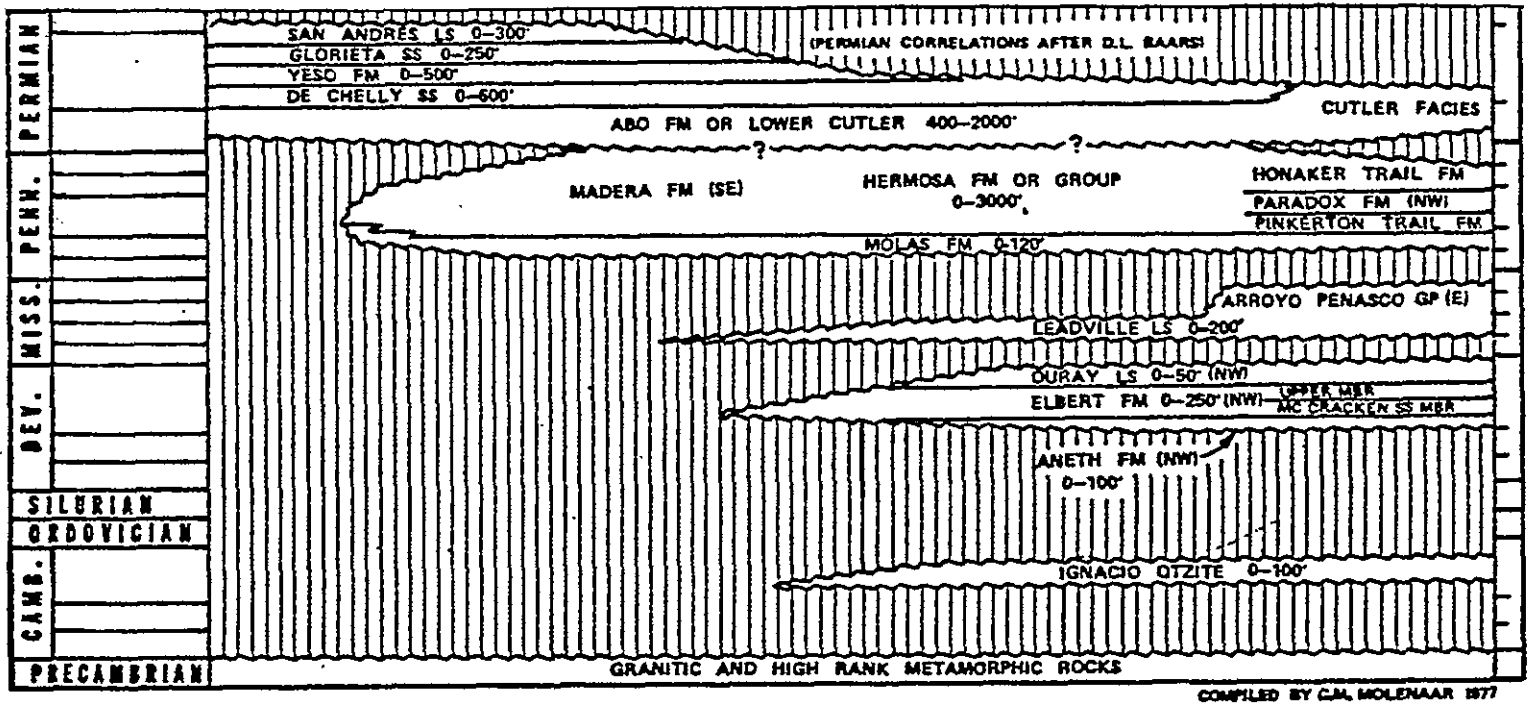


Figure 7. Time-stratigraphic nomenclature chart for Paleozoic rocks of the San Juan Basin (from Molenaar, 1977).

euxinic facies of the Elbert Formation (Stevenson and Baars, 1977).

The Elbert Formation (Devonian) conformably overlies the Aneth Formation (Fig. 7; Stevenson and Baars, 1977). Where the Aneth is absent, the Elbert Formation rests unconformably on Precambrian basement. The Elbert is divided into a lower McCracken Sandstone Member and an unnamed upper member. The McCracken Member is present in western San Juan County where it has a maximum thickness of 175 ft (Stevenson and Baars, 1977). It consists of poorly sorted, fine- to medium-grained, gray to red glauconitic sandstones. The upper member is present in San Juan, western Rio Arriba, northwest Sandoval, and extreme northwest McKinley Counties (Stevenson and Baars, 1977). Maximum thickness is 200 ft in San Juan County and thins to the south and east. It consists of green shales, thin-bedded limestones and dolostones, and white glauconitic sandstones.

The Ouray Formation (Devonian) conformably overlies the Elbert Formation (Fig. 7; Stevenson and Baars, 1977). The Ouray Formation is present in San Juan, western Rio Arriba, northeast McKinley, and northwest Sandoval Counties. In northwest New Mexico, it is 0-90 ft thick. The Ouray consists of dark-brown limestones and dolostones. It was deposited in a low-energy marine environment (Stevenson and Baars, 1977).

Mississippian sedimentary rocks are 0-200 ft thick in northwest New Mexico. They are thickest in northwest San Juan County and thin to the east and south. They are absent from the Zuni and southern Defiance uplifts, and from Cibola and southern Bernalillo Counties.

The Leadville Limestone (Mississippian, Fig. 7) is present in northern San Juan and northern Rio Arriba Counties (Armstrong and Mamet, 1977). The Leadville rests uncomformably on Devonian sedimentary rocks. Where the Devonian is absent, the Leadville Limestone rests unconformably on Precambrian basement. The Leadville consists of shallow-marine, crinoidal limestones and dolostones.

The Arroyo Peñasco Group (Mississippian, Fig. 7) is present in southern San Juan, southwestern Rio Arriba, northern McKinley, and Sandoval Counties (Armstrong and Mamet, 1977). The lower part of the Arroyo Peñasco Group is equivalent to the Leadville Limestone of northwest New Mexico and the Kelly Limestone of west-central New Mexico. The Arroyo Peñasco Group is comprised of two formations (ascending): the Espiritu Santo and Terrero Formations. The Espiritu Santo consists of quartz conglomerates, sandstones, siltstones, and shales that grade upward into stromatolitic limestones, dolostones, and dedolomitic limestones. The Terrero Formation consists of brecciated limestones, oolitic limestones, and pelletal limestones (Armstrong and Mamet, 1977).

Pennsylvanian sedimentary rocks are present throughout most of northwest New Mexico. They attain a maximum thickness of 2,500 ft in north-central San Juan County (Jentgen, 1977). They thin to zero over the Zuni and southern Defiance uplifts. The Pennsylvanian section thins to less than 500 ft in central McKinley County and thickens to 2,250 ft in eastern Cibola and western Valencia Counties (Kottlowski, 1959).

The Pennsylvanian section is comprised of two formations,

the Sandia Formation and the Madera Formation, throughout most of northwest New Mexico (Fig. 8). The Sandia Formation rests unconformably on Mississippian sedimentary rocks. Where the Mississippian is absent, the Sandia rests unconformably on the Precambrian. The Sandia consists of marine shelf limestones, gray to green shales, and arkosic to quartzose shallow marine sandstones. The Madera consists of biostromal marine-shelf limestones, black, gray, and red shales, and arkosic to quartzose shallow-marine to deltaic sandstones (Kottlowski, 1959; Siemers, 1983).

In the northwest part of the San Juan Basin, the Pennsylvanian section is comprised of the Molas Formation and the Hermosa Group (Fig. 7; Jentgen, 1977). The Molas Formation rests unconformably on the Mississippian and is equivalent to the lower part of the Sandia Formation. Maximum thickness is approximately 150 ft in northwest New Mexico. The Molas Formation is a clastic red-bed sequence that consists of brown to variegated siltstone, red shale, calcareous sandstone, and minor limestone lenses; limestone conglomerates are present in the lower part of the unit.

The Hermosa Group consists of the Pinkerton Trail, Paradox, Honaker Trail, and Rico Formations (Fig. 7). The Pinkerton Trail Formation rests conformably on the Molas Formation. It is equivalent to the upper part of the Sandia Formation. Maximum thickness is approximately 200 ft. The Pinkerton Trail Formation consists of fine- to medium-crystalline fossiliferous limestones and light- to dark-gray silty shales.

The Paradox Formation conformably overlies the Pinkerton

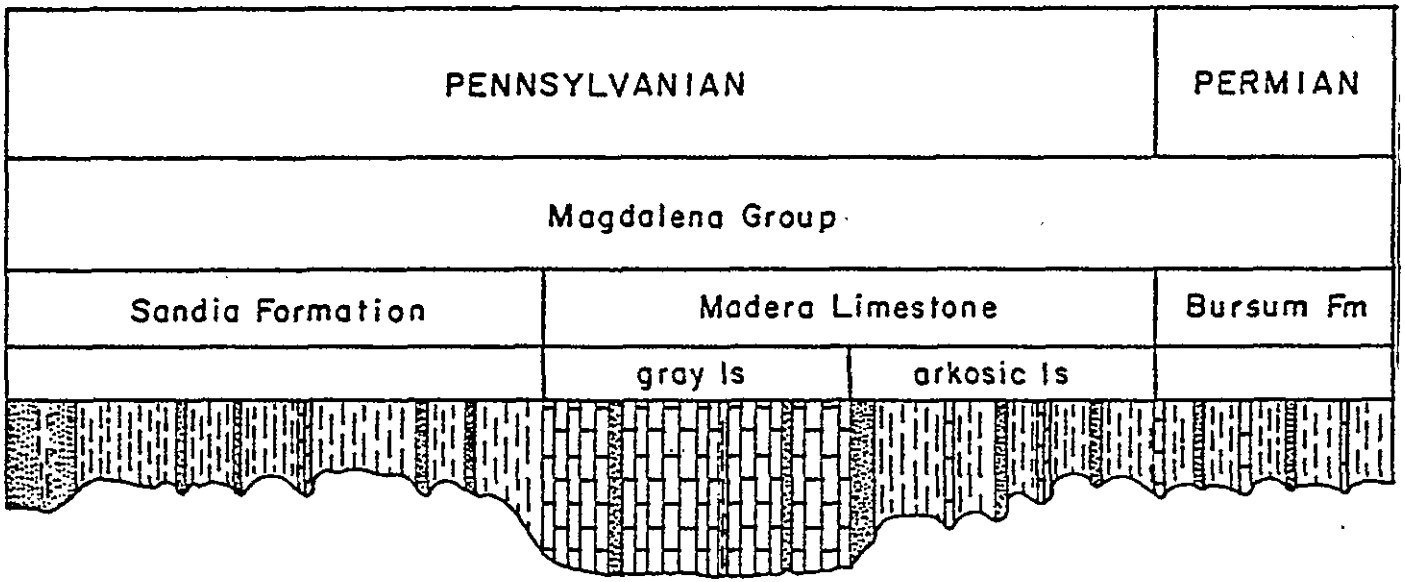


Figure 8. Generalized stratigraphic section of Pennsylvanian sedimentary rocks in west-central New Mexico (from Siemers, 1983).

Trail Formation (Fig. 7; Jentgen, 1977). It is equivalent to the uppermost part of the Sandia Formation and the lower part of Madera Formation. The Paradox Formation consists of conglomeratic and cherty limestones, siltstones, and arkosic sandstones; some of the limestones are biohermal. The Paradox Formation has been divided into five zones. In southeast Utah, the five zones are defined by black shale layers that occur between salt cycles. The cyclic stratigraphy is recognizable in the carbonates of the Paradox Formation in northwest New Mexico. The five zones are (ascending): Alkali Gulch, Barker Creek, Akah, Desert Creek, and Ismay.

The Honaker Trail Formation rests conformably on the Paradox Formation (Fig. 7; Jentgen, 1977). It is equivalent to the upper part of the Madera Formation. The Honaker Trail Formation consists of massive cherty limestones and dolostones, calcareous gray shales, siltstones, and arkosic sandstones.

The Rico Formation conformably overlies the Honaker Trail Formation (Jentgen, 1977). It is a transitional unit between marine sedimentary rocks of the Hermosa Group and fluvial sedimentary rocks of the Cutler Formation (Permian). The Rico Formation consists primarily of marine carbonates that grade upward into clastic nonmarine red beds.

In the San Juan Basin, the Abo Formation (Permian) overlies the Hermosa Group and Sandia Formation (Pennsylvanian; Fig. 7). The contact appears to be conformable in some places and disconformable in other places. The Abo is generally 1,200-1,600 ft thick in the San Juan Basin; it thins to 600 ft on the Defiance uplift and 200 ft on the Zuni uplift (Baars and

Stevenson, 1977; Baars, 1962). The Abo is a red bed sequence; it consists of fluvial and lacustrine, arkosic sandstones, conglomerates, and shales. The Abo grades northward into the arkosic Cutler red beds of Rio Arriba and northeast San Juan Counties.

The Yeso Formation (Permian) overlies the Abo Formation with apparent conformity (Fig. 7). The lower part of the Yeso is a sand-rich unit that has variously been called the Meseta Blanca Sandstone Member and the De Chelly Sandstone (Baars, 1974; Baars and Stevenson, 1977). The Meseta Blanca is 200-800 ft thick in northwest New Mexico. It consists of a fine-grained, cross-stratified, orange sandstone. In the San Juan Basin, it is an aeolian deposit. The aeolian sandstones grade southward into shallow-marine sandstones in Valencia, Torrance, and Socorro Counties. The Meseta Blanca grades northward into the arkosic Cutler redbeds of Rio Arriba and northeast San Juan Counties.

The upper part of the Yeso Formation conformably overlies the Meseta Blanca Member (Baars, 1962; Baars and Stevenson, 1977). The upper part of the Yeso Formation is 1,000 ft thick in Valencia County. It thins northward and pinches out in southern San Juan and Rio Arriba and northern Sandoval Counties. The upper part of the Yeso consists of red to orange shales, fine-grained limestones, dolostones, and anhydrite and halite beds.

The Glorieta Sandstone (Permian) conformably overlies the Yeso and Cutler Formations (Fig. 7; Baars, 1962). It is 200-300 ft thick in Valencia and Cibola Counties (Baars, 1962). It thins northward and pinches out in southern San Juan and southern Rio

Arriba Counties (Baars, 1962; Baars and Stevenson, 1977). The Glorieta is a white, quartzose, well-sorted, fine- to medium-grained, shallow-marine sandstone.

Mesozoic Stratigraphy

(by V. T. McLemore and G. Roybal)

Triassic sedimentary rocks belonging to the Chinle Formation unconformably overlie the Permian rocks and consists of a thick section of maroon to red-brown shales with interbedded sandstones, conglomerates, and local thin limestones. The Chinle Formation is divided into five members (in ascending order by age): Shinarump, Monitor Butte, Petrified Forest, Owl Rock Members, and an unnamed upper member (Repenning et al., 1969; New Mexico Geological Society and NMBMMR, 1983). Correlations of the various members may be speculative unless a complete section of the Chinle Formation is exposed. The Chinle Formation varies from 1,100 to 1,700 ft thick in the Colorado Plateau (Repenning et al., 1969) and represents a continental sequence of floodplain and fluvial environments. Thin sandstone lenses of the Wingate Sandstone extend into western parts of San Juan County and overlie Chinle rocks. The precise age of the Wingate is uncertain, but presumed Triassic.

Jurassic sedimentary rocks overlie Triassic rocks and consist of the Entrada Sandstone, Todilto Formation, Summerville Formation, Bluff Sandstone, and the Morrison Formation (Fig. 9). The Entrada Sandstone consists of an eolian massive-bedded sandstone which is correlated with the Exter Sandstone in eastern New Mexico and the Wingate Sandstone in western New Mexico and Arizona. The Todilto Formation overlies the Entrada Sandstone and consists of two informal members: a basal limestone and an upper gypsum-anhydrite. When just the limestone is present, this unit is referred to as the Todilto Limestone. The actual

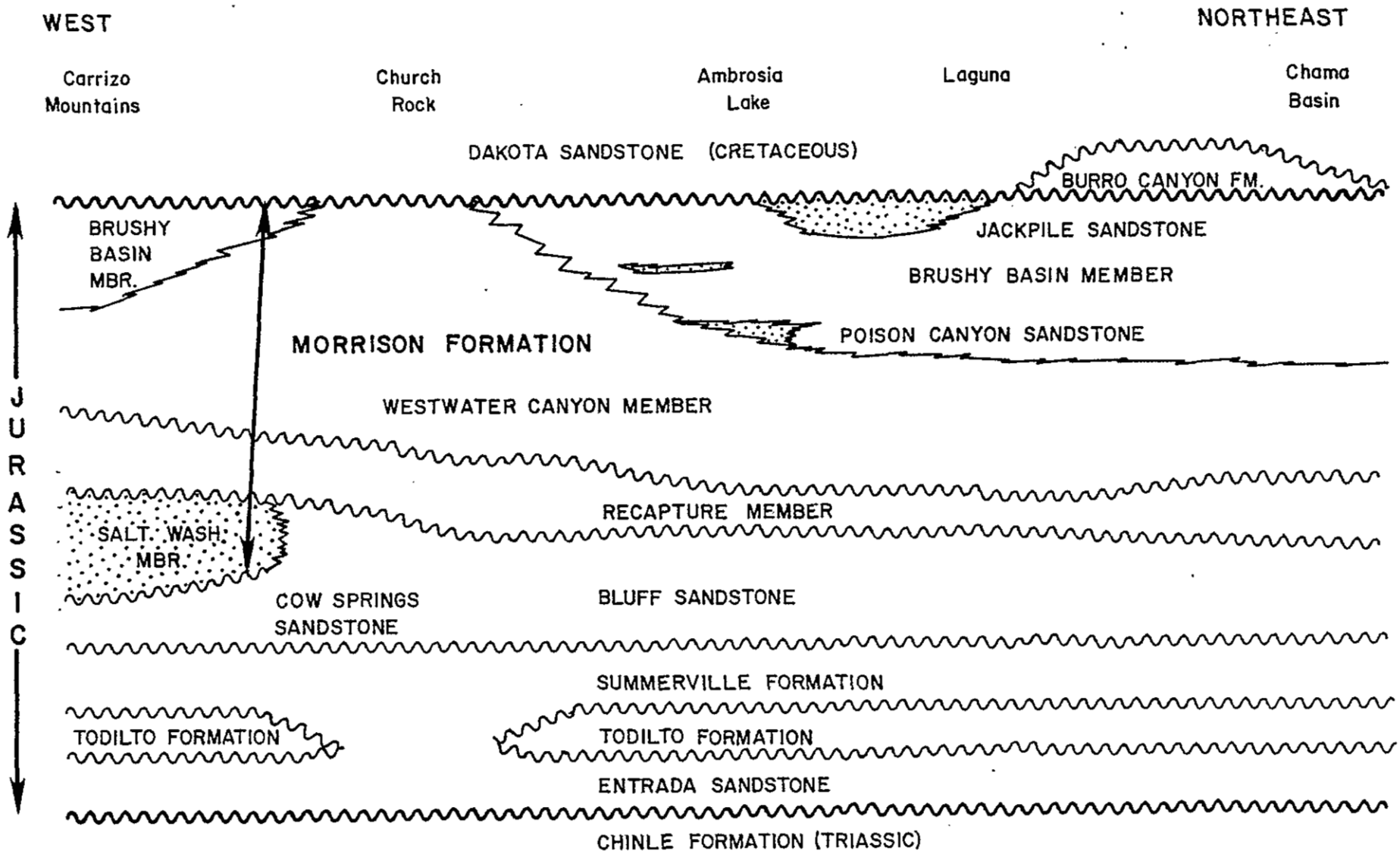


Figure 9 **Stratigraphic correlations of Jurassic rocks in the San Juan Basin.**

depositional environment of the Todilto Formation is controversial. Recent isotopic evidence favors a marine origin (Ridgley and Goldhaber, 1983) rather than a lacustrine origin.

The Summerville Formation and Bluff Sandstone overlie the Todilto Formation. These units consist of a sequence of thin-bedded to massive sandstone and gypsiferous shales.

The youngest Jurassic unit is the Morrison Formation which consists of four members: Salt Wash, Recapture, Westwater Canyon, and Brushy Basin. The Salt Wash Member is exposed only in western San Juan County and consists of sandstone with interbedded shale and siltstone. The Recapture Member consists of alternating maroon and gray shales, siltstones, and fine-grained sandstones (Hilpert, 1969; Green, 1975). Near the top of the Recapture, a disconformity separates the lower eolian-sabkha sequence from the overlying fluvial-lacustrine sequence (Green, 1975). The overlying Westwater Canyon Member consists of sandstones and shales deposited in fluvial and lacustrine environments. The Westwater Canyon Member is the major uranium-bearing sequence, although orebodies occur throughout the Morrison. Shales of the Brushy Basin interfinger with the Westwater Canyon Member. Several sandstones occur in the Brushy Basin Member, including the Jackpile sandstone. The Poison Canyon sandstone, of economic usage, is defined as the lower Brushy Basin by industry, but is defined as a tongue of the Westwater Canyon Member by the U.S. Geological Survey. The Jackpile sandstone occurs at the top of the Morrison Formation in eastern San Juan Basin and is not exposed in San Juan or Rio Arriba Counties.

The Cretaceous stratigraphy in western Rio Arriba County includes Early upper to Middle upper Cretaceous rocks. The oldest Cretaceous rocks are located in the east (Fig. 10) becoming progressively younger to the west. These units represent major transgressive-regressive cycles of the Cretaceous seaway (Molenaar, 1983a, b). Deposition of most of the sediments occurred during major regressions. Regressive sequences consist principally of marine mudstones, coastal-plain, deltaic, interdeltaic, and alluvial-plain deposits, whereas major transgressions are characterized by marine shales (Molenaar, 1983a, b).

The first and second major transgressive-regressive sequences are not represented at the surface, in western Rio Arriba County. The third major transgression-regression and the fourth major transgression are not clearly defined, but are represented by the upper part of the Marine Mancos Shale. This unit is composed of gray and calcareous shale, with zones of dense gray concretionary limestones and thin beds of hard sandstone (Dane, 1957). The thickness of this unit is between 500 and 700 ft in Rio Arriba County.

The fourth major regressive sequence is defined by the Point Lookout Sandstone, and the Cleary Coal Member of the Menefee Formation (Molenaar, 1983a, b; Shomaker, 1971). The Point Look Sandstone is a thin-bedded to massive buff to white sandstone, with a gradational contact with the Mancos Shale and a sharp contact with the overlying Menefee Formation (Dane, 1957). In western Rio Arriba County this unit is 170 to 240 ft thick. It

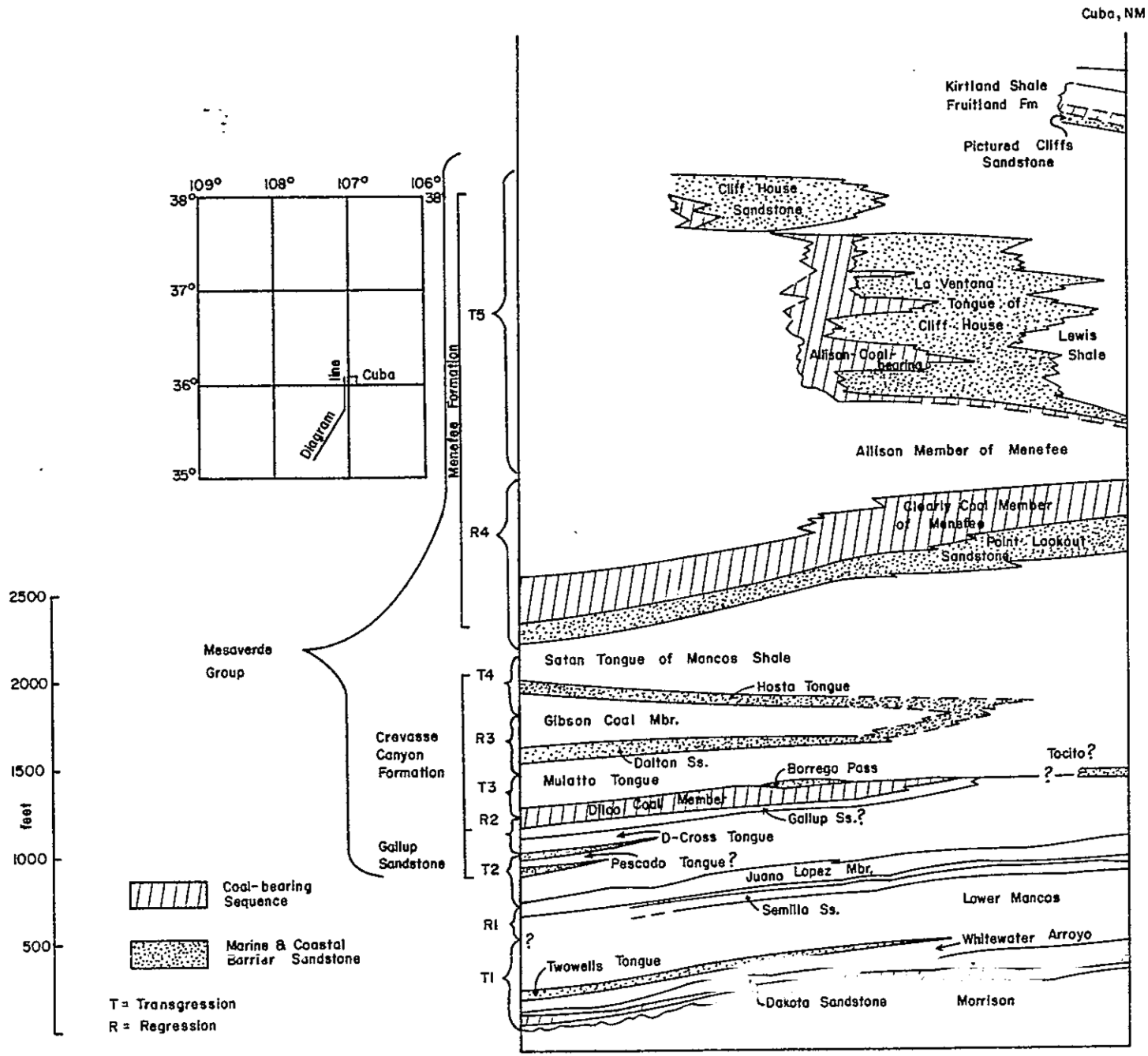


Figure 10 — Stratigraphic Diagram of Cretaceous Units on the Southeast side of the San Juan Basin (Modified from Fig. 7, Shomaker, Beaumont & Kottlowski, 1971, with additions from Dane, Landis and Cobban, 1972 and Molenaar, 1983 b)

represents an extensive coastal-barrier sandstone (Molenaar, 1977; 1983a, b).

The Cleary Coal Member of the Menefee Formation is a highly variable assemblage of white cross-bedded sandstones, gray clays and shales, brown and black carbonaceous shales, and coal beds (Dane, 1957). This unit ranges in thickness from 80 to 130 ft near Monero and up to 250 ft in the southern portion of the county. This regressive sequence represents nonmarine paludal to alluvial-plain deposits (Molenaar, 1977). Economic quantities of coal occur proximal to paleoshorelines (Molenaar, 1977), and the thickest accumulations of coal developed during stillstands.

In western Rio Arriba County, the fifth major transgression of the Cretaceous seaway is represented by the La Ventana Tongue of the Cliff House Sandstone, and the Lewis Shale. The La Ventana Tongue consists of hard buff and brown fine-grained calcareous sandstones, which stratigraphically alternate with softer gray shales and siltstones (Dane, 1957). The thickness of this unit in western Rio Arriba County ranges from 30 to 80 ft. Complex intertonguing between the La Ventana Tongue and the overlying Lewis Shale suggests that a number of minor regressions occurred throughout this major transgressive cycle (Molenaar, 1977).

The Lewis Shale is a light- to dark-gray marine shale with numerous beds of bentonite. Large septarian calcium carbonate concretions are located near the base of the Lewis Shale, and beds of gray slabby sandstone are present 700 to 1,000 ft above the base (Dane, 1957). In the northern portion of western Rio Arriba County the Lewis Shale is 2,000 ft thick and it thins to the

south.

The final major regression is represented by Pictured Cliffs Sandstone and Fruitland Formation. These units are exposed only in the northern portion of the county. The Pictured Cliffs Sandstone is a soft, white, quartz sandstone (Dane, 1957). In western Rio Arriba County this unit is very thin and rarely exceeds thicknesses of 150 ft. The unit represents a regressive coastal-barrier sandstone (Molenaar, 1977).

The Fruitland Formation represents nonmarine lower coastal-plain deposits, which are located behind the Pictured Cliffs paleoshoreline (Molenaar, 1977). Lithologically, this unit consists of a highly variable sequence of intercalated gray, brown, and black shale, yellowish-brown and tan crossbedded sandstone, and economic quantities of coal (O'Sullivan and Beikman, 1963). The thickest coals are located where stillstands or minor regressions occurred. The thickness of the Fruitland Formation is 160 ft thick in the northern portion of the county and this unit thins to nonexistence in the south.

The upper Cretaceous and Paleocene Animas Formation unconformably overlies the Fruitland Formation and Lewis Shale in western Rio Arriba County. The age of this unit is controversial, but based on faunal assemblages and radiometric dating the McDermott Member of the Animas Formation has been placed at Late Cretaceous to earliest Tertiary (Molenaar, 1977).

Cenozoic Stratigraphy

(by V. T. McLemore)

Cretaceous rocks in western Rio Arriba county are overlain unconformably by Tertiary and Quaternary sediments and volcanics. The Paleocene Ojo Alamo Sandstone overlies Cretaceous units and consists of sandstone, locally conglomeratic with shale lenses (Fassett and Hinds, 1971; O'Sullivan et al., 1972). The Nacimiento Formation interfingers with the Ojo Alamo Sandstone and consists of shales with lenticular beds of sandstone. The San Jose Formation overlies the Nacimiento Formation and consists of four members: Cuba Mesa, Regina, Llaves, and Tapicotos Member. At the base, the Cuba Mesa Member consists of conglomeratic sandstone with lenticular shale beds. The Regina Member overlies the Cuba Mesa and consists of variegated shales. The Llaves Member consists of sandstone with some shale and the Tapicotos Member consists of maroon shale and some sandstone.

Tertiary igneous rocks in western Rio Arriba County are rare. An augite andesite sill intrudes the Animas Formation near Dulce. A swarm of basaltic-lamprophyric dikes intrude sediments in the north-central part of Rio Arriba County. Few petrographic or geochemical studies have been performed on these dikes.

Mining History

(by V. T. McLemore and K. B. Brown)

Very little mining has occurred in western Rio Arriba County. Copper, silver, and uranium were mined from stratabound, sedimentary copper deposits. Some production may have occurred prior to 1880 by Indians and the Spanish; most production occurred sporadically from 1904 to 1961. A small coal field has yielded production and some aggregate has been produced. The majority of production from western Rio Arriba County has been oil and gas.

Numerous mining claims cover portions of western Rio Arriba (Fig. 11), but there are no active metal mines. Oil and gas are currently being produced and most federal land open to petroleum leasing has been leased and exploration continues.

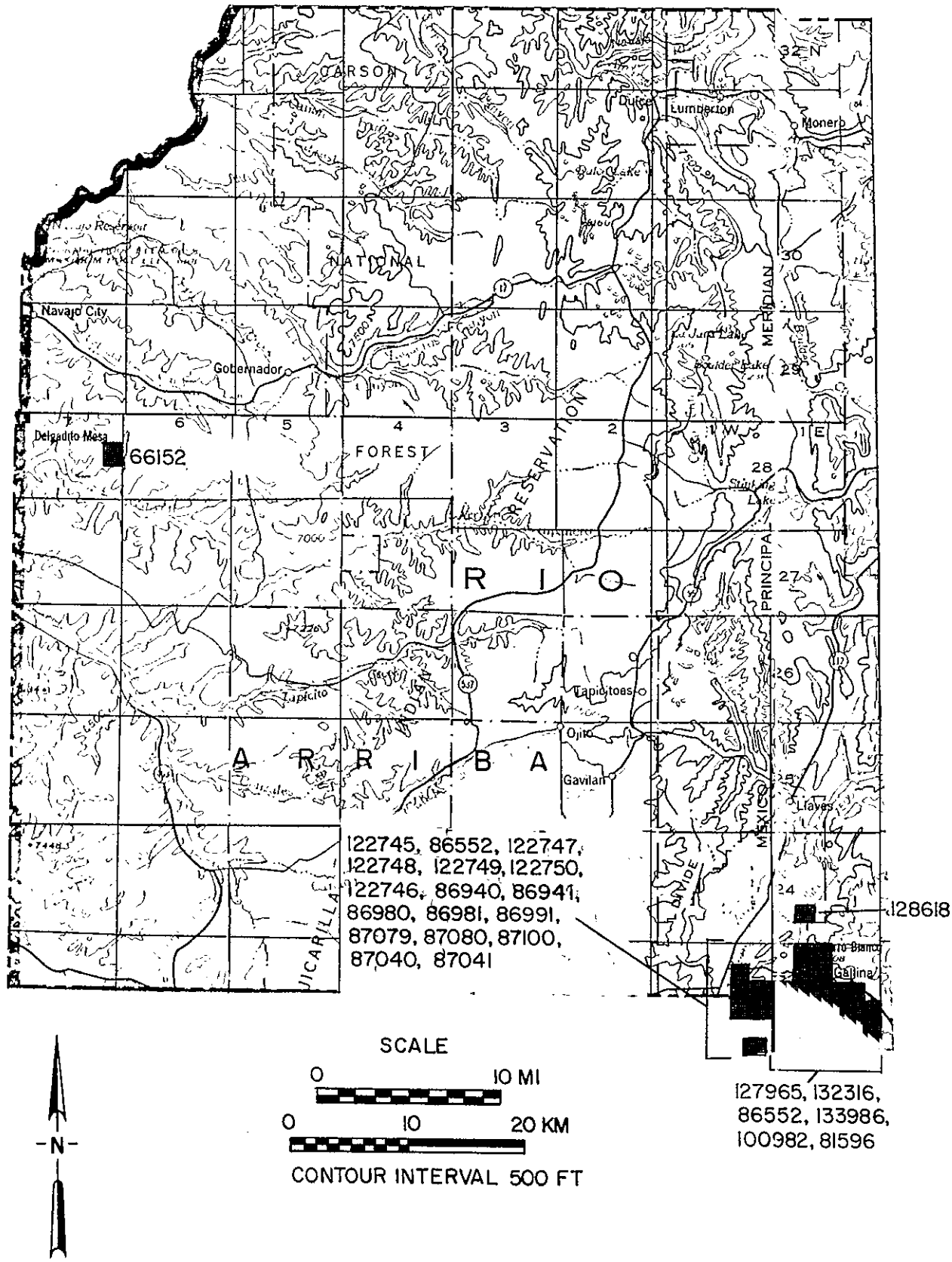


Figure 11. Sections with active mining claims in western Rio Arriba County, New Mexico.

DESCRIPTION OF KNOWN DEPOSITS AND MINERAL RESOURCE POTENTIAL

Petroleum Resources

(by R. F. Broadhead)

Petroleum Production History

Petroleum has been produced from western Rio Arriba County since the 1920's. Petroleum has been produced from 44 designated oil and gas pools in western Rio Arriba County (Appendix 2; Figs. 12-18). Nineteen wells have produced from undesignated oil and gas pools (Table 2; Figs. 12-18). Approximately 51 million bbls oil and 4.3 trillion cubic ft of natural gas have been produced from western Rio Arriba County (Table 3). All petroleum production in Rio Arriba County is from the part of the county covered in this report.

Known Petroleum Occurrences

All oil and gas from Rio Arriba County is produced from Cretaceous reservoirs (Table 3). Jurassic, Pennsylvanian, and Mississippian reservoirs, which produce in San Juan County, have been sparsely tested in Rio Arriba County. Geologic and production information from each of the 44 formally designated oil and gas pools is summarized in Appendix 2. Pool locations are shown in Figs. 12-17 and Maps 65 and 66. Geology and production information of wells that produce from undesignated pools is summarized in Table 2. Well locations are shown in Figs. 12-17 and Maps 65 and 66.

Nacimiento pool--One gas pool, the Gavilan, produces from the Nacimiento Formation (Tertiary) in Rio Arriba County (Fig. 12; Appendix 2). The Nacimiento has produced 0.001% of the oil and

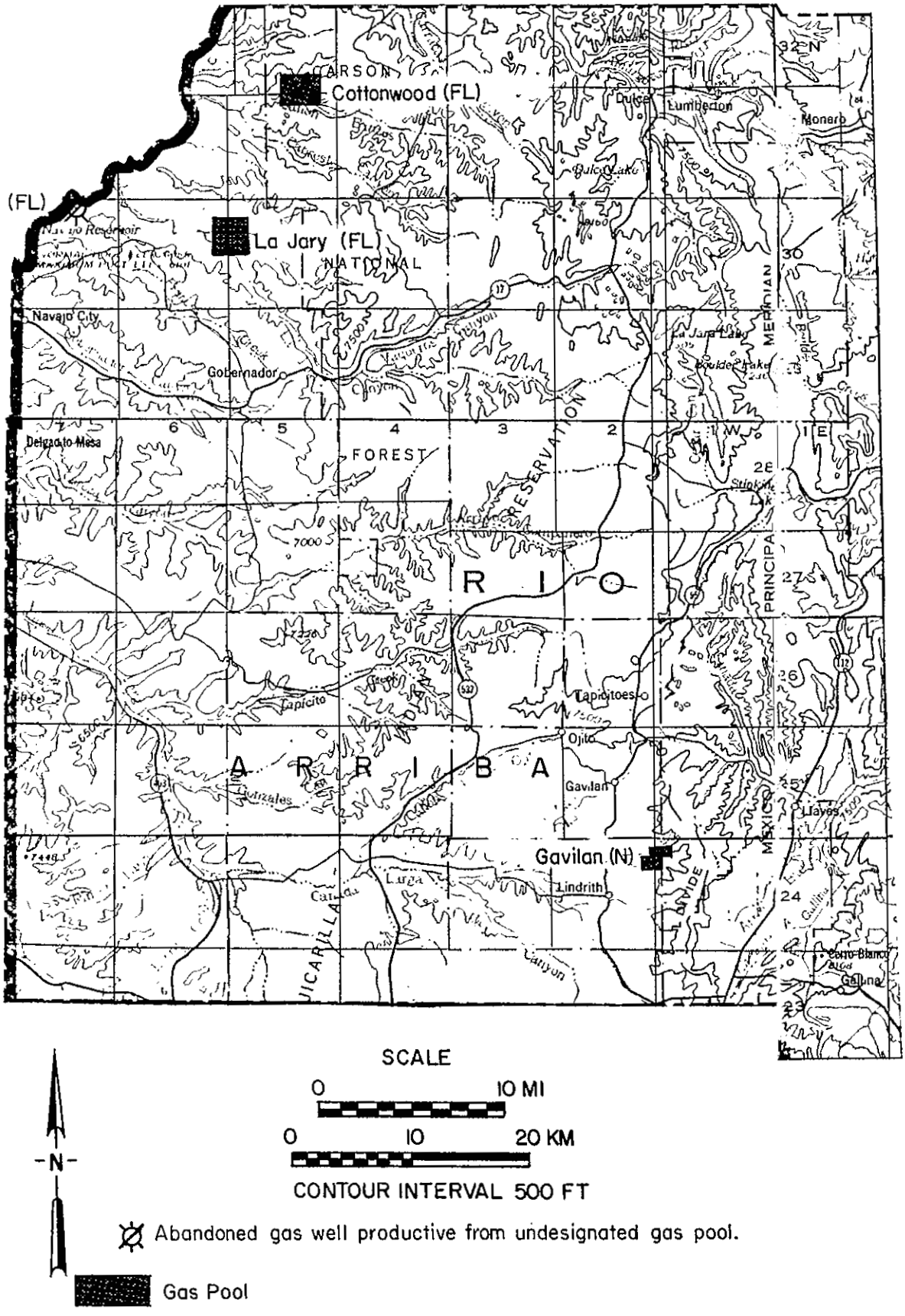


Figure 12. Gas pools that produce from the Nacimiento (N) and Fruitland (FL) Formations in western Rio Arriba County, New Mexico.

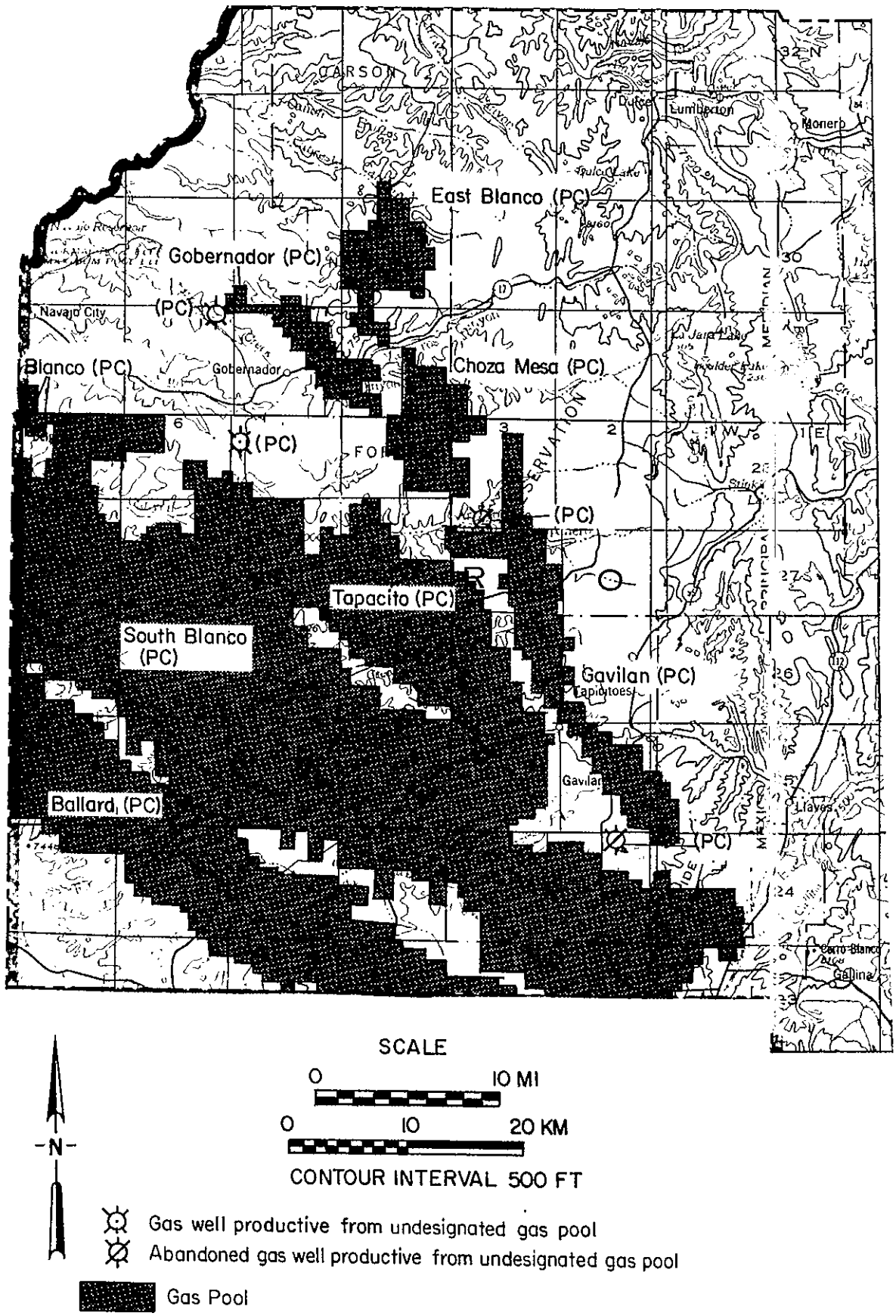


Figure 13. Gas pools that produce from the Pictured Cliffs (PC) Formations in western Rio Arriba County, New Mexico.

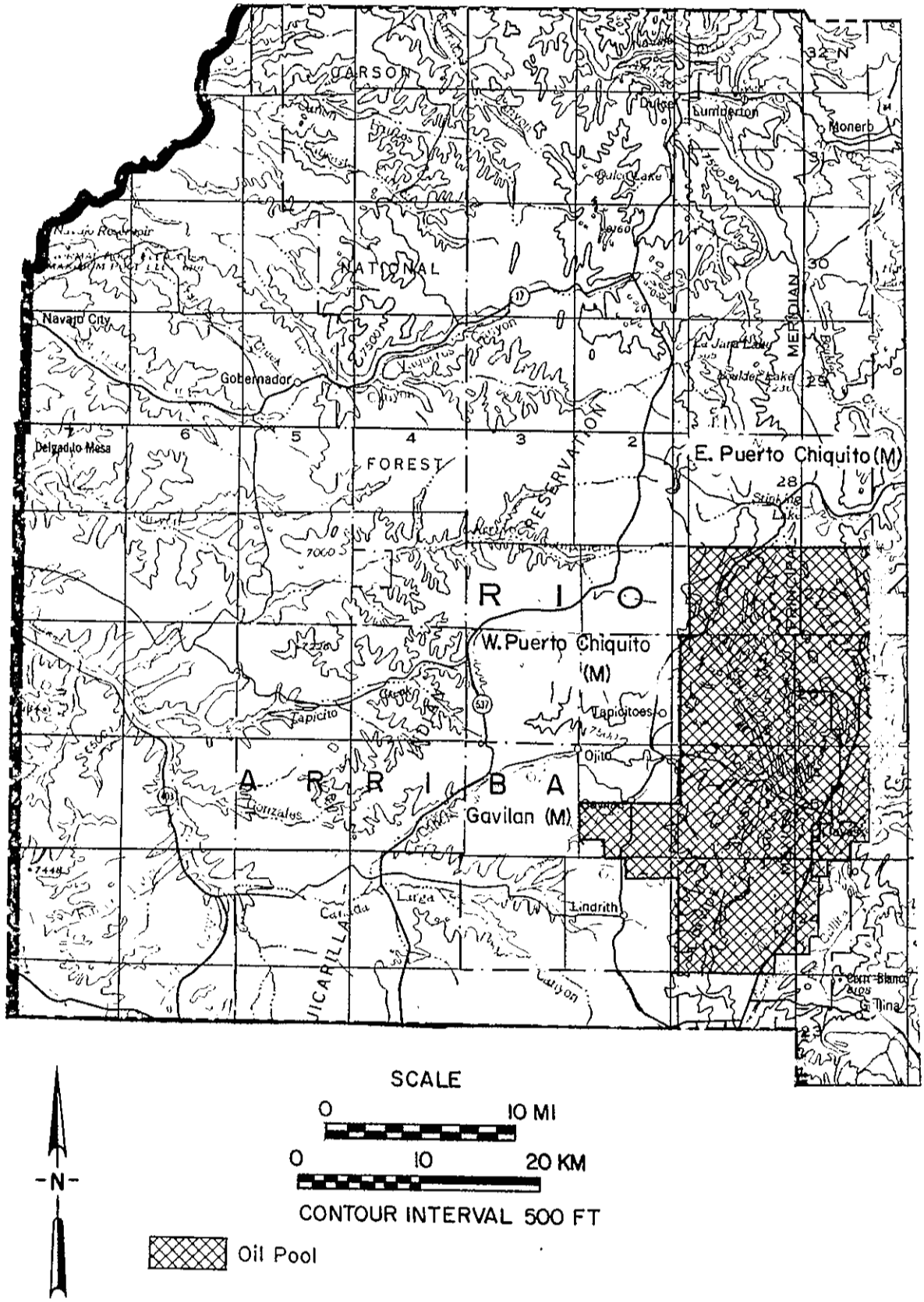


Figure 15. **Oil pools that produce from the upper part of the Mancos Shale (M) in western Rio Arriba County, New Mexico.**

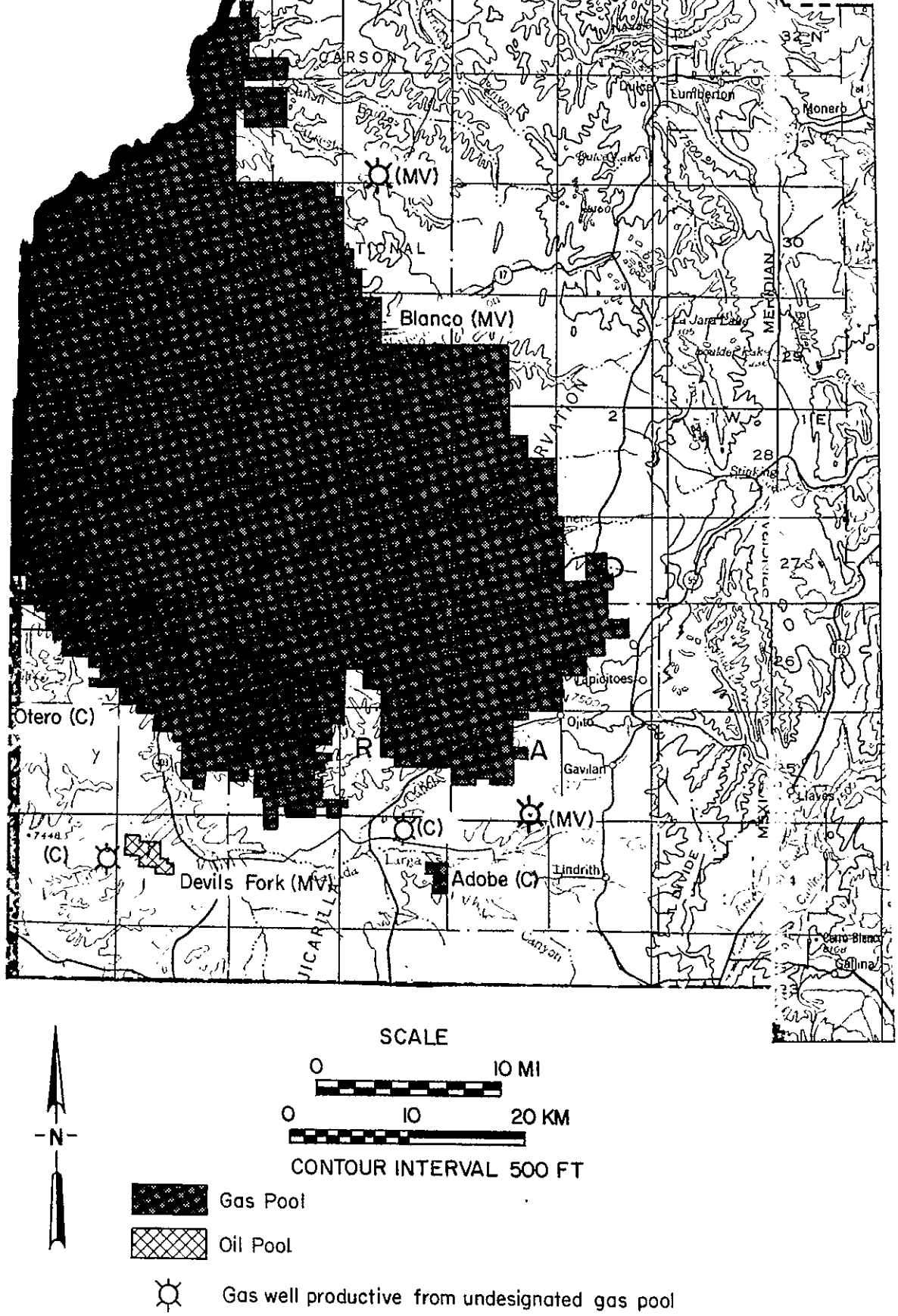


Figure 14. Oil and gas pools that produce from the Mesaverde Group (MV) and the Chacra producing interval (C) in western Rio Arriba County, New Mexico

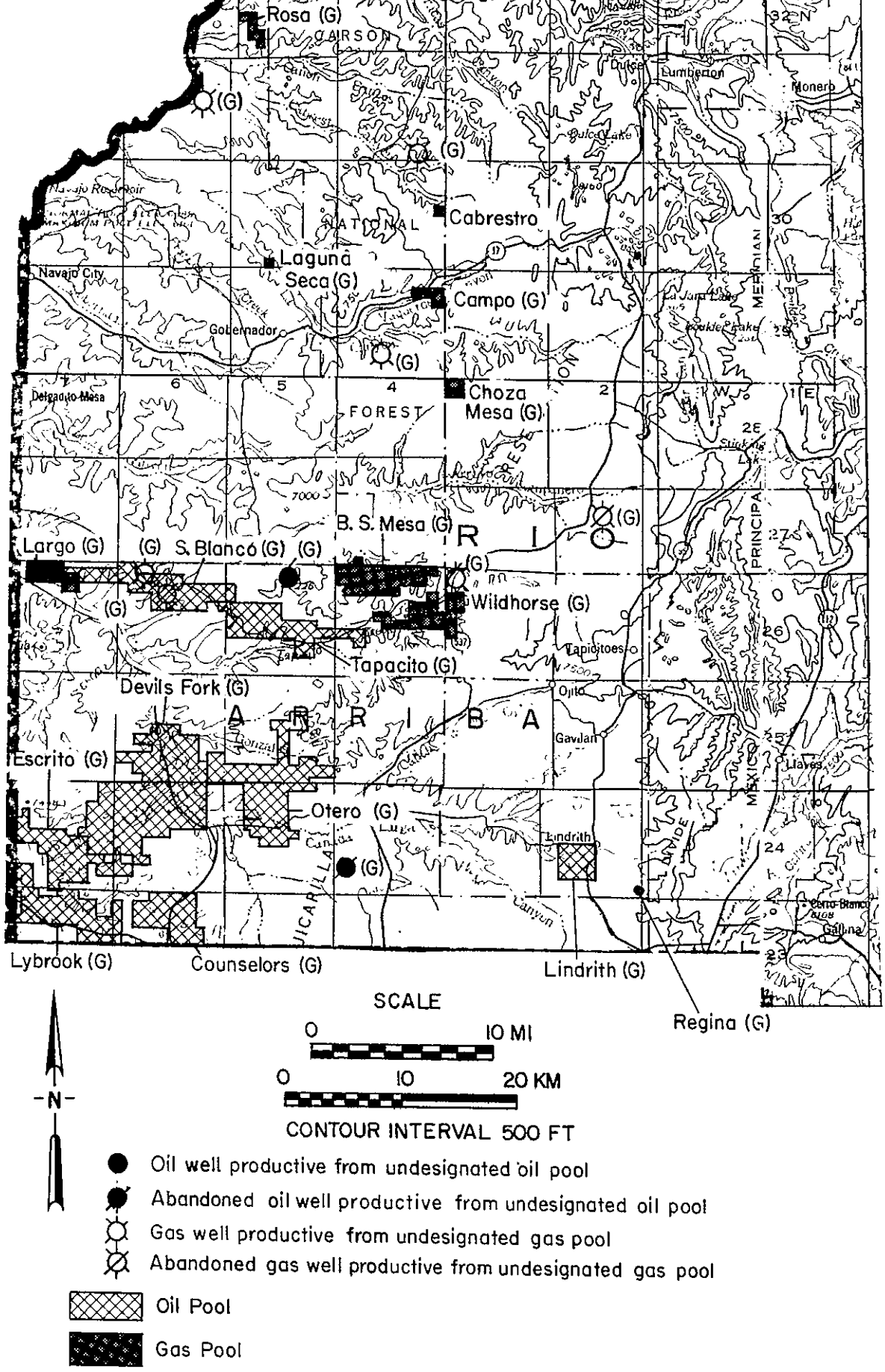


Figure 16. Oil and gas pools that produce from the Gallup (basal Niobrara) sandstone (G) in weste-n

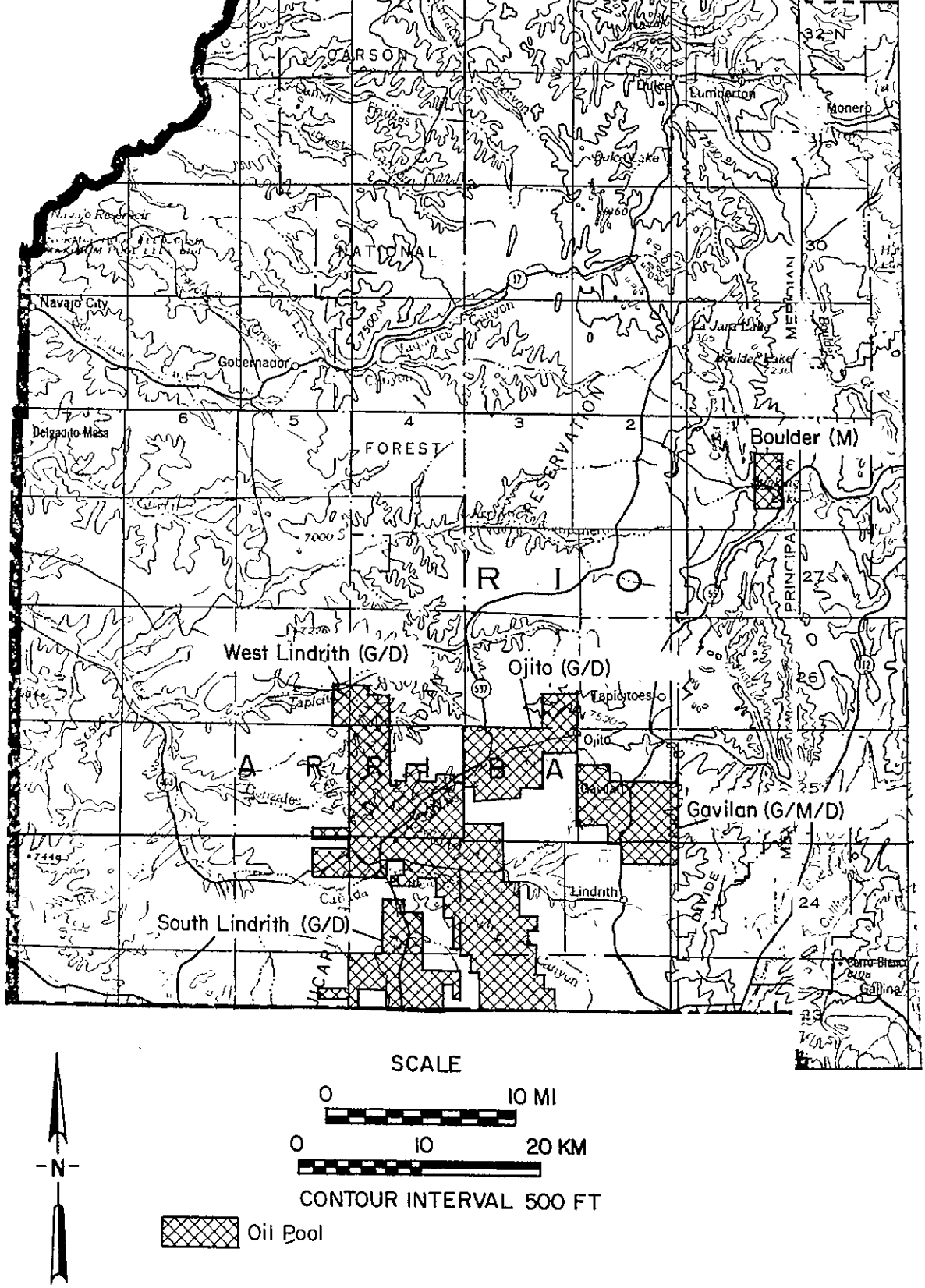


Figure 17. **Oil pools that produce from the Gallup (basal Niobrara) Sandstone (G), lower part of the Mancos Shale (M), and Dakota Sandstone (D) in western Rio Arriba County, New Mexico.**

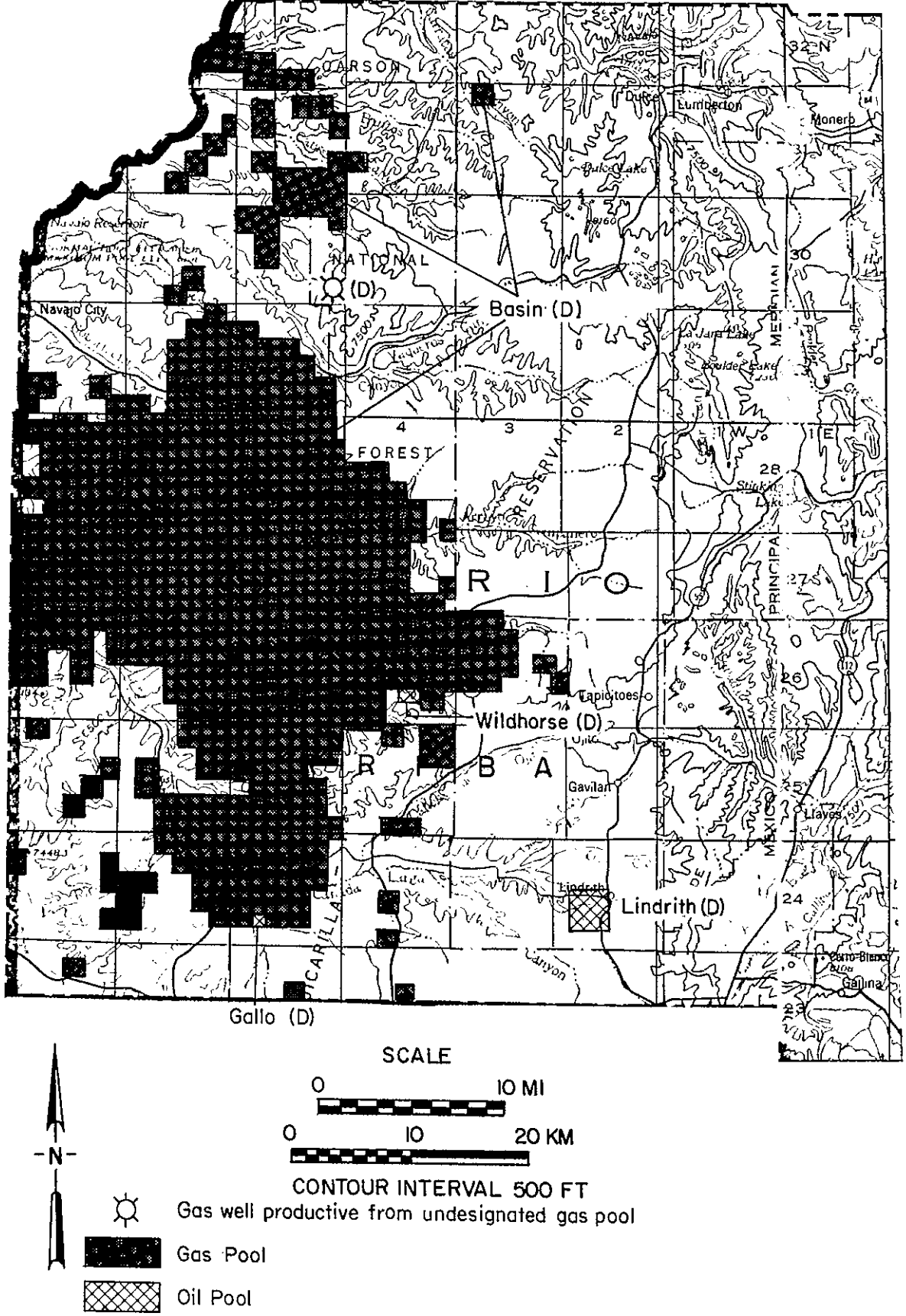


Figure 18. **Oil and gas pools productive from the Dakota Sandstone (D) in western Rio Arriba County, New Mexico.**

TABLE 2 – Wells productive from undesignated oil and gas pools in Rio Arriba County. owwo, old well worked over; gas, gas well; oil, oil well; abd, abandoned; MCFG, thousand ft^3 gas; BO, bbls oil; BW, bbls water.

Operator, well number, and lease	Location (section-township-range, and distance in ft from section boundaries)	Completion date (month/year)	Total depth (ft)	Status	Producing interval (ft)	Producing unit	Annual production, 1984	Cumulative production to 12/31/84
El Paso Natural Gas No. 3 Howell	990 FSL, 890 FWL 3-30N-7W	4/52	3,025	gas, abd		Fruitland (Cretaceous)	0	54,199 MCFG
Shar Alan Oil Co. No. 1 Jicarilla C 156	1820 FNL, 1805 FEL 3-23N-2W	10/62	3,201	gas, abd	3,060-3,124	Pictured Cliffs (Cretaceous)	6,719 MCFG + 495 BO	75,187 MCFG + 1,477 BO
Pacific Northwest Pipeline No. 1 Indian O	810 FNL, 530 FEL 32-28N-3W	3/57	6,171	gas, abd	3,650-5,664	Pictured Cliffs (Cretaceous)	0	808 MCFG
El Paso Natural Gas No. 29 San Juan 28-5 unit	1100 FNL, 940 FWL 18-28N-5W	2/81	6,248	gas	3,619-3,722	Pictured Cliffs (Cretaceous)	15,240 MCFG	52,842 MCFG
Northwest Pipeline No. 111 San Juan 29-6 unit	1150 FNL, 1730 FWL 1-29N-6W	11/79	3,715	gas	3,598-3,630	Pictured Cliffs (Cretaceous)	33,355 MCFG	120,671 MCFG
Schalk Development Co. No. 1 Schalk 31-4	1120 FNL, 960 FEL 32-31N-4W	12/79	6,230	gas	5,932-5,955	Point Lookout (Cretaceous)	522 MCFG + 109 BW	3,344 MCFG
Galloway No. 1 Myers	1117 FNL, 790 FWL 35-25N-3W	7/79	6,006	gas	5,746-5,839	Mesaverde (Cretaceous)	2,067 MCFG + 142 BO	18,837 MCFG + 832 BO
Cotton Petroleum Corp. No. 3 Apache (owwo)	1850 FSL, 1850 FEL 3-24N-4W	5/80	4,080	gas	3,840-3,949	Chacra (Cretaceous)	1,665 MCFG	14,765 MCFG
Caulkins Oil No. 224 Breech	978 FNL, 790 FWL 13-26N-7W	10/79	7,320	gas	3,618-3,716	Chacra (Cretaceous)	8,453 MCFG + 191 BO + 67 BW	311,935 MCFG + 3,064 BO
Amerada Petroleum No. 1 Jicarilla Apache E	1650 FSL, 990 FWL 30-24N-4W	12/56	7,080	oil, abd	5,722-5,766	Gallup (Cretaceous)	0	1,649 BO
Consolidated Oil & Gas No. 4 Tribal C	1750 FNL, 900 FEL 6-26N-3W	12/80	8,365	gas	7,655-7,681	Gallup (Cretaceous)	12,436 MCFG + 363 BO + 398 BW	77,703 MCFG + 1,613 BO
Amoco Production Co. No. 4 Jicarilla Apache Tribal 151	820 FNL, 1600 FWL 3-26N-5W	1/83	7,749	oil	6,584-7,000	Gallup (Cretaceous)	14 BO	14 BO
Caulkins Oil No. 102 Beech E	660 FSL, 1980 FWL 5-26N-6W	7/75	6,770	gas	6,502-6,548	Gallup (Cretaceous)	5,736 MCFG	52,243 MCFG + 125 BO
Caulkins Oil No. 629 Beech A	660 FSL, 760 FWL 9-26N-6W	9/75	6,628	gas, abd	6,390-6,448	Gallup (Cretaceous)	0	84,014 MCFG + 116 BO
Northwest Production No. 1-16 NE	1800 FSL, 990 FWL 16-27N-2W	4/57	7,365	gas, abd	7,210-7,346	Gallup (Cretaceous)	0	25,978 MCFG + 125 BO
Continental Oil Corp. No. 3 Conoco 29-4	1820 FSL, 970 FWL 28-29N-4W	5/78	8,136	gas	7,583-8,037	Gallup	1,993 MCFG	25,978 MCFG
Southland Royalty No. 1 Chicosa Canyon	830 FSL, 1100 FWL 35-31N-4W	8/81	8,718	gas	7,532-7,643	Gallup (Cretaceous)	3,281 MCFG + 19 BW	8,287 MCFG
Amoco Production Co. No. 67 Rosa unit	1520 FNL, 1510 FEL 14-31N-6W	2/82	8,126	gas	7,194-7,614	Gallup (Cretaceous)	11,561 MCFG	16,119 MCFG
Northwest Pipeline No. 91 San Juan 30-5 unit	1960 FSL, 835 FWL 25-30N-5W	11/83	8,033	gas	7,943-7,956	Dakota (Cretaceous)	35,411 MCFG	35,411 MCFG

TABLE 3 - Cumulative oil and gas production by stratigraphic unit in Rio Arriba County. Does not include associated gas produced from oil pools. Data compiled from New Mexico Oil & Gas Engineering Committee (1985).

Stratigraphic unit	Cumulative production to 12/31/84		Percent of oil produced in W. Rio Arriba County	Percent of gas produced in W. Rio Arriba County
	Oil, bbls	gas, million cubic ft		
Nacimiento (Tertiary)	179	338	0.001	0.01
Fruitland (Cretaceous)	0	54	0	0.001
Pictured Cliffs (Cretaceous)	272,749	1,183,154	0.5	30.0
Chacra (Cretaceous)	18,348	106,429	0.04	2.5
Mesaverde (Cretaceous)	5,325,254	1,793,636	10.3	42.4
Point Lookout (Cretaceous)	0	3	0	0.0001
Gallup (Cretaceous)	13,805,922	60,416	26.8	1.4
Gallup, lower Mancos, and Dakota (Cretaceous), commingled	9,531,133	0	18.5	0
Dakota (Cretaceous)	9,021,445	1,085,177	17.5	25.7
upper Mancos (Cretaceous)	11,714,176	0	22.8	0
lower Mancos (Cretaceous)	1,793,176	0	3.5	0
TOTAL	51,482,296	4,229,207		

0.01% of the gas that has been produced from Rio Arriba County. Nacimiento reservoirs are fluvial channel sands.

Fruitland pools--One well, the El Paso Natural Gas No. 3 Howell (Fig. 18; Table 2), has produced from the Fruitland Formation (Cretaceous) in an undesignated gas pool in Rio Arriba County. Two gas pools, the Cottonwood and the La Jara (Fig. 18; Appendix 2), have been discovered in the Fruitland but were abandoned before commercial production was established. The Fruitland has produced 0.001% of the gas produced in Rio Arriba County.

Fruitland pools are stratigraphic traps. Reservoirs are lenticular channel sandstones that are generally less than 10 ft thick. A single well may produce from several sandstone lenses and net pay may be 50 ft or more.

Pictured Cliffs pools--Eight gas pools have produced from the Pictured Cliffs Sandstone (Cretaceous) in Rio Arriba County (Fig. 13; Appendix 2). Four wells have produced gas from undesignated Pictured Cliffs gas pools (Fig. 13; Table 2). No Pictured Cliffs oil pools have been discovered in Rio Arriba County, but a relatively minor amount of oil is produced from the gas pools (Table 3). Pictured Cliffs gas pools are: Ballard, Blanco, East Blanco, South Blanco, Choza Mesa, Gavilan, Gobernador, and Tapacito. Pictured Cliffs pools have produced 30% of the gas and 0.5% of the oil produced in Rio Arriba County.

Pictured Cliffs pools are combination stratigraphic and hydrodynamic traps. Reservoirs are northwest-trending bar-shaped sandstones. The stratigraphic trapping is modified by

hydrodynamic mechanisms (Silver, 1968). Groundwater is recharged through Pictured Cliffs outcrops at the basin margins; hydrodynamic forces help confine gas to the basin center. Pictured Cliffs reservoirs are very fine- to medium-grained sandstones, that are interbedded with shales and coals. Porosity is 0-20% and permeability is 0.1-5.5 millidarcies. Gross reservoir thickness is 30-300 ft; average net pay for individual gas pools ranges from 25 to 50 ft. Because of low permeability, Pictured Cliffs reservoirs must be artificially fractured before gas can be produced economically. Pictured Cliffs gas is sweet.

Mesaverde pools--Two pools, the Blanco Mesaverde gas pool and the Devils Fork Mesaverde oil pool, produce oil and gas from the Mesaverde Group (Cretaceous) in western Rio Arriba County (Fig. 14; Appendix 2). The Galloway No. 1 Myers, located in sec. 35, T. 25 N., R. 3 W. (Fig. 14; Table 2) produces from an undesignated Mesaverde gas pool. The Mesaverde has produced 42.4% of the gas and 10.3% of the oil produced in Rio Arriba County (Table 3).

Mesaverde pools are combination stratigraphic and hydrodynamic traps. Reservoirs are the Cliff House and Point Lookout Sandstones and sandstones in the Menefee Formation. Cliff House and Point Lookout reservoirs are northwest-trending shoreline sandstones. Menefee reservoirs are lenticular nonmarine sandstones that are interbedded with shales and coals. Stratigraphic trapping is modified by hydrodynamic mechanisms (Silver, 1968). Groundwater is recharged through Cliff House and Pictured Cliffs outcrops at the basin margins; hydrodynamic

forces help confine the gas to reservoirs in the basin center.

Mesaverde sandstones are fine grained. Permeability is low. The gross thickness of productive strata is more than 1,000 ft in some wells, but net pay is generally less than 200 ft. Because of low permeability, Mesaverde reservoirs must be artificially fractured before gas can be produced economically. Mesaverde gas consists of approximately 99% hydrocarbons. Mesaverde gas is sweet. The gravity of Mesaverde oil is variable, ranging from 33° to 60° API.

Chacra pools--Two gas pools, Adobe and Otero, produce oil and gas from the Chacra-producing interval (Cretaceous) in Rio Arriba County (Fig. 14; Appendix 2). Two wells produce from undesignated Chacra gas pools (Fig. 14; Table 2; Hoppe, 1978b). The Chacra producing interval has been defined by the New Mexico Oil Conservation Division as that part of the Lewis Shale that is 0-750 ft below the Huerfanito bentonite. The La Ventana Tongue of the Cliff House Sandstone is part of the Chacra producing interval. The Chacra has produced 2.5% of the gas and 0.04% of the oil produced in Rio Arriba County (Table 3).

Chacra gas pools are stratigraphic traps. Reservoirs are northwest-trending bar-shaped or shoreline sandstones. The sandstones are fine- to very fine-grained and shaly. Chacra pools have an average net pay of 20-30 ft. Porosity is 6-12% and permeability is 0.15-0.3 millidarcy. Because of low permeability, Chacra reservoirs must be artificially fractured before oil and gas can be produced economically. Chacra gas consists of more than 95% hydrocarbons. Chacra gas is sweet.

Upper Mancos pools--Three oil pools produce from the upper part of the Mancos Shale in Rio Arriba County. Upper Mancos oil pools are: Gavilan, East Puerto Chiquito, and West Puerto Chiquito (Fig. 15; Appendix 2). Upper Mancos pools have produced 22.8% of the oil produced in Rio Arriba County (Table 3). Upper Mancos reservoirs may be partial, distal equivalents of the Gallup (basal Niobrara) sandstones.

Upper Mancos pools are fractured traps. Reservoirs are fractured shales. Gross thickness of the productive shale is typically 250 ft. Production is from discrete, stratigraphically defined, fractured zones within the gross productive unit. At the East Puerto Chiquito and West Puerto Chiquito Pools, fracturing does not appear to be associated with anomalous structural flexures, but rather, occurs on west-dipping monoclines. Gravity of upper Mancos oil is 34-40° API.

Gallup (basal) Niobrara) pools--Eight oil pools and nine gas pools produce from the Gallup Sandstone (Cretaceous) in Rio Arriba County (Fig. 16; Appendix 2). Gallup oil pools are: South Blanco, Counselors, Devils Fork, Escrito, Lybrook, Otero, Regina, and Tapacito. Gallup gas pools are: BS Mesa, Cabrestro, Campo, Choza Mesa, Laguna Seca, Largo, Lindrith, Rosa, and Wildhorse. Two wells have produced from undesignated Gallup oil pools (Fig. 16; Table 2). Seven wells have produced from undesignated Gallup gas pools (Fig. 16; Table 2). Gallup pools have produced 26.8% of the oil and 1.4% of the gas produced in Rio Arriba County (Table 3).

The true Gallup Sandstone is not the reservoir for the Gallup pools. The reservoirs are transgressive, offshore basal Niobrara (Tocito) sand bodies that are younger than the true Gallup Sandstone (Molenaar, 1973); they are separated from the true Gallup by the basal Niobrara unconformity and generally occur basinward (northeast) of the true Gallup. The basal Niobrara sand bodies are generally referred to as "Gallup" because of early stratigraphic miscorrelations in the San Juan Basin.

Most Gallup oil and gas pools are stratigraphic traps. The traps are formed by northwest-trending, linear, offshore-marine sand bodies that are sealed by Mancos shale. At some pools, anticlinal or monoclinal flexure has modified the fundamental stratigraphic trapping mechanism. At some pools, the basal Gallup reservoirs are northwest-trending, strike-valley marine sands (McCubbin, 1969). Productive Gallup is 10-400 ft thick; net pay is 5-125 ft of very fine- to coarse-grained sandstone. Average porosity of individual reservoirs ranges from 9 to 18%. Permeability ranges from less than 1 to 250 millidarcies. Gallup reservoirs with low permeability must be artificially fractured before oil and gas can be produced economically. Gallup reservoirs with higher permeability may produce economic quantities of oil and gas without artificial fracturing.

Four Gallup pools in Rio Arriba County are fractured traps: Campo (gas), Rosa (gas), Choza Mesa (gas), and Regina (oil). Reservoirs are fractured shales, siltstones, and fine-grained sandstones. Matrix permeability is low. Natural fractures are presumably related to tectonic flexure.

Gallup oil has a low sulfur content. In oil pools, oil gravity is 39-46° API. In gas pools, gravity is 38-65° API. Gallup gas is sweet and consists of 98-99% hydrocarbons.

Lower Mancos pools--One pool, the Boulder Mancos Oil pool (Fig. 17; Appendix 2), has produced oil and gas from the lower Mancos Shale (Cretaceous). The lower Mancos is that part of the Mancos Shale which is below the basal Niobrara unconformity. The Boulder Mancos Oil pool is a fractured trap (Needham, 1973). The trap is formed by fractured shales on a west-dipping monocline. Oil gravity is 37° API. The Boulder Mancos pool has produced 3.5% of the oil produced in Rio Arriba County.

Dakota pools--One gas pool and 3 oil pools produce from the Dakota Sandstone (Cretaceous) in Rio Arriba County (Fig. 18; Appendix 2). The gas pool is the Basin Dakota pool. The oil pools are: Gallo, Lindrith, and Wildhorse. One well, the Northwest Pipeline No. 91 San Juan 30-5 unit (Fig. 18; Table 2), produces from an undesignated gas pool that is probably part of the Basin Dakota pool. Dakota pools have produced 25.7% of the gas and 17.5% of the oil produced in Rio Arriba County.

The Basin Dakota pool is a combined stratigraphic and hydrodynamic trap (Silver, 1968; Deischl, 1973; Hoppe, 1978a). Reservoirs are northwest-trending bar-shaped sandstones that were deposited on beaches and adjacent shallow-marine shelves. The bar-shaped reservoir sandstones are sealed by less-permeable shaly units. This stratigraphic aspect of the trap is modified by hydrodynamic forces.

At the Basin pool, the productive zone in the Dakota consists of 200-350 ft of fine-grained sandstones, shales, conglomerates, and coals (Hoppe, 1978a). Net pay is 50-70 ft of sandstone and conglomerate. Matrix permeability is 0.1-0.25 millidarcy, but is enhanced by natural fractures. Because of low permeability, Dakota reservoirs must be artificially fractured before oil and gas can be produced economically. Basin Dakota gas consists of more than 94% hydrocarbons. Basin Dakota oil has a gravity of 50° API.

Gallup lower Mancos, and Dakota pools--Four oil pools have produced from two or more of the following stratigraphic units: Gallup sandstone, Juana Lopez sandstone, Greenhorn Limestone, Graneros Shale, and Dakota Sandstone. The four pools are (Fig. 17; Appendix 2): Gavilan Gallup oil pool, South Lindrith Gallup-Dakota oil pool, West Lindrith Gallup-Dakota oil pool, and Ojito Gallup-Dakota oil pool. Those four oil pools have produced 18.5% of the oil produced in Rio Arriba County (Table 3).

The major trapping mechanisms in the Gallup and Dakota are stratigraphic. Oil and gas in the Juana Lopez, Greenhorn, and Graneros are trapped by fractures that act in conjunction with stratigraphic or structural variations. Oil gravity is 40-46° API in the Gavilan, South Lindrith, and West Lindrith pools. Oil gravity is 72° API in the Ojito Pool.

Petroleum Resource Potential

Five key factors were analyzed in order to evaluate the petroleum potential of western Rio Arriba County: commercial accumulations of petroleum, source rocks, reservoirs, traps, and

preservation of petroleum that has been generated and trapped. The petroleum potential is evaluated based on geologic analyses of the five factors.

The potential for petroleum occurrence in an area is classified as high if geologic analyses indicate that reservoirs and traps are present in that area. Source rocks must be present unless analyses indicate that reservoirs in the area lie along migration paths that connect those reservoirs to source rocks that exist outside the area. Geologic analyses must also indicate that petroleum which has been generated has been preserved. Furthermore, a classification of high in a basin or on an uplift is only warranted if there is petroleum production elsewhere in that basin or on that uplift, or if known but undeveloped commercial petroleum accumulations have been proven to exist (usually by drilling) in that basin or on that uplift.

The potential for petroleum occurrence in an area is classified as moderate if geologic analyses indicate that reservoirs and traps are present unless analyses indicate that reservoirs in the area lie along petroleum migration paths that connect those reservoirs to source rocks that exist outside the area. A moderate classification differs from a high classification because a basin or uplift may be assigned a moderate classification even though there are not any known petroleum accumulations in that basin or on that uplift. Part of a producing basin may be assigned a moderate potential for petroleum occurrence if reservoirs, traps, or source rocks are present to only a limited extent or if there is doubt that

petroleum has been preserved.

The potential for petroleum occurrence in an area is classified as low if geologic analyses indicate that source rocks, reservoirs, and traps are questionably present in that area, but the analyses also indicate stratigraphic units in that area are known to contain source rocks and reservoirs elsewhere. An area may also have a low classification if source rocks, reservoirs, and traps are probably present but if geologic analyses indicate that petroleum has almost certainly not been preserved.

The potential for petroleum occurrence in an area is classified as very low if geologic analyses indicate that source rocks, and more importantly, reservoirs are probably not present in that area. A classification of very low is almost always reserved for areas of outcropping Precambrian igneous or metamorphic rocks that have not been thrust over a Phanerozoic section that might have petroleum potential. A classification of very low is also assigned for areas where extensive intrusive volcanism has occurred, such as in a volcanic caldera.

Most of the western Rio Arriba County is assigned a high potential for petroleum occurrence (Fig. 19). Major oil and gas pools are known to exist in the county (Figs. 12-18). Source units of oil and gas have been documented in the Cretaceous section and may exist in the Jurassic and upper Paleozoic sections. Cretaceous reservoirs are present throughout western Rio Arriba County. Jurassic and upper Paleozoic reservoirs may be present throughout large parts of the county. It is also known that structural, stratigraphic, hydrodynamic, and fractured

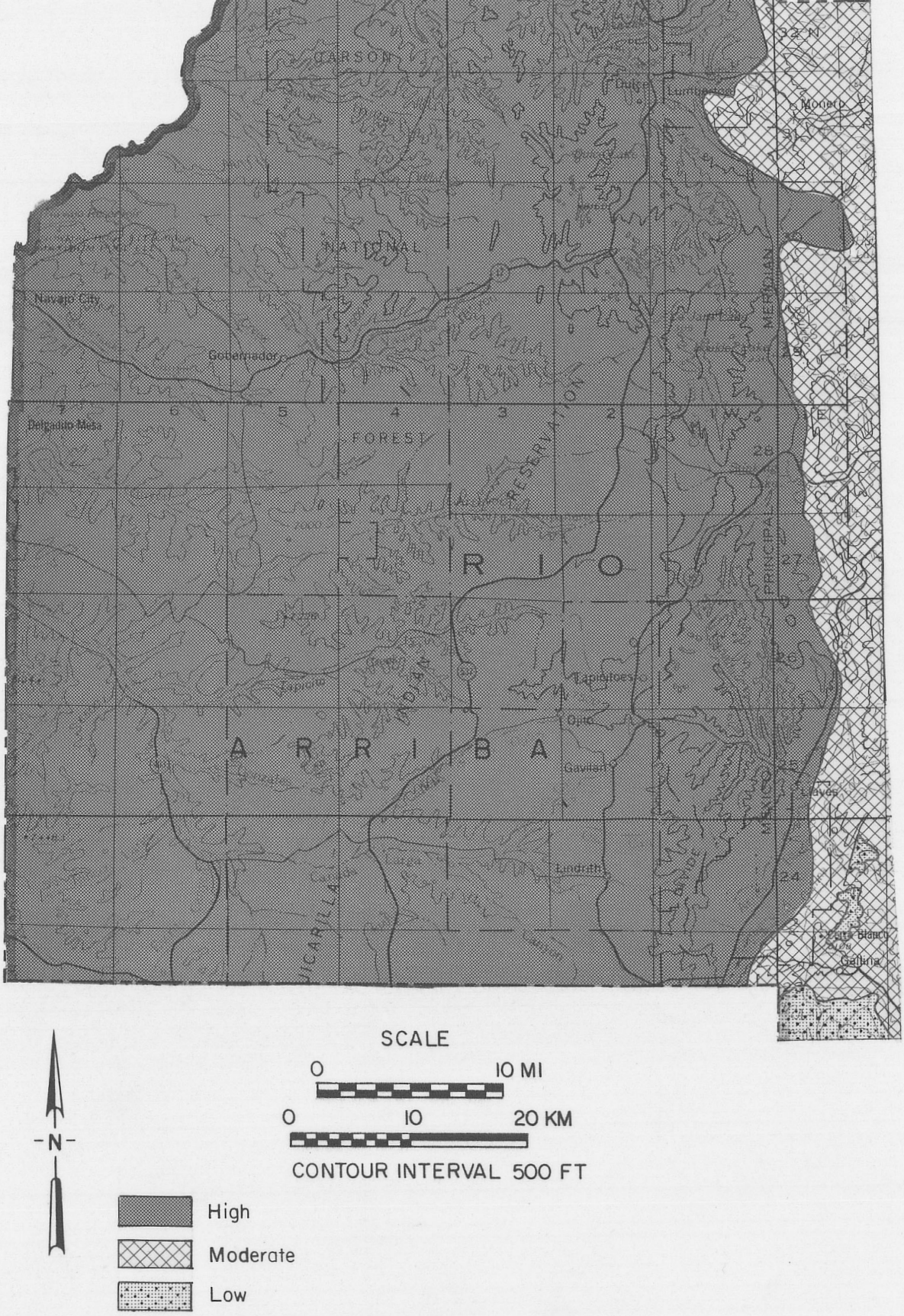


Figure 19. Potential for petroleum occurrence in western Rio Arriba County, New Mexico.

traps exist. Oil and gas that have been generated and trapped within western Rio Arriba County have been preserved.

Source rocks of oil and gas are believed to exist in western Rio Arriba County. Marine Mancos (Cretaceous) shales are considered the source of oil that is produced from several pools in the Mesaverde, Gallup, lower Mancos, and Dakota of the San Juan Basin (Ross, 1980). Marine Mancos shales are present throughout most of the subsurface of western Rio Arriba County, but their thermal maturity and kerogen content have not been analyzed. However, the presence of several oil pools in Mancos, Gallup, and Dakota reservoirs indicates that Mancos source rocks exist in Rio Arriba County. Those source rocks have probably been matured to the oil-generation stage in at least part of Rio Arriba County. It is possible that Mancos source rocks have been matured past the stage of oil generation and preservation in northwest Rio Arriba County where burial depths are greater and heat flow is higher (Reiter and Clarkson, 1983). Similar relationships may apply to the Lewis Shale (Cretaceous).

Shales in the nonmarine Mesaverde Group (Cretaceous) are sources of oil and gas in the San Juan Basin. The Mesaverde appears to be the source of nonassociated gas that is produced from the Point Lookout and Cliff House Sandstones (Rice, 1983). The Mesaverde may be a source of oil produced from Dakota reservoirs in western San Juan County, although it is possible that Dakota oil was generated in the nonmarine, lower part of the Dakota (Rice, 1983).

The Dakota produces mostly nonassociated gas. That

nonassociated gas is believed to be the product of thermal cracking of reservoired oil at high temperatures (Rice, 1983). The high temperatures are a result of: (1) relatively deep burial in the northern part of the San Juan Basin, and (2) heat emitted from Oligocene volcanics in the San Juan volcanic field of southwest Colorado.

The Fruitland Formation (Cretaceous) is another source unit in the San Juan Basin. Fruitland coals overlie the Pictured Cliffs Sandstone (Cretaceous) and appear to be the source of nonassociated gas produced from the Pictured Cliffs (Rice, 1983).

Fetid limestones of the Todilto Formation (Jurassic) are the source of oil produced from the Entrada Sandstone (Jurassic) in the San Juan Basin (Vincelette and Chittum, 1981; Ross, 1980). Entrada oil pools are located in southeast San Juan County, northeast McKinley County, and northwest Sandoval County. Visual kerogen analyses and pyrolysis indicate the Todilto has been matured to the stage of oil generation in southwest Rio Arriba County (Vincelette and Chittum, 1981). The Todilto has been matured to the stage of condensate and gas generation in northwest Rio Arriba County. Higher levels of maturation in the northwest part of the county are the result of deeper burial depths and high heat flows associated with the San Juan volcanic field of southwest Colorado.

Limestones and gray to black shales in the Pennsylvanian section are possible source rocks in western Rio Arriba County. The organic geochemistry of Pennsylvanian units in the San Juan Basin has not been documented. The presence of 13 oil and gas pools in the Pennsylvanian of San Juan County indicates that

Pennsylvanian source rocks are present in the San Juan Basin.

Reservoir rocks of oil and gas are known to exist in western Rio Arriba County. Upper Cretaceous sandstones and fractured shales are prolific producers of oil and gas. Possible reservoirs in the productive and nonproductive parts of the county are Cretaceous sandstones and shales, the Entrada Sandstone (Jurassic), Triassic sandstones, Permian, and Pennsylvanian sandstones and carbonates, and Mississippian carbonates. Upper Cretaceous units are primary reservoir targets for two reasons. First, they are prolific producers of oil and gas in western Rio Arriba County and in adjacent San Juan, McKinley, and Sandoval Counties. Second, Upper Cretaceous sandstones have intercalated and intertonguing relationships with shaly Cretaceous source units: Mesaverde shales, the Mancos Shale, and the Lewis Shale. The Mancos Shale may be the source rock at oil pools that have a reservoir of fractured Mancos shale.

Primary Cretaceous reservoir targets are the Pictured Cliffs Sandstones, the Mesaverde Group, the Mancos Shale, the Gallup Sandstone, and the Dakota Sandstone. All five units are prolific producers of oil and gas in Rio Arriba County.

The Pictured Cliffs Sandstone is well developed throughout most of western Rio Arriba County (Stone et al., 1983). The Pictured Cliffs consists of shoreface, estuarine, lagoonal, and inner-shelf sandstones (Finley, 1984). The Pictured Cliffs was deposited in a progradational strand plain system and sandstone reservoirs have widespread lateral continuity.

Sandstones of the Mesaverde Group are present throughout most of western Rio Arriba County (Stone et al., 1983). The most significant and widespread Mesaverde reservoirs are the Point Lookout and Cliff House Sandstones. The Point Lookout is a widespread, regressive shoreline sandstone formed by strand line and deltaic progradation (Finley, 1984). Individual sandstone beds have wide lateral continuity. The Cliff House is a transgressive sandstone. Continuity of reservoirs does not appear to be as good as in the Pictured Cliffs (Finley, 1984).

The best Gallup reservoirs are northwest-trending offshore marine bars that produce in San Juan County and in southwest Rio Arriba County at the South Blanco, Tapacito, BS Mesa, Wildhorse, Escrito, and Lybrook Pools (Fig. 16). Although the best Gallup reservoirs are developed along a northwest trend that passes through southwest Rio Arriba County, oil and gas have been produced from the Gallup in central and northern Rio Arriba County, where Gallup sediments are finer grained and more basinal (Reese, 1977). Therefore, it appears that Gallup reservoirs are present throughout the subsurface of western Rio Arriba County.

Detailed stratigraphic and hydrologic studies (Stone et al., 1983) indicate that the Dakota Sandstone is well developed throughout western Rio Arriba County. The Dakota of the San Juan Basin consists of fluvial, deltaic, and coastal sand deposits (Owen, 1973). Both marine and nonmarine Dakota facies produce oil and gas in the San Juan Basin, but the upper marine part of the Dakota produces the most. The lower nonmarine part of the Dakota is generally saturated with water (Hoppe, 1978a).

The Mancos Shale is present throughout the subsurface of

western Rio Arriba County. Relatively impermeable sandy zones are reservoirs in the Mancos (Reese, 1977). Because of low matrix permeability, natural fractures must be present if economic levels of production are to be established. Presumably, the fractures were formed by tectonic fracture of brittle shale (Gorham et al., 1977). Fractures will remain open only in brittle shales, which generally are sandy or dolomitic. Plastic shales above and below the brittle zones will seal the reservoir.

The Entrada Sandstone (Jurassic) is a primary reservoir target in western Rio Arriba County. The Entrada is a fine- to medium-grained aeolian sandstone. Available data indicate it is porous and permeable only in southwestern Rio Arriba County (Vincelette and Chittum, 1981). In central and northern Rio Arriba County, compaction and silica cementation have rendered the Entrada nonporous and impermeable.

Paleozoic reservoirs are important targets in western Rio Arriba County. Few wells have drilled and tested the Paleozoic section in the San Juan Basin. Therefore, the reservoir quality of Paleozoic units is not well documented.

Permian units that may be good reservoirs are the Glorieta Sandstone, the Meseta Blanca Member of the Yeso Formation, and the Abo Formation. Permian reservoirs have a limited petroleum potential in the San Juan Basin because the Permian is apparently devoid of petroleum source rocks. The Glorieta is a fine- to medium-grained sandstone. It is present in the southern tier of townships covered by this report, where it has a maximum thickness of 50 ft (Baars and Stevenson, 1977). The Glorieta

pinches out to the north. Peterson et al. (1965) indicate that the Glorieta is a nonporous unit in Rio Arriba County. The Meseta Blanca is a fine-grained, clean aeolian sandstone. It is present in southwest Rio Arriba County, where it has a maximum thickness of 300 ft (Baars and Stevenson, 1977). The Meseta Blanca grades northward into sandstones and shales of the Cutler Formation. The Abo Formation is present in southwest Rio Arriba County, where it has a maximum thickness of 1,800 ft (Baars and Stevenson, 1977). The Abo grades northward into sandstones and shales of the Cutler Formation. The Abo consists of interbedded, red, fine- to coarse-grained arkosic sandstones, siltstones, and shales. Some Abo sandstones exhibit good porosity in drill cuttings (Peterson et al., 1965). Thickness of the total Permian section in west-central and northwest Rio Arriba County ranges from 1,400 to 2,000 ft (Peterson et al., 1965). Most of that section belongs to the Cutler Formation. Cutler sandstones may be porous reservoirs. The Cutler contains a maximum of 100 ft of porous sandstone in western Rio Arriba County (Peterson et al., 1965).

The Pennsylvanian section in western Rio Arriba County is virtually untested. Therefore, the reservoir properties of Pennsylvanian units are poorly known. The Pennsylvanian section has a maximum thickness of 2,500 ft in western Rio Arriba County (Jentgen, 1977). Pennsylvanian strata thin eastward to less than 500 ft in R. 1 E. as they onlap the late Paleozoic Uncompaghre uplift. Productive Pennsylvanian reservoirs in San Juan County are limestones; porous zones are coral and algal bioherms. Sandstones are other possible Pennsylvanian reservoirs.

The Leadville Limestone (Mississippian) is a secondary reservoir target. Armstrong and Mamet (1977) indicate it is present in western Rio Arriba County, where it has a maximum thickness of approximately 150 ft. It is erosionally truncated to the east as it onlaps the late Paleozoic Uncompaghre uplift. Reservoir properties of the Leadville are poorly known. Generally, the Leadville appears to be a dense, finely crystalline limestone. In San Juan County, the Leadville produces relatively minor amounts of carbon dioxide, helium, and oil. The Leadville produces significant quantities of carbon dioxide at McElmo dome in southwest Colorado; McElmo dome contains estimated reserves of 10 trillion ft^3 of carbon dioxide (Wash, 1984).

Possible traps in western Rio Arriba County are stratigraphic, hydrodynamic, fractured, and structural. All four types of traps are known to exist in the Cretaceous section. Most of the oil and gas produced in Rio Arriba County is trapped stratigraphically and hydrodynamically. Facies changes in the Cretaceous section have probably formed undiscovered stratigraphic traps. Undiscovered structural traps may also exist in the Cretaceous section. Structural warps on monoclines, combined with facies variations, may also form traps. Undiscovered fractured traps may exist in the Mancos and Lewis Shales. Fractures are formed on structural flexures.

Undiscovered stratigraphic traps may exist in the Entrada Sandstone (Jurassic). In the San Juan Basin, oil is trapped stratigraphically in the Entrada by closure formed on aeolian

sand dunes (Vincelette and Chittum, 1981). The Entrada is sealed by overlying impermeable anhydrites of the Todilto Formation (Jurassic). Vincelette and Chittum (1981) indicate that undrilled Entrada traps may be present in southwest Rio Arriba County.

Undiscovered structural traps may exist in the Paleozoic section. Known Paleozoic oil and gas pools in San Juan County are structural traps. However, the association of porous zones with bioherms in the Pennsylvanian section indicates that undiscovered stratigraphic traps may exist. Facies variations associated with deltaic and shallow-marine Pennsylvanian sands may also form stratigraphic traps. The Paleozoic section has not been drilled sufficiently to establish depositionally dependent porosity zonations.

Most petroleum that has been generated and trapped in western Rio Arriba County has probably been preserved. Throughout the county, geologic conditions are similar in both productive and nonproductive areas. Reservoirs may be flushed in areas close to where they crop out. Even in those areas, however, petroleum accumulations may be preserved by depositional or diagenetic permeability barriers. Intense volcanism and tectonism that could have destroyed petroleum accumulations are not apparent, except in the northernmost part of Rio Arriba County. There, the Paleozoic section has been subjected to high temperatures caused by deep burial and proximity to the San Juan volcanic field of southern Colorado. The temperatures in the Paleozoic section may have exceeded the preservation limits of oil and gas (Reiter and Clarkson, 1983).

The Tertiary igneous intrusive bodies and dikes in northwest Rio Arriba County are poor reservoirs. The intrusive located five miles north of Dulce may have thermally degraded oil and gas that were trapped before those rocks were intruded.

The western part of Rio Arriba County is assigned a high potential for petroleum occurrence (Fig. 19). Petroleum potential is considered to be high for five reasons. First, the Cretaceous section is a prolific producer of oil and gas. Second, source rocks are thought to be present in Fruitland Formation, Mesaverde Group, Lewis Shale, Mancos Shale, Dakota Sandstone, and Todilto Formation; Pennsylvanian shales and limestones are possible, but undocumented, source rocks. Third, the entire area of high potential is underlain by Cretaceous, Jurassic, or Paleozoic reservoirs. Fourth, favorable stratigraphic, hydrodynamic, fracture, and structural trapping mechanisms are present. Fifth, most petroleum that has been generated and trapped has probably been preserved. The probability of petroleum occurrence decreases to the east because of erosional truncation of reservoirs at the ground surface and because of proximity to outcrops of reservoir units; reservoir units may be flushed by ground water in areas close to where they crop out.

Petroleum potential is considered to be moderate, and not high, east of the outcrop belt of the Point Lookout Sandstone. Geologic conditions are similar to those west of the Point Lookout outcrop belt except that fewer Cretaceous reservoirs are present and Cretaceous and Jurassic reservoirs may have been flushed by ground water. There is still good petroleum potential

in the upper Paleozoic section.

Potential for petroleum occurrence is low where Permian and Pennsylvanian sedimentary rocks crop out in the southeast part of the study area. Possible reservoirs are Permian sandstones and Pennsylvanian limestones and sandstones. Mesozoic reservoirs are absent. The Paleozoic section is thin. Because it crops out, it may not have been flushed by ground water.

The Tertiary intrusive center located five miles north of Dulce is assigned a moderate petroleum potential for two reasons. First, heat emitted from that intrusion may have destroyed petroleum that had been trapped in adjacent reservoirs. Second, the intrusive igneous rocks are probably poor reservoirs. However, fractures and vesicles within the igneous body may have trapped petroleum that migrated into the intrusion after it had cooled; this has occurred at the Dineh-bi-Keyah oil pool of northeast Arizona (Danie, 1978).

Several north-trending igneous dikes of Tertiary age are present in north-central Rio Arriba County (Dane and Bachman, 1965). The area occupied by those dikes is assigned a high potential for petroleum occurrence. That area is sparsely drilled but produces some gas from the Pictured Cliffs Sandstone (Fig. 13) and the Dakota Sandstone (Fig. 18). The geology is similar to productive areas of the county, although temperatures are higher because of proximity to the San Juan volcanic field. The dikes probably did not emit enough heat to thermally destroy significant amounts of petroleum that had been trapped prior to dike intrusion.

POTENTIAL FOR DEVELOPMENT

Petroleum is a marketable commodity that will be in great demand well into the twenty-first century. The major uses of petroleum are: (1) a major energy source and (2) feedstock for the petrochemical industry. Because of the great long-term demand for petroleum and the critical role that petroleum plays in the transportation and industrial sectors of the United States, any accumulations of commercial size discovered in the future from Rio Arriba County will almost certainly be developed and produced. Oil pools are readily developed because oil can be conveniently shipped by trucks from the wellsite to the refinery. The transportation of natural gas from the wellsite to the gas processing plant and the consumer is almost always through an underground pipeline. Therefore, gas pools are not developed as readily as oil pools unless there is a pre-existing pipeline close to the gas pool. The presence of several large gas pipelines in western Rio Arriba County (U.S. Geological Survey and New Mexico Bureau of Mines and Mineral Resources, 1981) ensures that any gas pools that may be discovered will also be developed and produced.

Coal Resources

(by G. Roybal and K. Cook)

Introduction

Western Rio Arriba County contains one outcrop of Cretaceous coal-bearing sequence which has been designated as a recognized field. This field, named the Monero coal field, is delineated by the outcrop of coal-bearing Cleary Coal Member of the Menefee Formation. The only other known occurrences of coal in this area are deep (>250 ft) Fruitland and Menefee Formation coals. The Fruitland Formation is present in outcrop, but is predominately sandstone and siltstone along the Nacimiento uplift.

A general geologic description and known characteristics of coals is given for the Monero field and deep coals. Coal mining and past production is discussed for this field. Production figures for western Rio Arriba County and for individual mines and prospects are given in Table 4. Descriptions of individual mines and prospects are listed in Appendix 1.

Resource (minimum 1.2 ft bed thickness) and reserve figures (minimum 2.5 ft) as defined by Wood et al. (1983) are given in the text. The data are derived from point source data in the data base, which is continually updated as new information is acquired at the New Mexico Bureau of Mines and Mineral Resources. Appendices 3, 4, and 5 contain the raw data (except for confidential data) for both the resource and coal quality data given in the text. Resource potential for the Monero coal field and deep coals are shown graphically on Figure 20 and the accompanying 1:100,000 maps (Maps 75 and 76).

TABLE 4. Coal mine production from western Rio Arriba County.

Mine	Location	Total production (tons)
Angel	sec. 7, T.31N., R.1E.	4,600[1]; 3,600[2]
Kutz-Luchetti	sec. 7, T.31N., R.1E.	222,637[1]; 44,179[2]
Laing	sec. 7, T.31N., R.1E.	5,671[1,2]
Ray	sec. 7, T.31N., R.1E.	3,500[1]
Barne-Caranta	sec. 8, T.31N., R.1E.	17,899[1]; 11,000[2]
Tomacino-Davito	sec. 8, T.31N., R.1E.	6,280[1]
Monero	sec. 8, T.31N., R.1E.	359,808[1]; 301,700[2]
McBroom	sec. 17, T.31N., R.1E.	32,646[1]; 34,206[2]
Unknown (Christ)	sec. 17, T.31N., R.1E.	4,061[1]
Caranta (No. 14)	sec. 18, T.31N., R.1E.	185,238[1]
Monero and Erler	sec. 20, T.31N., R.1E.	142,133[1]
Rainbow	sec. 30, T.31N., R.1E.	144,281[1]
Amargo Knot No. 2	sec. 1, T.31N., R.1W.	10,007[1]
Burns and Biggs	sec. 8, T.31N., R.1W.	21,709[1,2]
Peisker Prospect	sec. 8, T.31N., R.1W.	385[1]
Lobato Prospect	sec. 9, T.31N., R.1W.	136[1]
Miller	sec. 8, T.31N., R.1W.	107,290[1]
Lumberton-Kutz-Garcia	sec. 10, T.31N., R.1W.	45,957[1]
Bellino Prospect	sec. 17, T.31N., R.1W.	260[1]
Bellino-Peisker	sec. 17, T.31N., R.1W.	32,428[1]
Kern	sec. 21, T.25N., R.1E.	2,500[1]
Sterling	3 mi. E. Monero	750[1]
Simers	?	4,195[1]
Caranta Brothers	T.31N., R.1E.	100[1]
Rio Arriba	sec. 7, T.31N., R.1E.	26,000[1]; 2,000[2]
Kutz	sec. 7, T.31N., R.1E.	91,006[2]
San Luis	?	1,000[2]
Peacock	?	106,356[2]
Luchetti and Crist	T.31N., R.1E.	12,997[2]
Western Fuels	sec. 20, T.31N., R.1E.	28,000[2]
Rio Arriba County (1926-1963)		1,000,963[2]

[1] Nickelson (in press)
[2] New Mexico State Mine Inspector's Reports (1895-1963)

Monero Field

General Description--The Monero field extends from the southern edge of T. 22 N., R. 1 E. to the Colorado-New Mexico state line (Fig. 20). It covers portions of T. 22-32 N., R. 1 W.-2 E., encompassing an area of 140 sq mi.

Beds of the Menefee Formation in this field dip at angles of

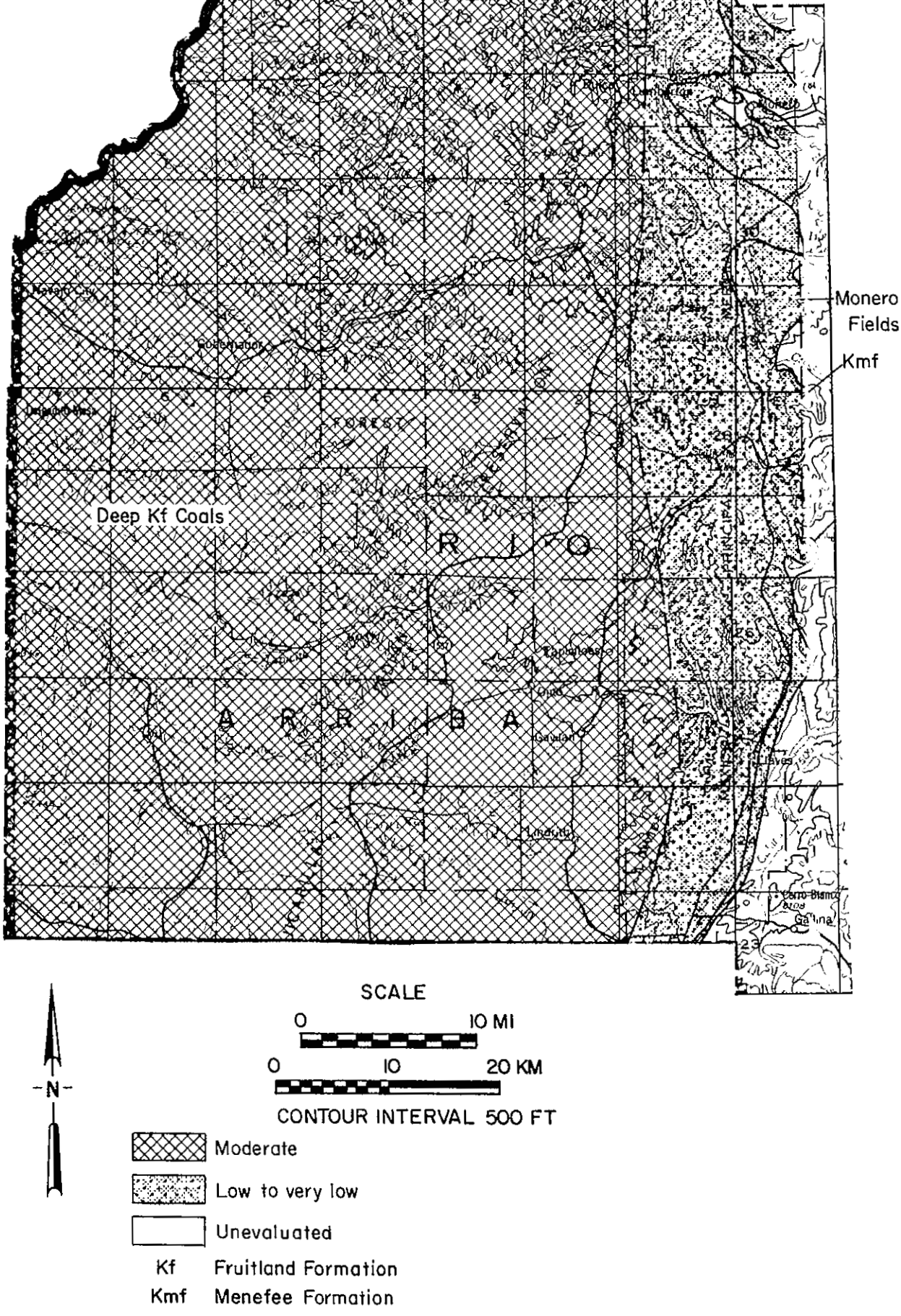


Figure 20. Coal resource potential in western Rio Arriba County, New Mexico.

5-10 degrees to the west. The northern portion of the field has several northwest trending faults near the towns of Monero and Lumberton.

TABLE 5 - Quality analyses for coals in western Rio Arriba County Monero Field.

	No.	Avg.	S.D.	Max.	Min.
Prox. Moisture:	43	3.60	3.09	17.40	1.50
Prox. Ash:	43	10.10	3.00	16.40	4.10
Volatile Matter:	42	37.65	1.68	40.57	32.70
Fixed Carbon:	42	49.98	2.06	55.10	45.10
Ult. Moisture:	13	4.15	1.92	7.20	1.70
Carbon:	13	69.02	5.72	75.40	55.90
Hydrogen:	13	5.39	0.14	5.60	5.20
Nitrogen:	13	1.48	0.15	1.70	1.10
Sulfur:	43	1.56	1.01	3.50	0.30
Org. S.:	0	0.00	0.00	0.00	0.00
Pyr. S.:	0	0.00	0.00	0.00	0.00
Sul. S.:	0	0.00	0.00	0.00	0.00
Ult. Ash:	13	7.16	2.31	10.40	4.10
Oxygen:	13	13.37	7.73	33.30	8.90
*Btu:	40	12682	902	13798	8972
**mmmf Btu:	40	14530	1107	14993	9388

S.D. = Standard deviation.
* Btu = British Thermal Unit; A calorific value
**mmmf Btu = Moist mineral matter free Btu; determines rank of coal

Coal-bearing sequences of the Menefee Cleary Coal Member are located along the back slope of a 1 to 3 mile wide cuesta, which extends along the entire length of the field (Shomaker, 1971). Most of the coal is covered by less than 250 ft of overburden. These coals are discontinuous and generally less than 5 ft thick.

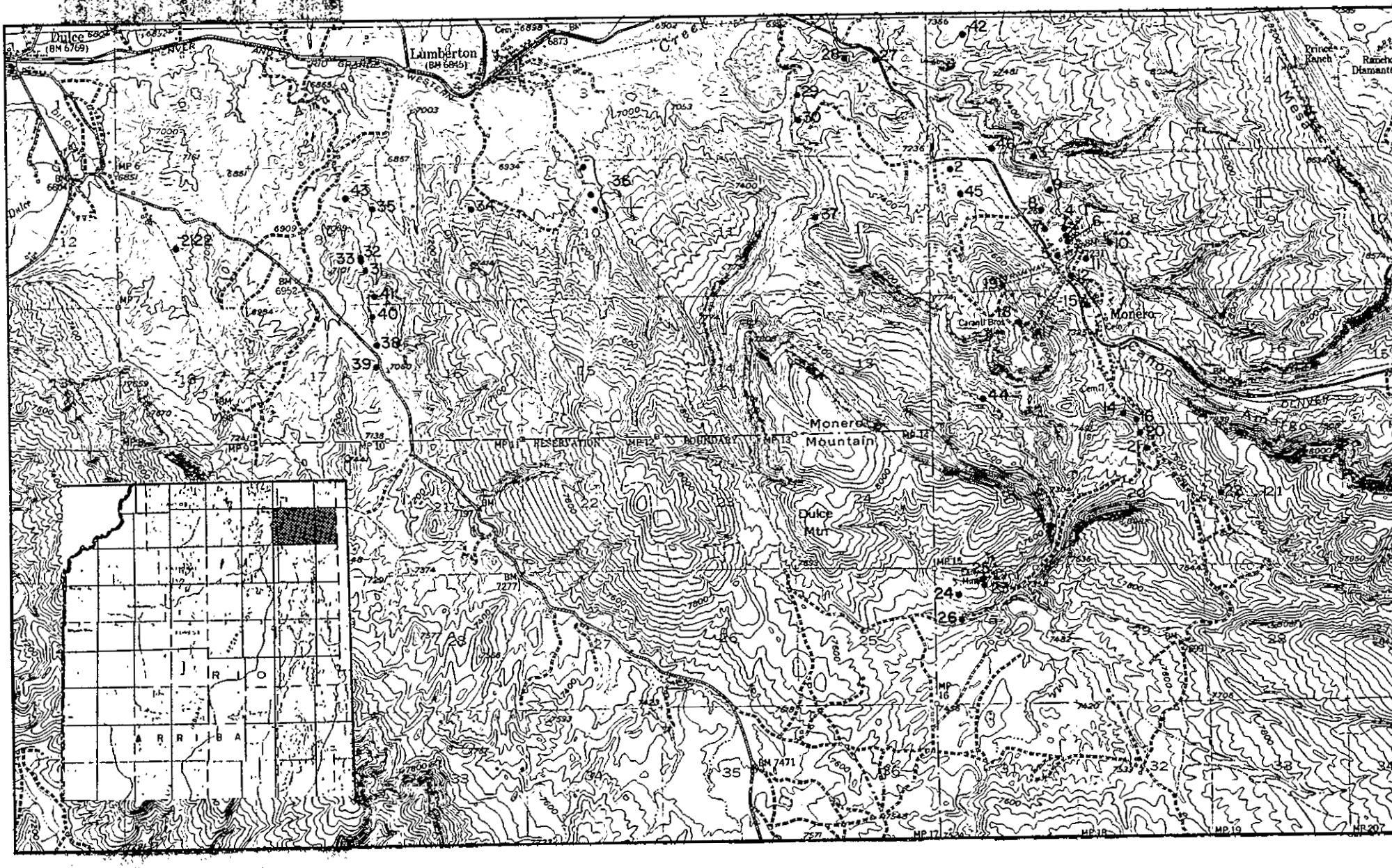
Averages of 43 samples are shown in Table 5. The averages for ash content, sulfur content, and mmmf (moist mineral matter free) Btu (British thermal unit) in the Monero field are 10.10%, 1.56%, and 14,530 Btu/lb, respectively. The mmmf Btu indicates

that the rank of the coals are high volatile A bituminous. In comparison to other Menefee coals (Table 6), the ash content is low, sulfur content is high, and the mmmf Btu is the highest for all Menefee coals in the Monero field.

TABLE 6. Quality analyses for all Menefee coals.

	No.	Avg.	S.D.
Prox. Moisture:	217	12.84	5.55
Fixed Carbon:	195	41.28	6.74
Prox. Ash:	217	11.10	6.10
Volatile Matter:	195	35.59	4.10
Ult. Ash:	134	12.21	7.26
Ult. Moisture:	122	14.94	4.21
Carbon:	134	56.85	7.96
Hydrogen:	133	4.68	0.88
Nitrogen:	134	1.08	0.34
Oxygen:	134	13.95	6.74
Total Sulfur:	214	1.06	0.74
Org. S.:	71	0.58	0.22
Pyr. S.:	70	0.32	0.34
Sul. S.:	40	0.05	0.10
Btu:	213	10595	1412
mmmf Btu:	213	12062	1340

Mining and Past Production--A number of small mines have operated in the Monero field in the past (Figure 21; Table 7). These mines are located in T. 31 N., R. 1 E.-1 W. Most of these mines operated from the 1890's through the 1930's, and the last mine in the area ceased operations in the 1960's. Most of the coal was used as steam coal by the Denver and Western Rio Grande Railroad, which served the towns of Lumberton and Monero (Shomaker, 1971). The remainder of coal mined in the Monero field was used for domestic purposes (Nickelson, in press). There is no mining activity at the present time in the Monero field. Table 4 shows estimates of total coal production for



Mines in Monero Coal Field, western Rio Arriba County, New Mexico.

mines in the Monero field.

Table 7 - Mines shown on Figure 21. Monero field map (as listed in Appendix 1).

1.	Angel Mine	26	Unknown
2.	Kutz-Luchetti, Peacock Mine	27.	Unknown
3.	Laing Mine	28.	Tafoya Prospect
4.	Ray Mine	29,30.	Amargo Knot No. 2 Mine
5.	Walker Caranta Mine	31.	Burns & Biggs Lumber Co. Mine
6.	Unknown	32.	Peisker Prospect
7.	Unknown	33.	Unknown
8.	Unknown	34.	Lobato Prospect
9.	Unknown	35.	Miller Mine
10.	Barne-Caranta Mine	36.	Lumberton-Kutz-Garcia Mine
11.	Tomacino-Davito Mine	37.	Castlelone Prospect
12,13.	Monero Mines	38.	Unknown
14.	McBroom Mine	39.	Cornell Prospect
15.	Peacock Coal Co. Prospect	40.	Bellino Prospect
16.	Unknown	41.	Belino-Peisker Mine
17-19.	Caranta Mines	42.	Sczerbiak Prospect
20,21.	Monero & Erler Mines	43.	Prospect
22.	Unknown	44.	Old Sims Mine
23-25.	Rainbow Mine	45,46.	Martinez Prospect

Resource and Development Potential--Resources and reserves were estimated for the Monero field using drill hole and outcrop data. The total resource estimate (minimum bed thickness = 1.2 ft) for this field at depths from 0-250 ft is 11.5 million tons. The total reserve estimate (minimum 2.5 ft) at these depths is 10.3 million tons. The coal resource potential for the Monero field is low because of the thinness and discontinuity of the coal beds and sparsity of data.

The development potential for the Monero field is also very low. Beds are too thin and discontinuous to be economically exploited using conventional mining methods. Access to the area is good, with State Highway 95 dissecting the south-central portion of the field and State Route 17 cutting across the northern end of the field.

Deep coals

General Description--Deep coals (>250 ft) have been observed in cuttings, cores, and geophysical logs from oil and gas drill holes. Shomaker and Whyte (1977) discuss the deep coals of the San Juan Basin, including western Rio Arriba County, and most of the information on deep coals in this report was obtained from their work.

Most of the known occurrences of deep coal in western Rio Arriba County are located in the Fruitland Formation, with minor amounts in the Menefee Formation. These coal-bearing sequences represent poorly-drained coastal swamp environments, which were deposited during regressive cycles of the Cretaceous seaway.

According to Shomaker and Whyte (1977) Fruitland Formation coals are overlain by as much as 4,000 ft of overburden in T. 28-30 N., R. 4-5 W. Overburden thickness gradually decreases to the north, south, west, and rapidly increases to the east.

Individual seams of Fruitland Formation coals are thickest (30 ft) in the deeper parts of the basin (T. 28-29 N., R. 4-5 W., and T. 29-30 N., R. 6 W.). These coals thin to 10-20 ft to the north and south, and disappear to the east T. 23-32 N., R. 1-2 W. The thickest total accumulation of Fruitland coal (70 ft) occurs in the west-northwest portion of the county. The cumulative thickness decreases to the south and east.

Fruitland Formation coals are hard, brittle, and black, with blebs of resin and veinlets of pyrite and marcasite (Shomaker and Whyte, 1977). Based on analyses of 67 samples collected throughout the basin Shomaker and Whyte (1977) describe these deep coals as low sulfur (<1%), high ash (>15%) coals. Fruitland

coals absolute Btu value ranges from 9,000 Btu/lb (subbituminous) in the southern end of the basin to 15,720 Btu/lb (bituminous) in the northwestern part of the basin (Shomaker and Whyte, 1971).

Deep coals in the Menefee Formation are difficult to correlate because of the lenticularity and thinness of beds, as well as the lack of closely spaced drill holes (Shomaker and Whyte, 1977). Menefee coals are covered by at least 4,500 ft of overburden in the extreme western portion of Rio Arriba County (T. 25-32 N., R. 6-8 W.). The thickness of coals in this area ranges from 5-10 ft. Information of overburden and coal thickness east of this area is lacking.

Quality analyses by Shomaker and Whyte (1977) for Menefee coals from the southern end of the San Juan Basin (northern Sandoval County) and the Monero field suggest that deep Menefee coals in western Rio Arriba County have ash contents between 6.3% and 12.0% and sulfur contents from <1% to 3.5%, with an average sulfur content near 1.5%. These data show heating values between 9,860 Btu/lb and 12,740 Btu/lb, indicating that the coal rank is probably high volatile C or B bituminous.

Resource and Development Potential--Total resources for the Fruitland and Menefee deep coals in Rio Arriba County with minimum thickness categories of 2.5, 5, and 10 ft are reported in Table 8. The resource potential for deep coals located in the Fruitland Formation is moderate in the western portion of western Rio Arriba County and low to very low in the eastern portion of the area. Drill hole data indicate that a significant amount of coal is present in the western portion of the county, but

thicknesses rapidly decrease to nonexistence to the east. The resource potential for Menefee coals is very low due to the lenticularity and thinness of beds and sparsity of data.

The development potential of all deep coals is very low for conventional uses. The depth of these coals would require new methods of extraction and production, which at present are not economically feasible. Choate et al. (1982) show high coalbed methane contents (>5 Bcf) in deep Fruitland Formation coals, which are correlative with deeper parts of the San Juan Basin. They state that the deep coals in the basin exhibit all the necessary geologic criteria, suggesting a high coalbed methane production potential, but Choate et al. (1982) caution that additional studies should be conducted to determine the extent of gas production.

TABLE 8. Resources for deep coals in western Rio Arriba County (reported in millions of tons).

Depth	Coal Thickness 2.5 ft	5 ft	10 ft
250- 500	0.52	----	----
500-1000	----	----	----
1000-2000	34.5	34.5	20.4
2000-3000	214.0	133.9	69.2
3000-4000	1120.2	907.6	159.4
4000-5000	10.08	10.08	----

URANIUM RESOURCES

(V. T. McLemore and W. L. Chenoweth)

Introduction

Although uranium has been produced elsewhere in the San Juan Basin (McLemore, V. T., 1983), very little has been found in western Rio Arriba County. The Morrison Formation is either barren, eroded, or too deep in western Rio Arriba County and has very low potential. In eastern Rio Arriba County, the uranium resource potential is low (Fig. 22), because insufficient data exist to fully evaluate the potential. The only attempted uranium production has been from stratabound, sedimentary copper deposits in the Gallina district. Additional deposits occur in the Nacimiento district. Uranium may also occur in the Ojo Alamo Sandstone, beach-placer sandstones in the Point Lookout Sandstone, and the San Jose Formation.

Stratabound, sedimentary copper deposits

Uranium occurs in the stratabound, sedimentary copper deposits in the Abo and Chinle Formations and Madera Group in the Gallina and Nacimiento Mountains districts (Appendix 1; Fig. 22). Two prospects in the Gallina district yielded a small amount of uranium production (Table 9). Since the material was less than 0.10% U_3O_8 it was not purchased by the U.S. Atomic Energy Commission. Other mines in the Coyote and Abiquiu districts in eastern Rio Arriba County have also produced small quantities of uranium from these rocks (McLemore, V. T., 1983; Chenoweth, 1974). Uranium mineralization typically occurs with copper mineralization and both are associted with organic material in

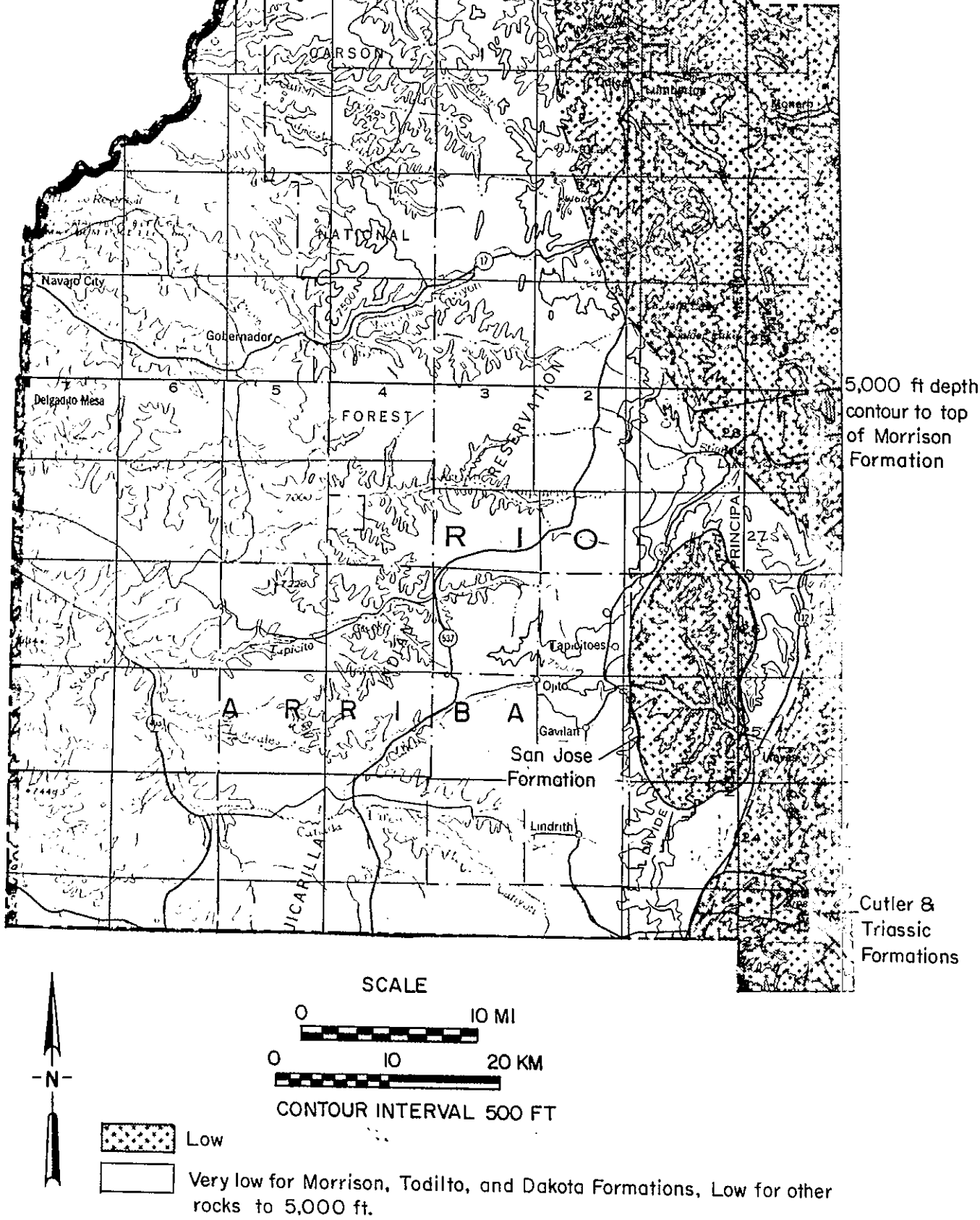


Figure 22. Uranium resource potential in western Rio Arriba County, New Mexico.

fluvial sandstones, siltstones, and conglomerates (discussed in more detail under Metal Deposits). Uranium contents rarely exceed 0.10% U_3O_8 (Table 10). High .pn 77 radiometric anomalies and high geochemical anomalies in the NURE data occur near some of these deposits (McLemore et al., 1984). In most places, uranium and copper mineralization is sporadic and discontinuous and the uranium potential is low.

The largest stratabound copper deposits in the Nacimiento Mountains occur in the Chinle Formation in Sandoval County (Woodward et al., 1974); however, only trace amounts of uranium mineralization are associated with these stratabound deposits (Appendix 1; McLemore et al., 1984; Chenoweth, 1974). Locally, copper may be absent at uranium occurrences found in the Poleo Sandstone Lentil (Member of the Chinle Formation). However, organic material which controls uranium mineralization elsewhere in the Chinle, is rare in the Poleo Sandstone Lentil (Vizcaino et al., 1978). It is doubtful that any economic uranium ore deposits occur in the Chinle Formation and the mineral-resource potential for uranium is low.

Table 9 - Uranium production (no pay ore) from mines in the Gallina district, Rio Arriba and Sandoval Counties.

Name	Location	Ore (tons)	U_3O_8 (lbs)	U_3O_8 %	V_2O_5 (lbs)	Year of Production
White Flo #1	23N.1E.19	4	7	0.08	43	1954
Corral #3	23N.1W.25	20	12	0.03	24	1956

Table 10 - Chemical analyses of selected samples from stratabound, sedimentary copper deposits in the Gallina district, western Rio Arriba County, from McLemore, V. T. 1983. No gold was detected. Analyses by Lynn Brandvold and associates, NMBMMR.

Location	Name	% U_3O_8	Cu %	Ag oz/ton
23N.1E.30	Max Jacque	0.036	0.00	0.0
23N.1E.30	Max Jacque	0.05	0.25	0.3
21N.2E.12	Section 12	0.14	35.4	20.5
21N.2E.12	Jarosa	0.06	0.22	0.00

Uranium in the Ojo Alamo Sandstone

General Description--Drilling during the 1970's at Mesa Portales in Sandoval County, near Cuba indicates that low-grade uranium occurs in several blanket-like horizons in the Ojo Alamo Sandstone. In addition to a few uranium occurrences at Mesa Portales, geochemical and radiometric anomalies are detected by water and stream-sediment geochemical surveys and by the aerial-radiometric studies (Green et al., 1982a, b; McLemore et al., 1984).

Geology--Uranium mineralization occurs in sandstones and is associated with iron-staining, clay galls, and carbonaceous material. The sandstones are composed of quartz and feldspar and were deposited by braided to meandering streams on an alluvial fan. Mudstones are associated with the orebodies and probably provided permeability barriers. However, sandstone-to-shale ratios and permeability are too high in most places to be favorable (Vizcaino and O'Neill, 1977). The lack of a clear mineralization pattern may suggest that these deposits are modified roll-type or remnant orebodies (Green et al., 1982a, b).

Resource and Development Potential--The U.S. Department of Energy (1980) estimates that speculative-potential uranium resources in the $50 per pound and less category in the Ojo Alamo Sandstone in the Mesa Portales area are 45 tons of U_3O_8 at an average grade of 0.25% U_3O_8, despite the absence of proven economic orebodies (McLemore, 1981). The extreme northern portion of this area is in Rio Arriba County. The mineral-resource potential is low (McLemore et al., 1984). The potential for development is low until the market for uranium improves substantially.

Beach-placer Sandstones

Uranium is also found in beach-placer sandstone deposits in the San Juan Basin (discussed in more detail under Metal Deposits; Appendix 1). Two deposits are known in the study area (Chenoweth, 1957a). These deposits are low grade and small tonnage and probably do not represent any economic potential. Numerous radiometric anomalies are present in the Cretaceous rocks and may indicate additional deposits (McLemore et al., 1984). The mineral-resource potential and the potential for development is very low.

San Jose Formation

Minor occurrences of uranium and radiometric anomalies also are found in the San Jose Formation throughout the northern San Juan Basin (Chenoweth, 1957b; McLemore, V. T., 1983; McLemore et al., 1984) where uranium is associated with carbonaceous material in fluvial sandstones. However, despite favorable lithologies in this unit (Green et al., 1982b; Vizcaino and O'Neill, 1977), no economic orebodies have yet been found. The resource and development potential is low.

Geothermal Resources

(by V. T. McLemore and K. Klein)

Geothermal resources are the natural concentration of heat, generated within the interior of the earth, that can be extracted economically (Muffler, 1981). In New Mexico, geothermal energy is used for space heating (Hatton and Peters, 1982); several areas are being investigated for potential use in generating electricity.

The Geothermal Steam Act of 1970 established criteria for the U.S. Geological Survey to utilize in designating areas that are prospectively valuable for geothermal energy; these areas are termed KGRA's (Known Geothermal Resource Areas; Godwin et al., 1971). The New Mexico State Land Office also designates favorable areas for potential geothermal resources; these areas are termed KGRF's (Known Geothermal Resource Fields; Hatton, 1977, 1980, 1981a, b; Hatton and Peters, 1982).

There are no KGRA's or KGRF's delineated by the U.S.G.S. or the New Mexico State Land Office in western Rio Arriba County. A few wells in western Rio Arriba County suggest anomalously high heat flow in some areas (Swanberg, 1980); however, there is no indication of any potential for geothermal reservoirs in western Rio Arriba County and the resource potential is very low (Maps 84 and 85).

Metals

(by V. T. McLemore)

Deposit Types

Only two types of known metal deposits occur in western Rio Arriba County: stratabound, sedimentary copper deposits and beach-placer sandstone deposits. Additional stratabound, sedimentary copper deposits occur to the east, also in Rio Arriba County (McLemore, V. T., 1983; North and McLemore, 1986) and to the south in Sandoval County (McLemore et al., 1984).

Stratabound, sedimentary-copper deposits

Stratabound, sedimentary-copper deposits are numerous and widespread in western United States (Gibson, 1952; Phillips, 1960; Fischer and Stewart, 1961) and throughout the world (Gustafson and Williams, 1981) and may be locally associated with relatively high concentrations of silver, gold, lead, zinc, uranium, and vanadium. These deposits are typically associated with red-bed sedimentary sequences and have been called sandstone copper deposits, but they are not restricted to sandstones.

General Description--Copper and associated mineralization typically occurs in bleached red or gray to green sandstones, conglomerates, siltstones, shales, and limestones deposited in intracratonic basins with a lack of volcanism or magmatic activity (Gustafson and Williams, 1981). In Rio Arriba County, stratabound, sedimentary-copper deposits occur in continental Permian and Triassic sediments in the Gallina and Nacimiento districts (Fig. 23; Appendix 1). Additional deposits occur in Permian and Triassic sediments in the Abiquiu and Coyote

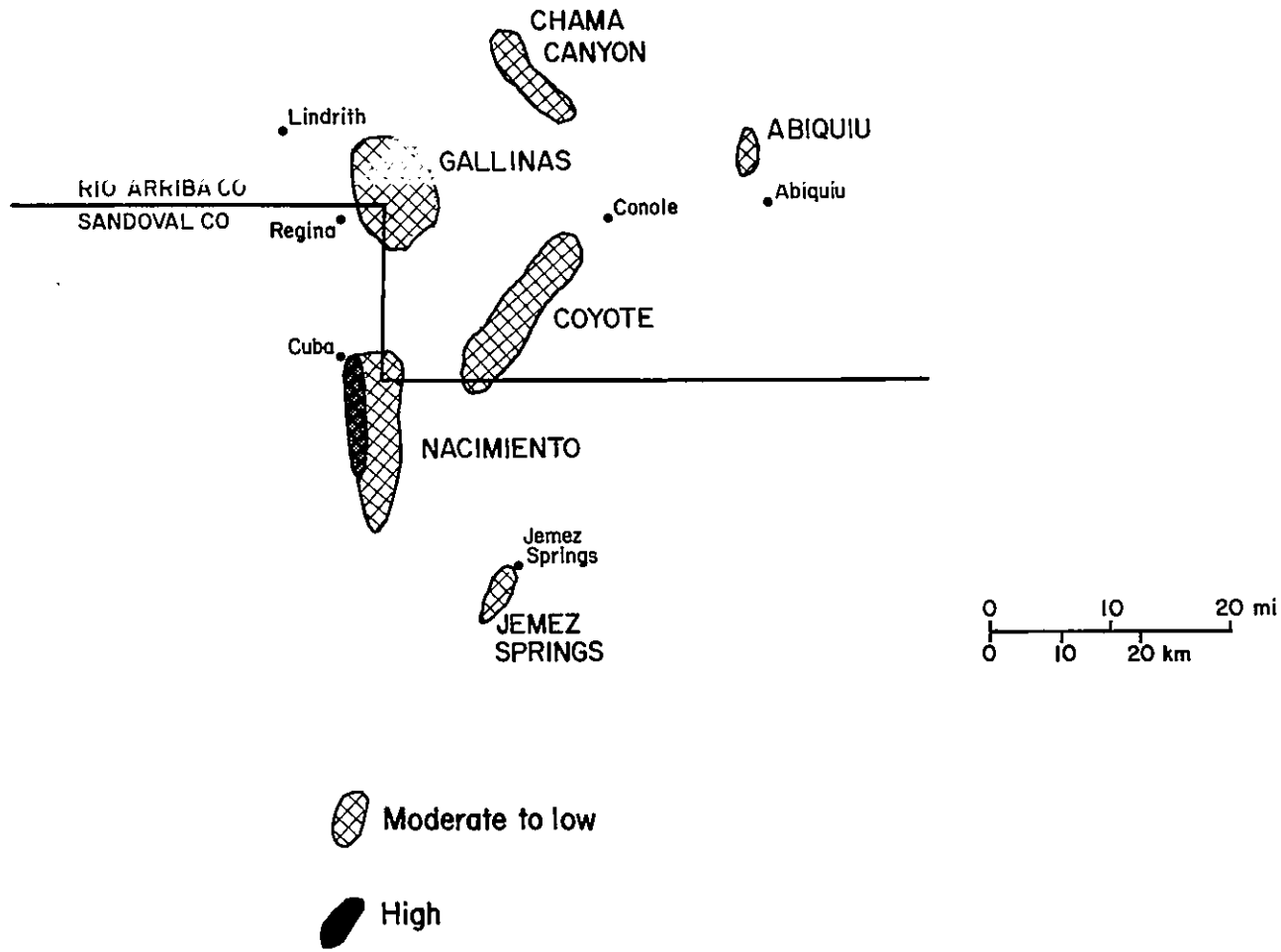


Figure 23. Stratabound, sedimentary copper deposits in western Rio Arriba and Sandoval Counties, New Mexico.

districts to the east (Fig. 23; North and McLemore, 1986; McLemore et al., 1984).

Copper deposits in Permian rocks are associated with small, meandering stream channels and equivalent finer-grained facies; whereas deposits in nearby Triassic rocks are associated with large braided stream complexes (LaPoint, 1979). Permian sandstones are typically more arkosic than Triassic sandstones. Sediments from both Permian and Triassic units were derived from major uplifts of exposed Precambrian rocks.

Copper and associated metals were probably transported in solution at low temperature through permeable sediments and along faults. Oxidizing waters could leach metals from (1) Precambrian rocks enriched in these metals, (2) Precambrian base-metal deposits, and (3) clay minerals and detrital grains within the host rocks (LaPoint, 1976, 1979). Cuprous chloride (Rose, 1976) or cuprous carbonate (LaPoint, 1979) complexes are soluble in oxidizing waters at low temperatures (77°F) and can transport these metals easily. Low temperatures are indicated by the lack of hydrothermal activity. Sources for chlorides or carbonates occur in older evaporite and carbonate sequences. Precipitation occurred at favorable oxidation-reduction interfaces in the presence of organic material or H_2S-rich waters. Later groundwater and structural events may alter or destroy some deposits (LaPoint, 1979).

Nacimiento district--The largest copper deposits occur in the Chinle Formation in the Nacimiento Mountains. Although these deposits may have been worked by Indians and the Spanish, serious mining did not occur until after the 1880's. The Nacimiento mine

in Sandoval County yielded over 7 million lbs of copper and over 75,000 oz of silver (McLemore, et al., 1984). In Rio Arriba County, most of the metal production is from the Eureka mine where over 662,000 lbs of copper and 893 oz of silver were produced (Table 11).

Mineralization is associated with organic debris and other carbonaceous material in conglomerates of the Agua Zarca Sandstone Member (Chinle Formation). Copper oxides and chalcocite are the dominant copper minerals. A sample assayed 19.4% copper and 0.0126% silver (Bingler, 1968). The conglomerate is very siliceous and may have potential for high-silica flux.

Table 11 - Mineral production from western Rio Arriba County. Most of this production is from the Eureka mine. Production for 1904 and 1961 from U.S. Bureau of Mines Mineral Yearbooks and for 1956 and 1957 from New Mexico State Inspector of Mines Reports. *Fiscal year.

Year	Ore (tons)	Gold (oz)	Silver (oz)	Copper (lbs)	Total Value ($)
1904	467	2	52	846	190
1956*	NA	-	841	126,000	56,688
1957*	NA	-	-	536,000	192,383
1961	4	-	-	~ 80	30
TOTAL	471	2	893	662,926	192,413

Gallina district--Small copper orebodies occur in fluvial sandstones and adjacent units in the Abo and correlative Cutter Formations in the Gallina district (Map 81). Small occurrences are present in the Madera Group, occasionally along faults. One selected sample assayed 35.4% copper and 20.5 oz/ton silver. Other samples assayed lesser amounts of copper, uranium, and silver. Lead, zinc, and vanadium are also present in varying amounts. No metal production is reported, however minor production may have occurred in prehistoric times by the Indians and the Spanish. Uranium and vanadium were produced in the 1950's as discussed previously.

Resource and Development Potential--The mineral resource potential of copper and silver in the Agua Zarca Sandstone Member of the Chinle Formation in the Rio Arriba portion of the Nacimiento Mountains is moderate, but only in braided stream channels (Fig. 23). The resource potential of copper and associated metals elsewhere in eastern Rio Arriba County is low to moderate because of discontinuity, low grade, and small tonnage. The potential for development is low due to (1) low copper prices and (2) subeconomic tonnages compared to porphyry copper deposits.

Beach-placer sandstone deposits

Beach-placer sandstone deposits are concentrations of heavy minerals that form on beaches or in long-shore bars in a marginal-marine environment (Mickle and Mathews, 1978; Mickle, 1978; Mathews et al., 1979). Numerous beach-placer sandstone deposits are found in northern New Mexico (Fig. 24) and at least

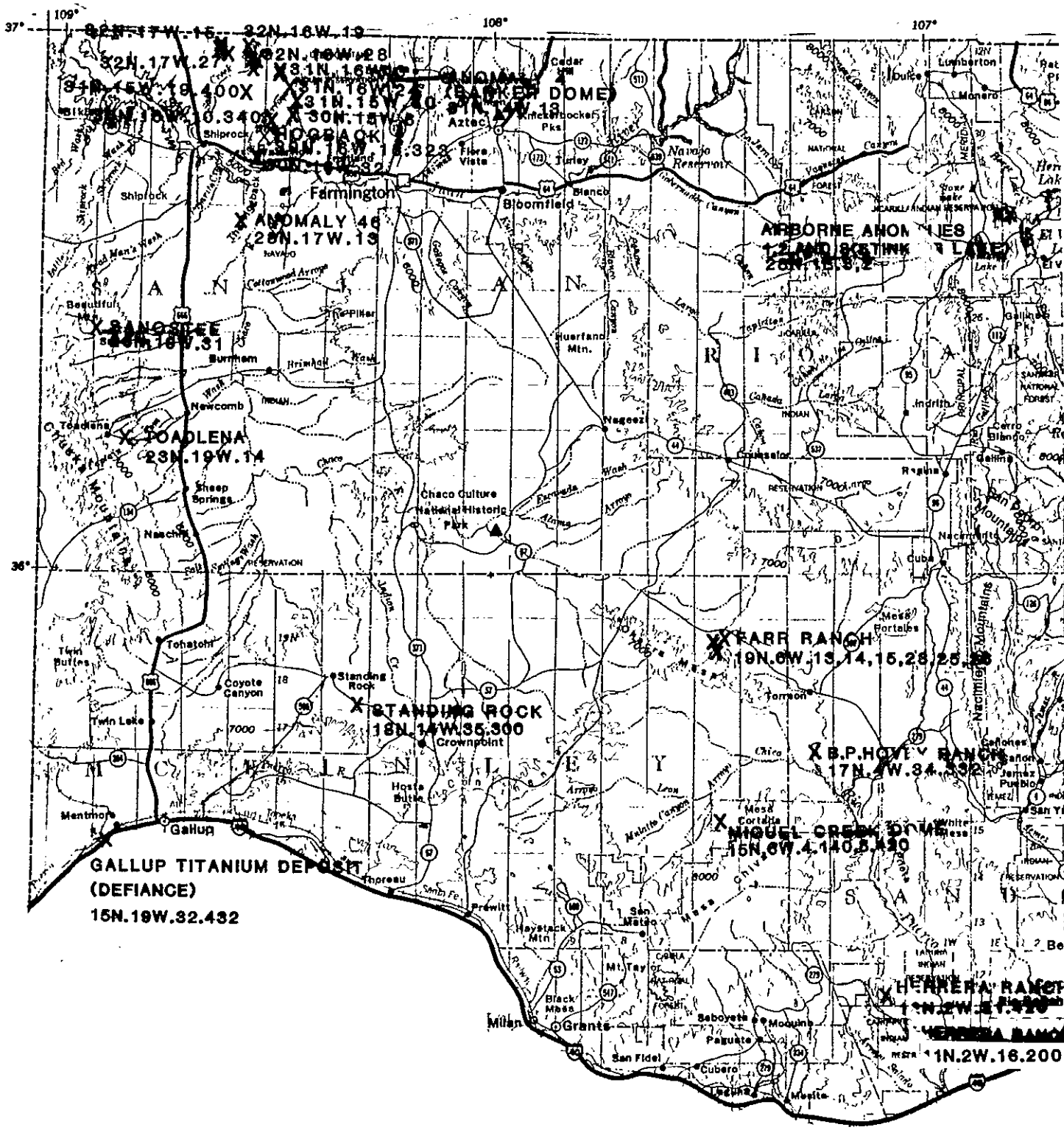


Figure 24. Beach placer deposits in the San Juan Basin, New Mexico.

three wells have penetrated similar deposits in the subsurface elsewhere in the San Juan Basin (Chenoweth, 1957). Although beach-placer sandstone deposits are found in strata of any age, the deposits in the San Juan Basin are restricted to Upper Cretaceous rocks in the Gallup, Dalton, Point Lookout, and Pictured Cliffs Sandstones (Chenoweth, 1957; Houston and Murphy, 1977).

The beach-placer sandstones have radioactive zircon, monazite, and columbium minerals. In addition, minerals such as ilmenite, anatase, leucoxene, magnetite, hematite, zircon, garnet, and tourmaline are common in these sandstones. Anomalously high concentrations of Ti, Fe, Sc, Zr, Ag, Nb, Th, U, and rare-earth elements are characteristic. These sandstones range from olive-gray, rust-brown, brownish-black to maroon, and are commonly called "black sandstone deposits." Beach-placer sandstone deposits occur at the top of beach sandstones and, at places, in two or more intervals. They represent regressive sequences and typically occur usually below major coal beds.

Only one locality in New Mexico, the Hogback #2 property in San Juan County, has been mined. Eight tons of "no-pay" ore yielding 3 lbs of U_3O_8 (0.02%) was produced from the Point Lookout Sandstone in 1954 (McLemore et al., 1986e).

Many of the beach-placer sandstone deposits in New Mexico are low-tonnage and low-grade and remain undeveloped. However, it is estimated that a total of 4,751,200 tons of ore containing 12.82% TiO_2, 2.07% ZrO_2, 15.51% Fe, and less than 0.10% $eThO_2$ (radiometric equivalent ThO_2) are present in the San Juan Basin in New Mexico (Dow and Batty, 1961). The Stinking Lake deposit

in Rio Arriba County is estimated to contain up to five million tons of material averaging up to 5% TiO_3 (Bingler, 1968). The reliability of these estimates are uncertain.

Additional deposits probably remain undiscovered in the area. Drilling is required along strike and behind known deposits. The small size, low-grade, and difficulty in recovery of individual deposits prevent large-scale mining of them despite their economic potential. In addition, Recent beach-placer sandstone deposits in Florida and Georgia are mined for titanium, and thorium is recovered as a byproduct from monazite. Monazite from these deposits constitutes only 0.3 to 1.0% of the heavy minerals recovered, but thorium may be as high as 5% in the monazite. Thus the amount of thorium produced in the future will probably come from these recent deposits or as byproduct of other mining ventures. The resource potential is moderate and the development potential is low.

Industrial Materials

Introduction (by J. M. Barker)

Industrial materials are very difficult to classify. They have often been called "non-metallics" or "industrial minerals" among many terms. Both terms are inadequate because industrial materials include solids, liquids (brine), and gases (carbon dioxide, nitrogen, etc.) along with minerals, rocks, manufactured products (lime), and some metals (boron, lithium, silicon) in a strict chemical sense. The end use of the material is typically the defining factor in classification so that coal, lignite, bitumen, asphalt, uranium/thorium and others are, in certain instances, considered "industrial materials", the term used in this report. Details of the classification problems of industrial materials are in Wright and Burnett (1962); Fisher (1969); Bates (1969); Kline (1970); Dunn (1973); and Blair (1981).

Classification schemes span a broad spectrum from end use to economic values. In between, are mixed parameter classifications such as geologic-end use or geologic-economic schemes. For this study, Bates' (1960) classification (modified) is most illustrative (Table 12). A simple case differentiates chemical materials (used for what they contain) from physical materials (used for what they do).

Chemical materials are often used captively by a fully integrated producer/consumer and predominantly serve one end use in this context. Physical materials are rarely used by the producer and serve multiple end uses (Blair, 1981). Fuels and metallic materials have an inherent or intrinsic value.

Industrial materials have an implied value (Blair, 1981). Synthetic products form a third class in that they are manufactured from industrial material feed stock.

Table 12 - Classification of Industrial Minerals

Aspect	Mainly rocks	Mainly minerals
Relative Production	Large	Small
Unit Value	Low	High
Place Value	High	Low
Imports and Exports	Few	Many
Occurrence	Widespread	Restricted
Geology	Simple	Complex
Processing	Simple	Complex
Typical End Use	Physical	Chemical

The geography, industrial base, and demographics of northwest New Mexico cause certain aspects to be preferentially emphasized. New Mexico has a small population and its population density is small. Heavy industry is nearly absent and large chemical facilities are not abundant. This leads to restricted local commodity markets centered on the Rio Grande Valley and the Interstate highway routes. Thus, place value, the location of the deposit relative to consumption centers, is quite important in New Mexico. The relative remoteness of New Mexico to large industrial/chemical centers makes transport cost a key component for exporting materials. These relationships are summarized in Table 13. Western Rio Arriba County has a low population/industrial base even by New Mexico standards. Thus, many potential economic materials are uneconomic solely on a place-value basis. Of the materials produced in New Mexico, only

TABLE 13 - Some relationships between industrial materials based on conditions within New Mexico.

Rank by output (1)	Relative Production	Number of producers	Place Value (2)	Unit Value (3)	Specification category (4)	Remarks
Sand & Gravel	Large	very many	High	Low	P	abundant in New Mexico
Crushed Stone	Large	many	High	Low	P	abundant in New Mexico
Potash	Large	moderate	Low	High	C	abundant in New Mexico
Perlite	Medium	moderate	Low	Medium	P	abundant in New Mexico
Cement	Medium	very few	Low	Medium	C	small market in New Mexico
Gypsum	Medium	moderate	High	Low	C,P	abundant in New Mexico
Salt	Medium	moderate	High	Low	C	abundant in New Mexico
Sulfur (as H_2SO_4)	Small	very few	High	Medium	C	expensive transport, by product
Clay	Small	few	Moderate	Low	C,P	uncommon in New Mexico
Humate (5)	Small	few	Low	Medium	C	abundant in New Mexico
Dimension Stone	Small	few	High	Low	P	abundant in New Mexico
Mica	Small	very few	Low	Medium	P	largest producer in West

NOTE

(1) does not include CO_2, helium, or lime produced in New Mexico
(2) high place value usually implies that commodity must be near consumers
(3) low = <$25/ton, med = $25-100/ton, high = >$100/ton
(4) P = physical material used for what it does; C = chemical material used for what it contains
(5) includes "leonardite" and weathered coal

humate has a possiblity of rapid expansion in agriculture if efficacy questions can be answered satisfactorily (Gosz et al., 1977, 1978; McCaslin and Boyle, 1980; Roybal and Barker, 1985, 1986).

Twenty-two major end uses for industrial materials have been identified (Lefond, 1983) along with about 100 major and several hundred minor industrial materials unevenly distributed throughout the major categories. A very simplified geology-end use matrix is presented in Table 14a-c to highlight this diversity along with resources and possible resources for Rio Arriba County emphasized. This matrix by no means covers all the possible industrial material types. Building or dimension stone, for example, has at least 56 types of stone used in this capacity. Many of these types of stone occur within Rio Arriba County but only those with a favorable combination of quality, quantity, markets, and transportation can be distributed and sold.

For chemical end uses industrial materials tend to be highly differentiated products compared to undifferentiated commodities such as copper, gold, and mercury, among many. Specifications for undifferentiated products are the same for each producer. They serve ready-made, highly-visible markets with set prices and standard, generally simple specifications. In contrast, industrial materials are highly diverse with no central market, no set price, and complex specifications. This relationship is often seen in the extreme where each customer for an industrial material sets unique specifications that must be met, basically on a custom basis, over the long-term by the producer.

lists of industrial materials and end uses. X = present; P = produced; [2] = Northrop (1959); [3] = U.S. Geological Survey (1965); [3] = U.S. Bureau of Mines Mineral Yearbooks; [4] = Austin (1982).

Rock, Mineral, Material	Composition	End use	Geology: Sedimentary Rocks: Clastic	Sedimentary Rocks: Chemical & $(O)_3$'s	Sedimentary Rocks: Organic	Metamorphic Rocks	Igneous Rocks: Plutonic Rocks (subsurface): Deep	Plutonic Rocks (subsurface): Shallow (including hydrothermal)	Volcanic Rocks (surface): Flow	Volcanic Rocks (surface): Pyro.
Alunite	$K\,Al_3(SO_4)_2(OH)_6$	3,14								
Andalusite	$(Li,Ba)Al((O_4)(F,OH)$	3								
Anhydrite	$Al_2\,SiO_5$	2,21								
Asbestos Minerals	various silicates	15,16,22								
Asphaltite	mixture of hydrocarbons									
Barite	$BaSO_4$	2,3,15,19,22								
Bauxite Minerals	various	2,3,15,21,22								
Beryl	$Be_3Al_2Si_6O_{18}$	2,3								
Borate Minerals	various	2,3,11,14,16,19								
Bromine	Br	3								
Brucite	$Mg(OH)_2$	14,21								
Carbon Materials	C or C-compounds	2,15,16,19,21,22								
Celestite	$SrCO_3$	3								
Chalcocite	CuS_2	14								
Chalcopyrite	$CuFeS_2$	14								
Chromite	$FeCr_2O_4$	2,3,17,19,21								
Clay Minerals	layer silicates	1,2,5,15,16,17, 19,21,22								
Cordierite	$Mg_2Al_4Si_5O_{18}$	2								
Corundum	Al_2O_3	3								
Cuprite	Cu_2O	14								
Diaspore	$AlO(OH)$	2,21								
Diatomite	$SiO_2 \cdot nH_2O$	15,21,22								
Dolomite	$Ca,Mg(CO_3)_2$	2,4,9,11,14,15, 16,19,21,22								
Dumortierite	$(Al,Fe)_7BSi_3O_{18}$	2								
Epsomite	$MgSO_4 \cdot 7H_2O$	14								
Feldspar Group	silicate	1,2,8,11,15,16,19								
Fluorspar	CaF_2	2,3,16,19						[3]		
Galena	PbS	22								
Garnet	silicate	1								
Gases	various	13,14,16								
Gems	various	1,2	unknown? [3]							
Glauconite	silicate	14,15								
Graphite	C	2,21								
Gypsum/Anhydrite	$CaSO_4 \cdot nH_2O$	2,3,8,10,13,14, 15,19,22			X [4]					
Halite	NaCl	2,3,8,22								
Helium	He									
Humate	humic acid	14			X [4]					
Ilmenite	$FeOTiO_2$	22,16								
Iron Oxide Minerals	$Fe_xO_y \cdot nH_2O$	1,2,16,20,22								
Iodine Materials	I	3								
Kyanite	Al_2SiO_5	2,21								
Limestone	$CaCO_3$	2,3,4,9,11,13- 16,19,21,22								
Lithium Materials	various	2,3								
Magnesite	$MgCO_3$	2,3,11,14,21								
Manganese	various	8								
Mica Minerals	various	13,15,16,22								
Molybdenite	MoS_2	14								
Nepheline Syenite	rock	2,11,15,19								
Nitrate Materials	various	2,3,14								
Ocher	hydrated iron oxide									
Olivine	$(Mg,Fe)_2SiO_4$	2,14,17								
Periclase	MgO	2,14								
Perlite	volc. glass	5,11,15,21,22								
Phosphate Materials	$Ca_5(PO_4)_3(OH,F,Cl)$	3,14								
Potash Minerals	KCl, etc.	2,3,14,16,19,22								
Pollucite	$(Cs,H_2O)_2Al_2O_{10}$	14								
Pumice										
Pyrite	FeS_2	3,19,20								
Pyrolusite	MnO_2	3,14								
Pyrophyllite	$Al_4(Si_8O_{20})(OH)_4$	2,15								
Pyrrhotite	Fe_xS	3								
Rare Earths & Thorium	various	3,19								
Siderite	$FeCO_3$	20,22								
Silica Materials	SiO_2	1-4,9,11,13, 15-17,19,21,22								
Sillimanite	Al_2SiO_5	2,21								
Sodium Minerals	various	2,3,11,19,21,22								
Sphalerite	$(Zn,Fe)S$	14								
Spodumene	$LiAlSi_2O_6$	2,3								
Staurolite	$(Fe,Mg,Zn)_2Al_9Si_4O_{23}(OH)$	17								
Stone	various	1,2,4-9,12,14, 15,19,20								
Strontianite	$SrCO_3$	13								
Sulfur	S	3,14								
Talc	$Mg_6(Si_8O_{20})(OH)_4$	2,15								
Titanium Minerals	TiO_2	2,3,15,16								
Tourmaline	complex silicate	2								
Trona	Na_2CO_3	3								
Vermiculite	complex silicate	5,11,15,21								
Wollastonite	$Ca(SiO_3)$	2,15								
Witherite	$BaCO_3$	3								
Zeolite	complex silicates	15								
Zirconium Minerals	various	2,3,16,17,21								

Table 14b - List of industrial materials to accompany Table 14a.

Alunite
Amblygonite
Andalusite
Asbestos
- chrysotile — crocidolite
- actinolite — amosite
- anthophyllite — tremolite

Barite
Bauxite (Gibbsite, Boehmite)
Beryl
Borate
- borax
- colemanite
- kernite
- probertite
- tincalconite
- ulexite

Bromine
Brucite
Carbon
- amorphous
- graphite
- coal (anthracite)
- lignite
- peat
- gilsonite, elaterite, wurtzilite
- bitumen, albertite, grahamite, impsonite
- asphalt

Celestite
Cerussite
Chalcocite

Magnesite
Mica Minerals
- muscovite (sericite)
- phlogopite
- biotite
- lepidolite

Molybdenite
Nepheline Syenite
Nitrate Materials
- guano
- niter, nitre (KNO_3)

Olivine
Periclase
Perlite
Phosphate Materials
- apatite
- allophane (colloid)

Potash Minerals
- sylvite — carnallite
- langbeinite — polyhalite
- kieserite
- potassium sulphate
- potassium carbonate (pearl ash)

Psilomelane
Pyrite
Pyrolusite
Pyrophyllite
Pyrrhotite

Strontianite
Sulfur
Talc
Titanium Minerals
- rutile, anatase, brookite
- titania, titanite (sphene)

Tourmaline
Trona
Vermiculite
Wollastonite
Witherite
Zeolite
Zirconium (Hafnium) Minerals

Chalcopyrite
Chromite
Clay Minerals
- kaolin, dickite, metahalloysite, halloysite, endellite
- illite
- smectite, montmorillonite, bentonite, hectorite
- attapulgite/sepiolite/meerschaum

Cordierite
Corundum
- emery

Cuprite
Diaspore
Diatomite
Dolomite (see limestone)
Dumortierite

Epsomite
Feldspar
- potassium (orthoclase, microcline)
- sodium (albite)
- calcium (anorthite)
- perthite

Fluorspar
- cryolite

Galena
Garnet
Gases
- nitrogen — sulfur dioxide
- helium — hydrogen sulfide
- carbon dioxide — noble

Rare Earths & Accessory Minerals
- bastnaesite — thorium
- monazite — yttrium
- xenotime

Siderite
Silica
- opaline
- flint
- chert
- agate
- rottenstone
- tripoli
- ground
- novaculite
- colloidal
- quartzite
- pebbles (beach, river)
- sandstone
- gannister
- crystal

Sillimanite
Sodium
- sodium sulfate (salt cake)
- sodium carbonate (soda ash, trona)
- sodium nitrate (caliche)
- NaI
- NaBr
- sodium bicarbonate

Gems (semi-precious and precious)
Glauconite
Graphite
- amorphous
- flake

Gypsum/Anhydrite
- calcined
- selenite

Halite
Humate
Ilmenite
Iron Oxide
- rouge — goethite
- crocus — lipidocrocite/epidocrocite
- ochre — limonite
- sienna — hematite
- umber — magnetite
- micaceous

Iodine Materials
Kyanite
Limestone
- calcite — vaughanite (lithographic)
- aragonite — shell
- chalk (whiting) — coquina
- dolomitic — caliche
- argillaceous

Lithium Minerals
- brine — amblygonite
- spodumene

Sphalerite
Spadumene
Staurolite
Stone
- limestone — granite
- dolomite — syenite
- dolomitic limestone — anorthosite
- marble — aplite
- calcareous marl — andesite
- shell — dacite (porphyry)
- coquina — rhyolite
- coral — trachyte
- travertine — felsite
- onyx — gabbro
- sandstone — basalt
- graywacke — diabase
- chert — traprock
- shale — norite
- argillite — diorite
- quartzite — peridotite
- gneiss — tuff
- schist — pumice, pumicite
- slate — perlite
- amphibolite — volcanic glass
- talc — volcanic rock
- serpentine — volcanic cinders
- greenstone — volcanic breccia
- arkosic quartzite — scoria

Frequently, continually varying specifications of delivered materials are contractural grounds for abrogation of formal sales agreements. Producers catering to different markets may have dozens of "products" based on one material, but each slightly different, because of each consumer's preference for minor differences in grain size, shape, purity, and other characteristics.

The relationships described above lead to the dominance of price, product specifications, customer location, transportation, and production costs over geology. Many industrial materials are potentially present in western Rio Arriba County (Table 14a-c). Only in the braodest sense are they a resource because no markets exist for them or end-user specifications cannot be met.

Table 14c - List of end use categories for industrial minerals as numbered on Table 14a.

End Use	Number on Table
Abrasive	1
Ceramics/Art	2
Chemical	3
Crushed Stone	4
Lightweight Aggregate	5
Sand and Gravel	6
Slag	7
Cement	8
Dimension and Cut Stone	9
Gypsum and Anhydrite	10
Insulation	11
Roofing	12
Electronics and Optical	13
Fertilizer	14
Filler, Filter, Absorbent	15
Flux	16
Foundry Sand	17
Precious/Semi-Precious Gem	18
Glass	19
Mineral Pigment	20
Refractory	21
Well Drilling	22

Source: Lefond (1983)

Barite and Fluorite (by V. T. McLemore)

Although no barite or fluorite deposits are reported from Rio Arriba County, a belt of anomalous barium values occurs in NURE stream-sediment samples along the Kirtland-Fruitland contact and in the Nacimiento Formation in northern San Juan and southern Rio Arriba Counties (McLemore et al., 1984). Strontium and sodium anomalies are also present. Barite concretions have been reported in the Kirtland and Nacimiento Formations (Talmage and Wootton, 1937; D. L. Wolberg, NMBMMR, pers. comm., June, 1984). These barium anomalies may be related to the concretions. The significance of these anomalies is unknown, but they may represent bedded barite and strontianite mineralization so additional work is suggested.

Carbon dioxide (by R. F. Broadhead)

Carbon Dioxide Occurrences--Western Rio Arriba County has not produced commercial quantities of carbon-dioxide (CO_2) gas. Natural gas produced from oil and gas pools in western Rio Arriba County consists partly of helium (Table 15), but the CO_2 is not separated from the gas and subsequently sold. Gases produced from Cretaceous and Tertiary reservoirs in Rio Arriba County consist of less than 5% CO_2. Nonproductive wells drilled in Rio Arriba County have recovered gas that is more than 80% CO_2 from Pennsylvanian and Mississippian reservoirs (Table 16).

Generally, natural gas with less than 90% CO_2 is not produced for its CO_2 content. With future increased demand for CO_2, it is possible that gases with as little as 10-20% CO_2 could be produced for their CO_2 content. The CO_2 could be extracted

TABLE 15 - Carbon dioxide content of gases produced from oil and gas pools, western Rio Arriba County. See section on Petroleum Resource Potential for data on oil and gas pools.

Pool	Location (township-range)	Reservoir	Percent CO_2 in gas
Gavilan Nacimiento Gas Pool	T. 24 N., R. 2 W.	Nacimiento (Tertiary)	0.19
Gobernador Pictured Cliffs Gas Pool	T. 29 N., R. 5 W.	Pictured Cliffs (Cretaceous)	0.38
Blanco Mesaverde Gas Pool	T. 25-32 N., R. 2-13 W.	Mesaverde (Cretaceous)	0.85
Adobe Chacra Gas Pool	T. 24 N., R. 4 W.	Chacra (Cretaceous)	0.15
Large Chacra Gas Pool	T. 27-28 N., R. 7-8 W.	Chacra (Cretaceous)	0.42
South Blanco Tocito Oil Pool	T. 26 N., R. 5-6 W.	Gallup (Cretaceous)	0.18
BS Mesa Gallup Gas Pool	T. 26-27N. R. 4 W.	Gallup (Cretaceous)	0.80
Campo Gallup Gas Pool	T. 29 N., R. 4 W.	Gallup (Cretaceous)	1.42
Choza Mesa Gallup Pool	T. 28 N., R. 3 W.	Gallup (Cretaceous)	0.89
Counselors Gallup Oil Pool	T. 23 N., r. 6 W.	Gallup (Cretaceous)	0.53
Gavilan Gallup Oil Pool	T. 25 N., R. 2 W.	Gallup (Cretaceous)	0.53
Largo Gallup Gas Pool	T. 26 N., R. 7 W.	Gallup (Cretaceous)	0.86
Regina Gallup Oil Pool	T. 24 N., R. 1 W.	Gallup (Cretaceous)	0.35
Tapacito Gallup Oil Pool	T. 26 N., R. 4-6 W.	Gallup (Cretaceous)	0.75
Wildhorse Gallup Gas Pool	T. 26 N., R. 3-4 W.	Gallup (Cretaceous)	0.80
West Lindrith Gallup-Dakota Oil Pool	T. 24-25 N., R. 4 W.	Gallup & Dakota (Cretaceous)	0.62
Basin Dakota Gas Pool	T. 23-32 N., R. 3-14 W.	Dakota & Graneros (Cretaceous)	3-5
Wildhorse Dakota Oil Pool	T. 26 N., R. 4 W.	Dakota (Cretaceous)	1

[1] Data from Fassett (1978a, 1978b; 1983)

TABLE 16 - Carbon dioxide content of CO_2-rich gas recovered from nonproductive wells in Rio Arriba County (Moore, 1976).

Operator, well number, and lease	Location (section-township-range)	Reservoir unit	Sample depth	Percent CO_2 in gas
Lowry et al. No. 1 Morten	24-24N-5E	Pennsylvanian	1,632	95.5
Humble Oil & Refining Co. No. 1 Navajo C	8-23N-5W	Mississippian	8,070	83.1

from the gas; if the remainder of the gas is a valuable commodity (hydrocarbons or helium), it could also be sold.

CO_2 gas is produced commercially from McElmo dome in southwest Colorado. Reserves at McElmo dome are an estimated 17 trillion ft^3 of 98% pure CO_2 (Gerling, 1983). The reservoir is the Leadville Limestone (Mississippian). McElmo dome CO_2 is transported by pipeline to the Permian Basin where it is used for enhanced oil recovery.

Carbon Dioxide Resource Potential--CO_2 is found in porous rock reservoirs and is trapped similarly to natural hydrocarbon gases. In the reservoir, it is mixed with other gases, which are generally hydrocarbons. Helium and nitrogen may be present in substantial concentrations.

Four key factors were analyzed in order to evaluate the CO_2 potential of western Rio Arriba County: (1) known CO_2 accumulations, (2) reservoirs, (3) traps, and (4) presence of hydrocarbon gases that could dilute CO_2 to insignificant and uneconomic concentrations in the reservoir. Reservoirs and traps were discussed in detail in the section on petroleum resource potential and are only summarized here.

Although sources of CO_2 are an important consideration when evaluating the potential for CO_2 occurrence in an area, CO_2 sources are not evaluated in this report because little information is available on them. There are five theories of the origin of natural CO_2 gas (Picard, 1962; Foster and Jensen, 1972): volcanic emanations, breakdown of limestone adjacent to igneous intrusions, solution of limestones by ground water,

bacterial or thermal decomposition of organic matter, and degassing of Precambrian basement. Picard (1962) concluded that CO_2 in the Four Corners area originated by alteration of limestone; that idea is supported by the association of CO_2-rich gases with Mississippian limestone reservoirs in the Four Corners area.

The potential for CO_2 occurrence in western Rio Arriba County is rated moderate to low (Fig. 25). Natural gas that consists of more than 80% Co_2 has been discovered in Paleozoic reservoirs of western Rio Arriba County (Table 16), but economic accumulations have not yet been discovered. Economic accumulations of CO_2 are not known to exist anywhere within the New Mexico part of the San Juan Basin. Carbon dioxide is produced commercially at McElmo dome in southwest Colorado. A moderate potential for most of Rio Arriba County is warranted because reservoirs and traps may exist. A moderate potential is also warranted because Co_2 may not have been diluted by hydrocarbons to insignificant concentrations in Permian, Pennsylvanian, and Mississippian reservoirs. A high potential is not warranted because economic accumulations of CO_2 are not known to exist in western Rio Arriba County or any part of the San Juan Basin.

Reservoirs in western Rio Arriba County are Cretaceous, Jurassic, Triassic, Permian, Pennsylvanian, and Mississippian in age. Reservoir quality Cretaceous sands are present throughout western Rio Arriba County. However, Cretaceous traps appear to be filled with hydrocarbons; CO_2 in Cretaceous traps has been diluted to insignificant concentrations (Table 15). The Entrada

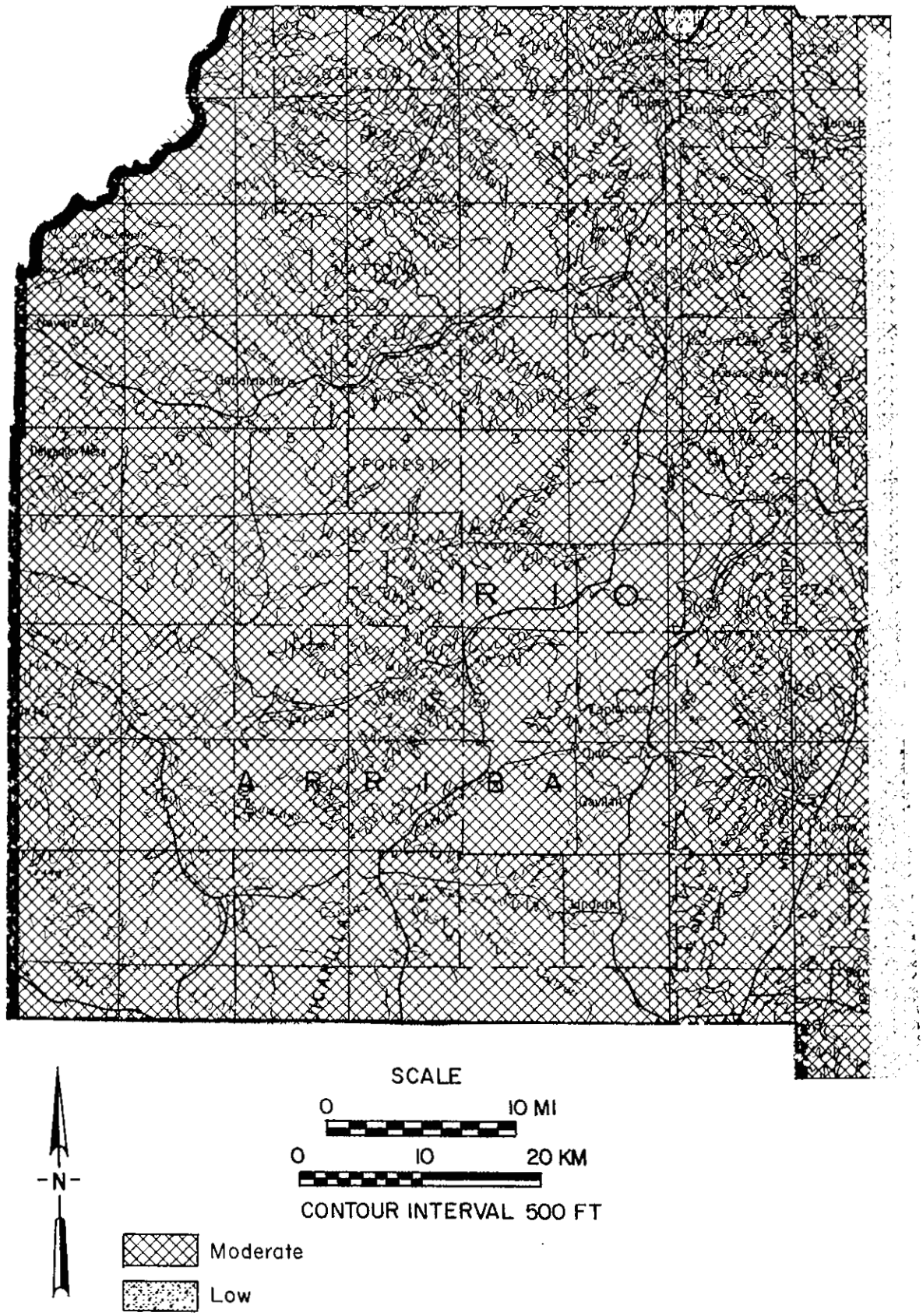


Figure 25. Potential for carbon dioxide occurrence in western Rio Arriba County, New Mexico.

Sandstone (Jurassic) is a reservoir-quality sand in southwest Rio Arriba County, but traps in the Entrada are probably filled with oil and not CO_2.

No gas analyses are available to indicate that CO_2 is present in Triassic sandstones in Rio Arriba County. The Triassic section does not contain petroleum source rocks and is not known to contain significant accumulations of hydrocarbons. Therefore, any CO_2 which was trapped in Triassic reservoirs may not have been diluted by hydrocarbons.

Upper Paleozoic reservoirs are Permian sandstones, Pennsylvanian carbonates and sandstones, and Mississippian sandstones. The upper Paleozoic section has been sparsely tested in Rio Arriba County, but the two gas analyses available indicate CO_2-rich gas is present in the Paleozoic section (Table 16). Gas in the Paleozoic section may be trapped stratigraphically and structurally. Gas trapped in Pennsylvanian and Mississippian reservoirs of neighboring San Juan County generally has a high CO_2 content (McLemore et al., 1986e).

The Cenozoic intrusive body located five miles north of Dulce is assigned a low potential for CO_2 occurrence. The igneous rocks that form the intrusive are poor reservoirs. It is possible, but unlikely, that fractures and vesicles within the intrusive rocks could serve as reservoirs for CO_2.

Potential for Development--Carbon dioxide has many commercial uses. The main use of CO_2 is for enhanced recovery of oil (Foster, 1980; Broadhead, 1985). Other uses of CO_2 are in refrigeration (dry ice), beverages, cryogenics, and as a

chemically inert shield (Foster and Jensen, 1972). Although current CO_2 supplies are adequate, demand will increase as more oil fields use CO_2 for enhanced recovery. Demand will also increase as present CO_2 sources are depleted by production. Long-term demand will increase well into the twenty-first century. Therefore, natural gases rich in CO_2 will eventually be produced for their CO_2 content. The potential for development of (yet) undiscovered CO_2 accumulations in western Rio Arriba County is high because of proximity to three oil-productive basins: (1) Permian Basin of southeast New Mexico and west Texas, (2) San Juan Basin of northwest New Mexico, and (3) Paradox Basin of southeast Utah.

Clays (by K. B. Brown)

General description--Clays and shales have a variety of ceramic, bulk filling, absorbent and fluid properties. They are commercially catagorized as common clay, kaolin, ball clay, fire clay, Fuller's Earth, bentonite, drilling mud, and specialty clays.

Natural clay mixtures contain various proportions of smectite, kaolinite, illite, and less common clay minerals, as well as impurities such as sand, iron, resistant minerals, and carbon. The percentage of each clay mineral, determinable by x-ray diffraction methods, influences the strength, plasticity, thixotropy, swelling and shrinkage percent, cation exchange capacity, fired color, and vitrification range of a given clay (Patterson and Murray, 1983).

Common clay, a mixture of kaolinite, illite, and smectite,

is used to make structural brick, tile and pottery (Patterson and Murray, 1983). High percentages of smectite in a clay cause shrinkage and cracking, making it unsuitable for bricks, tile, drainpipe, etc. (Allen and Balk, 1954). Clay, mostly kaolinite, also is used as a filler (in paint, plastic, rubber), adobe bricks (with sand), filling abandoned oil and gas wells, and tamping blast holes (Patterson and Murray, 1983). Illitic shale containing sulfur and carbon will bloat upon heating, making it useful as a lightweight aggregate (Patterson and Murray, 1983).

Fire clay, ball clay, and kaolin are high in kaolinite. Fire clay is used to make refractory brick. It must have a pyrometric cone equivalent (PCE) of 20 or more to be satisfactory for this purpose. Clays with a higher PCE produce higher-duty refractory brick (Patterson and Murray, 1983). Ball clay (70% or more kaolinite) is very plastic and most widely used in ceramics. Most kaolin is mined as an inexpensive, white filler for paper (Severinghaus, 1983).

Bentonite clays (smectite) are valuable for their thixotropic, swelling, and cation exchange properties. Sodium bentonite has a high cation-exchange capacity (CEC). It also forms a thixotropic gel in water. This gel has been used as drilling mud in the oil industry for decades. Palygorskite is a magnesium clay that does not lose thixotropy in the presence of salty fluids (as sodium bentonite does). Calcium bentonites can absorb a great deal of water and swell as a result. Shrinkage upon drying makes them unsuitable for structural uses, they are quite valuable as desiccants, absorbents, and filters. Fuller's Earth, a commercial filter, is a bentonitic calcium smectite.

Smectites are also valuable as fire retardants, fillers, carrying media for chemical products, and as sealants lining waste pits or tailings ponds.

Clays are alteration products of igneous and metamorphic minerals, alteration caused by hydrothermal action or surficial weathering. Many important clays also are diagenetic alterations of less useful clay minerals. Most commercial deposits are residual, pockets of concentration caught in low-energy environments after erosion from areas of alteration. Important accumulations of clay minerals are found in river floodplains, lakes, lagoons, and low-energy marine environments (Carroll, 1970).

The clay mineral formed is dependent upon the parent rock-type and conditions of alteration. Kaolinite is formed by tropical weathering of igneous rocks. If transported to the sea, it flocculates near the shore, whereas cotransported smectites are deposited further into the basin. Smectites and bentonites are weathering products of volcanic ash and accumulate in alkaline environments where little leaching takes place (Carroll, 1970; Parham, 1964).

Occurrence--The geology of western Rio Arriba County is predominantly Tertiary sediments, low in clay beds, deposited on the eastern fringe of the San Juan Basin (Bingler, 1968). The potential occurrence of sizable quantities of clay is low; clays have not been produced from Rio Arriba County. Near the eastern boundary of the study area, the Cretaceous Lewis Shale and Mesaverde Group crop out. These formations have moderate

potential of occurrence of lightweight shale aggregate, but development potential is low because of the low population density of this area of the county. Locally, specialty clays may occur, as residual bentonite (ash alterations in channels), or kaolinite underclays below coal. Van Sant (written communication, 1964) reports high grade kaolinite below the Cretaceous Dakota Sandstone. His samples are from the Mesa Prieta area, north of highway 96 between Youngsville and Gallina beyond the boundary of the study area (Fig. 26). There is a moderate potential that thin beds of similar clay may be found at the same stratigraphic horizon in nearby areas, although the development potential will be directly a function of the outcrop exposure. Lack of hydrothermal activity in western Rio Arriba County leaves the potential of hydrothermally-formed clays quite low.

Crushed Stone (by M. R. Bowie)

Essentially all parts of the study area in Rio Arriba County contain surficial rocks suitable for crushed stone applications. The rocks include sedimentary units of Paleozoic through Cenozoic age, and Cenozoic igneous intrusives. Only small quantities of crushed stone have been quarried and processed in the county and only limited production data are available (Table 17). This material was used principally as ballast during highway and county road construction. National Forest Service crews used stone quarried from the San Jose Formation for road-fill in the Carson National Forest. Stone resources may also be used in the future as channel linings or bridge abutments along major

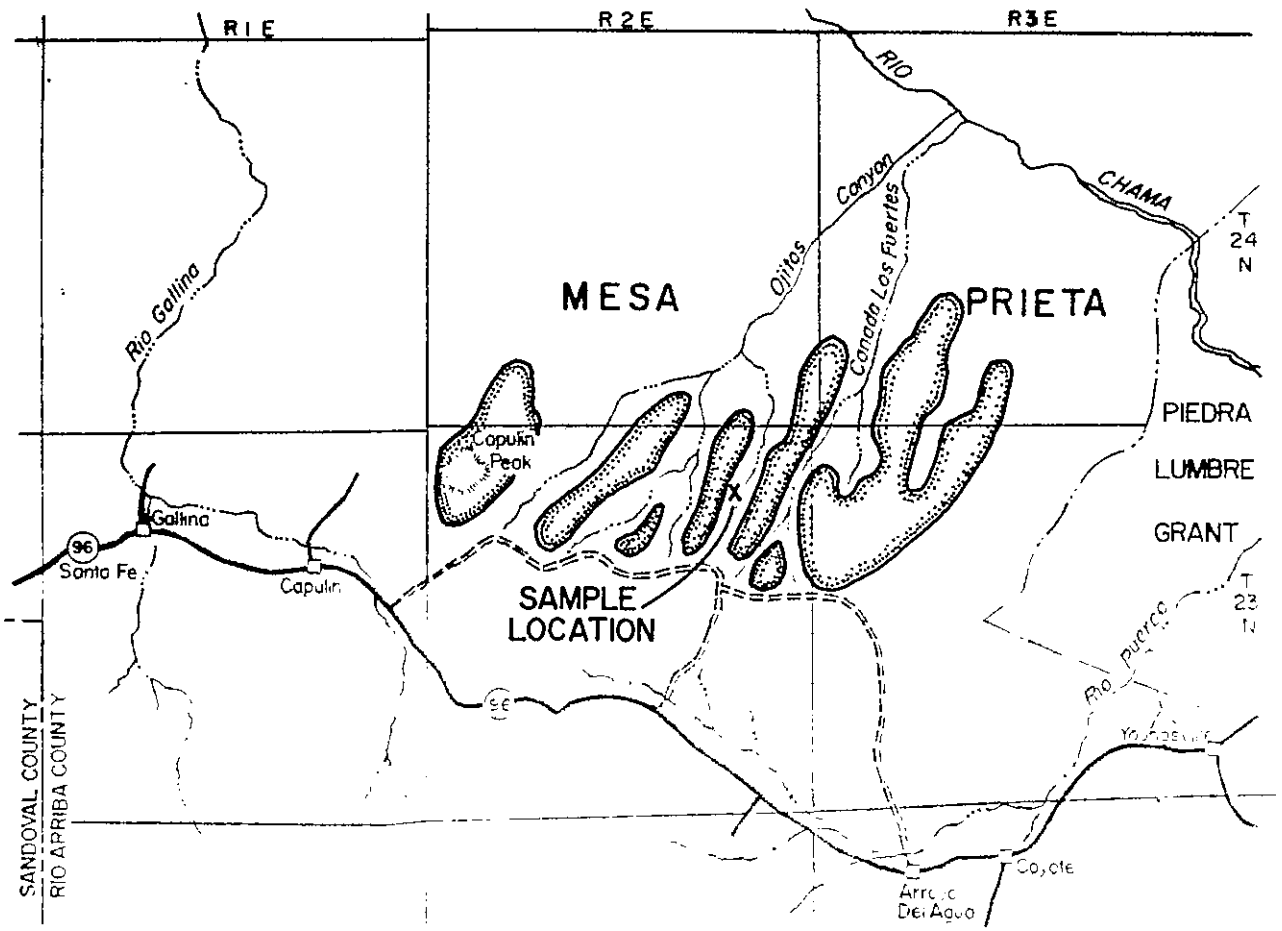


Figure 26. Mesa Alta area (Van Sant, 1964) Written Communication, stippled area represents extent of clay material.

waterways.

The resource potential for crushed stone in all parts of the study area is high (Fig. 27, Maps 92, 93). However, only limited testing of the resources has been done to assess their commercial capabilities. Detailed mapping, sampling, and drilling is required to adequately separate good stone from less desirable material, and to test the stone for specific industrial application.

Although the resource potential for crushed stone is high throughout the study area, the potential for development of these resources is variable. In general, the development potential is influenced by the nature and quality of the stone, its proximity to major transportation routes and markets, projected quarrying expenses, and competition from other nearby stone resources. The development potential for crushed stone resources in the study area is high along highways and primary county roads, along major waterways, and near population centers. Stone resources in more remote areas have only low to moderate development potential.

Table 17 - Historical production of crushed stone in Rio Arriba County (source: Bingler, 1968).

Year	Production (st)	Value ($)
1965	17,278	26,247
1964	120	4,000
1963	2,166	41,573
1962	155,925	157,500
1961	--	--
1960	--	--
1959	16,123	9,674
1958	16,400	9,900

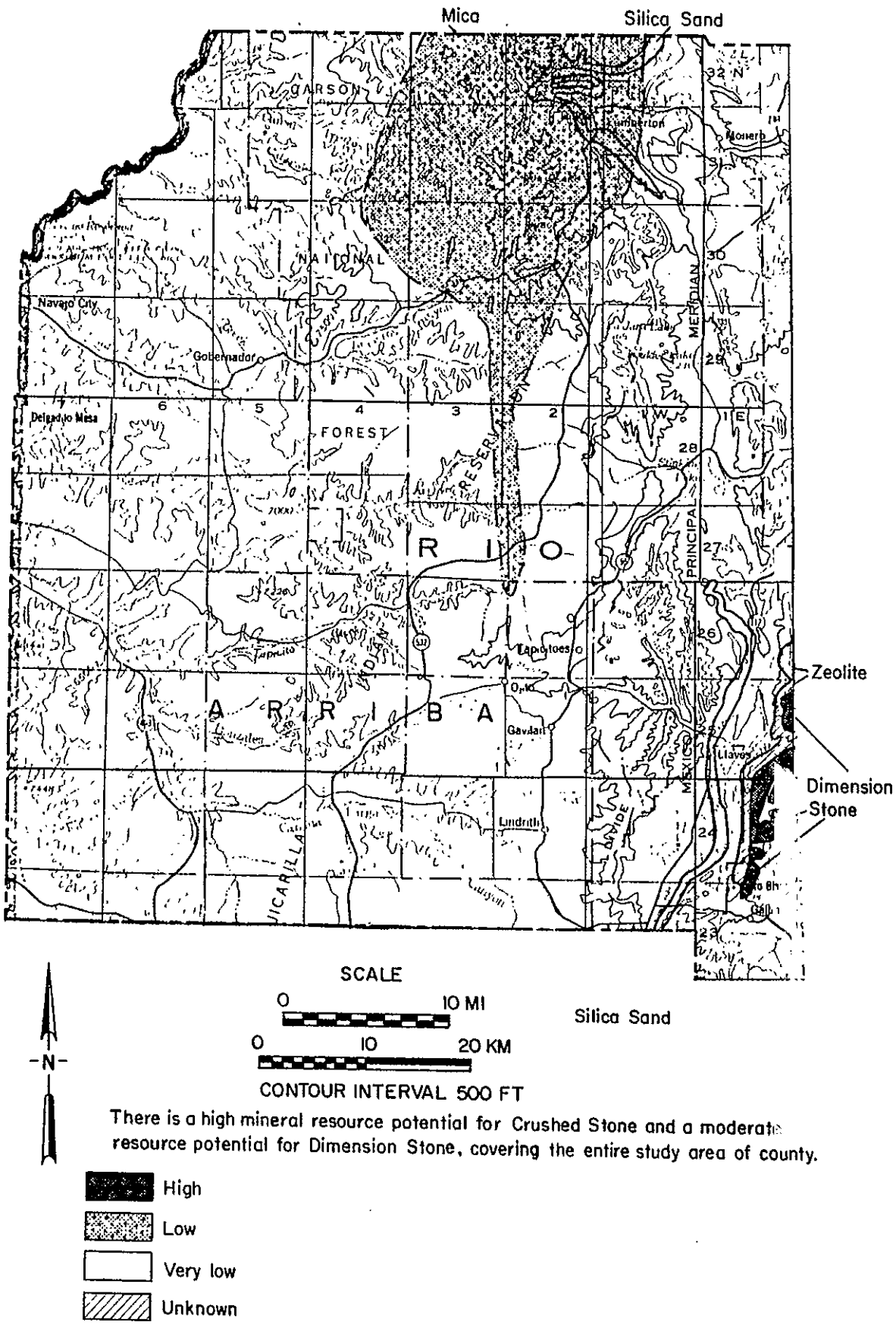


Figure 27. **Resource potential for crushed and dimension stone, mica, silica sand, and zeolite in western Rio Arriba County, New Mexico.**

Dimension Stone (by M. R. Bowie)

There are tremendous dimension stone resources in the study area (Table 18), yet there has been only minor usage of them. Little published data is available relative to commercial potential of the stone resources.

Of the rock units in the study area, the Triassic Chinle Formation and the Jurassic Entrada Sandstone have the greatest potential for use as dimension stone. Both units have been targeted for large-scale commercial operations in adjacent San Juan County (McLemore et al., 1986e). The rock is suitable for construction material, possibly for use in heavy masonry, bridge abutments, and dams. These units have a high resource potential for this commodity, in Rio Arriba County, whereas the other units listed in Table 18 have only a moderate resource potential (Fig. 27, Maps 92, 93). A thin sandstone sequence in the Lower Chinle has been quarried west of Abiquiu (Bingler, 1968). It consists of gray-white to yellowish-brown, fine- to medium-grained, massive to cross-bedded siltstone and discontinuous conglomerate lenses (Bingler, 1968). The lower Chinle grades upward into a transition zone of thin-bedded shaly sandstone to even-bedded shale which, in turn, grades into interbedded siltstone and shale of the upper Chinle. The upper member averages 300 ft in thickness but locally attains thicknesses of nearly 500 ft.

The Entrada Sandstone consists predominantly of tan to pinkish-tan to white, well rounded, well sorted, fine- to medium-grained, crossbedded quartz sandstone, with an average thickness of 200 to 250 ft. Weathered surfaces show a diversity of pale color shades.

Table 18 - Potential sources of dimension stone and crushed stone in Rio Arriba County.

Age	Lithologic Units
Tertiary	San Jose Formation, augite andesite
Cretaceous-Tertiary	Nacimiento Formation, Animas Formation, Ojo Alamo Sandstone
Cretaceous	Kirtland Shale, Fruitland Formation, Lewis Shale, Mesaverde Group, Mancos Shale, Dakota Sandstone
Jurassic	Morrison Formation, Todilto Limestone, Entrada Sandstone
Triassic	Chinle Formation
Permian	Cutler Formation

The potential for development of the potential dimension stone resources listed in Table 18 is dependent not only upon the quality and desirability of the stone, but also upon projected quarrying and transportation costs. In general, the development potential of stone near population centers is moderate to high, whereas it is only low to moderate in more remote areas.

Helium Resources (by R. F. Broadhead)

Helium Occurrences--Western Rio Arriba County has never produced commercial quantities of helium gas. Natural gas produced from oil and gas pools in Rio Arriba County contains some helium, but the precentage is insignificant and noncommercial. The U.S. Bureau of Mines (Moore, 1976) analyzed gas recovered from 39 wells in Rio Arriba County. Gas from only one well, the Humble Oil & Refining Co. No. 1 Navajo C (Fig. 28), located in sec. 8, T. 3 N., R. 5 W., contained helium in excess

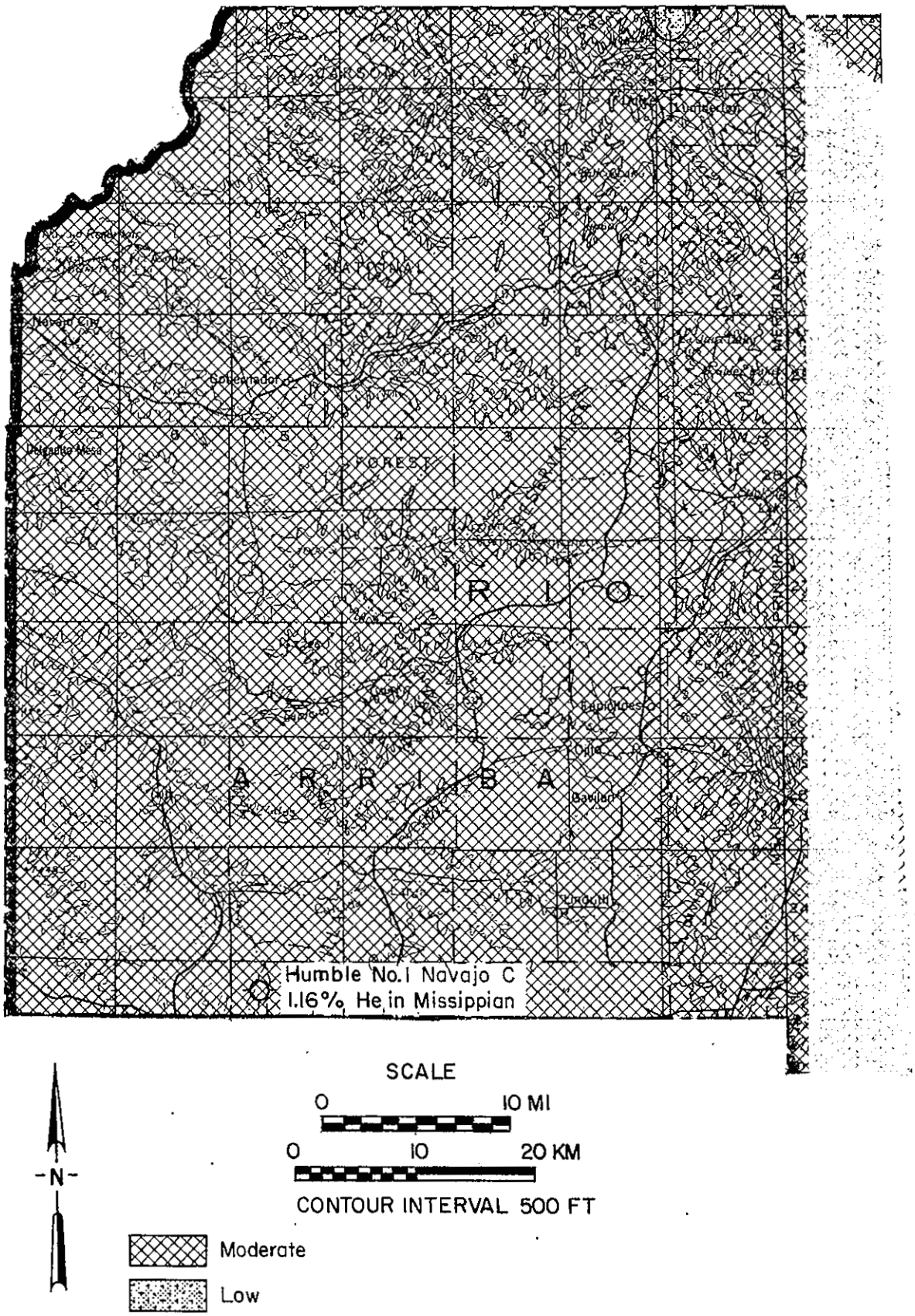


Figure 28. Helium potential in western Rio Arriba County, New Mexico.

of 0.1%; in the No. 1 Navajo C; gas recovered from the Mississippian at a depth of 8,070 ft contained 1.16% helium. The well was abandoned without attaining commercial production. Most analyses reported by Moore (1976) were of gases recovered from Cretaceous reservoirs. None of the Cretaceous gases contained significant amounts of helium. Generally, gas with less than 0.3% helium is considered uneconomic (Hertweck and Miller,1981; Casey, 1983; Spencer, 1983).

Helium has been produced commercially from several gas pools in the Four Corners area of New Mexico and Arizona. In New Mexico, helium has been produced commercially from five gas pools, all of which are located on the Four corners platform in western San Juan County (Casey, 1983). Reservoirs are chiefly Pennsylvanian, Mississippian, and Devonian. Gases produced from those pools contain more than 5% helium.

Helium Potential--Helium is found in porous, rock reservoirs and is trapped similarly to natural hydrocarbon gases. In the reservoir, it is mixed with other gases, chiefly nitrogen, carbon-dioxide, and hydrocarbons. Helium is usually less than 10 percent of the total gas in the reservoir. Helium is extracted from the produced gas and then it is marketed.

Helium in rock reservoirs originated from the breakdown of radioactive uranium and thorium. There are three sources of radioactive materials that may be important helium generators (Casey, 1983): (1) sediments containing uranium or thorium, (2) deep-seated igneous intrusives that de-gas as they rise and cool, and (3) Precambrian basement rocks that contain uniform, low

concentrations of radioactive materials. Picard (1962) concluded that helium in the Four Corners area originated by de-gassing of the Precambrian core of the Defiance uplift. Casey (1983) listed two important factors that may lead to the accumulation of helium: (1) presence of porous reservoir rock and (2) deep fault systems that could serve as conduits for the helium to pass from the source area to the reservoir rock. However, deep fault systems are not required if sedimentary uranium and thorium are the radioactive helium source because the reservoir rocks are physically near the source. It is probable that helium potential is higher in areas that do not have large quantities of hydrocarbon gases, which would dilute the helium in the reservoir.

Five key factors were analyzed in order to evalute the helium potential of western Rio Arriba County (Fig. 28): (1) known accumulations, (2) reservoirs, (3) traps, (4) presence of other gases, especially hydrocarbons, and (5) proximity to a helium source. Reservoirs and traps were discussed in detail in the section on petroleum resource potential and are only summarized here.

The helium potential of western Rio Arriba County is rated moderate. Possible reservoirs are Upper Cretaceous sandstones, the Entrada Sandstone (Jurassic), Triassic sandstones, Permian sandstones, Pennsylvanian limestones and sandstones, and Mississippian carbonates. Stratigraphic and structural traps are probably present in the Mesozoic and Paleozoic sections. Traps in the Cretaceous section are probably filled with hydrocarbons, which dilute the helium to insignificant concentrations; no

Cretaceous gases analyzed in western Rio Arriba County have significant concentrations of helium. The Entrada Sandstone (Jurassic) is a reservoir only in southwest Rio Arriba County; it is nonporous and impermeable elsewhere in the county. Traps in the Entrada are probably filled with oil rather than helium.

Traps in Triassic, Permian, Pennsylvanian, and Mississippian reservoirs may contain significant concentrations of helium. Helium in Triassic and Permian reservoirs is unlikely to be diluted significantly by hydrocarbons. Pennsylvanian and Mississippian reservoirs produce oil and hydrocarbon gas in San Juan County, but helium occurs in economic concentrations; the helium has not been diluted to uneconomic levels by the hydrocarbons. Only one analysis is available for gas recovered from Paleozoic reservoirs in western Rio Arriba County (Fig. 28) which indicates economic concentrations of helium may be locally present in the Mississippian.

There is no obvious source of helium in western Rio Arriba County. The Precambrian core of the Defiance uplift is thought to be the source of helium produced from the Four Corners platform in San Juan County (Picard, 1962). The Four Corners platform separates the central San Juan Basin of western Rio Arriba County from the Defiance uplift. It is unlikely that helium migrated from the Four Corners platform, down the Hogback monocline, and into the central basin. However, helium may have migrated into the central basin before the central basin was formed as a discrete tectonic element. Another possible, but undocumented, source of helium is the Precambrian basement of

western Rio Arriba County.

Western Rio Arriba County is assigned a moderate, and not a high potential, for helium occurrence because there has never been commercial helium production from that part of the county or from any portion of the central San Juan Basin. Nevertheless, the geology is favorable for helium occurrence.

The large Tertiary intrusive body five miles north of Dulce is assigned a low potential for helium occurrence. The igneous rocks that form that intrusive body are probably poor reservoirs. It is possible, but unlikely, that fractures and vesicles within the intrusive rock bodies could serve as reservoirs for helium.

Potential for Development--Helium has many commercial uses. The main uses of helium are (Spencer, 1983): cryogenics, welding, pressurizing and purging, synthetic breathing mixtures, leak detection, lifting gas (in balloons and blimps), heat transfer, controlled atmospheres (needed to grow crystals used in transistors and semiconductors), and medical applications. Known helium reserves are adequate to meet demand well beyond the year 2000 (Hertweck and Miller, 1981; Spencer, 1983). However, the long term demand for helium is uncertain (Spencer, 1983; Casey, 1983). Therefore, the potential for development of (yet) undiscovered helium accumulations in western Rio Arriba County is unknown.

Humate (by G. Roybal)

Definition--Geologically, humate refers to mudrocks rich in humic acids (Siemers et al., 1975). Weathered coals are also rich in humic acids, a product of the weathering process. Humate

is generally lower (17%) in humic acid than the weathered coal (66%; Siemers and Wadell, 1977). Weathered coal is commonly used as an ingredient in dispersants to control drilling mud viscosity which require a high humic acid content. Humate is generally used as a soil additive.

Occurrence--Humate is often associated with coal or is a part of coal-bearing sequences which represent facies in poorly-drained swamps in nearshore deltaic and fluvial sequences. The outcrops of the Cleary Coal Member of Menefee Formation in the Monero coal field are the only potential resource of humate or weathered coal in western Rio Arriba County.

Resource Potential--Carbonaceous, humic acid-rich mudrocks are common in the Menefee Formation, but there has been no formal investigation of their economic or resource potential. Siemers and Wadell (1977) estimated that humate deposits comprise 8 to 12 percent of the total thickness of the Menefee Formation, compared to 4 percent comprised of coal. Using these percentages and resource data available the humate resource for the Monero field would be 23 to 34 million tons.

Weathered coal occurs wherever there are coal outcrops and may extend 30-50 ft back from the outcrop. In the Monero field the weathered coal resource is limited by the poor exposure and the general lenticularity and thinness of the Menefee coals. The potential for weathered coal is best in the Monero-Lumberton area where coal outcrops on the sides of the mesas.

The resource potential for humate and weathered coal is low

to very low for the Menefee Formation in the Monero Field. This poor rating is due to the thinness of the entire coal-bearing sequence (50 ft., Shomaker, 1971) and the thinness of the coals and their lenticular nature.

Lightweight Aggregate (by J. S. Hingtgen)

Introduction--Lightweight aggregates are, in general, construction materials of lower density than rock aggregates like sand and gravel. Because of this, they are mostly used in roofing and wall components, where weight is important, and less often in foundation materials or as road base. Specialty uses of the lightweight aggregates often grow out of their utility in building construction products. Perlite, for example, is used for cryogenic insulating in much the same way it is used as a residential building insulator.

Lightweight aggregate typically includes perlite, pumice and pumicite, scoria and cinders, vermiculite and expansible shale. Perlite, expansible shale, and vermiculite are mined as dense rock, but special processing allows them to be made "lightweight." Each of these three mineral products contains bound water. By firing the ground particles within a narrow temperature range, the material can be made to expand. Pumice and scoria contain no significant bound water, but are already naturally expanded due to lava vesiculation. Processing of pumice and scoria involves simple milling and sizing to specified grades.

The lightweight aggregates are geologically diverse, being derived from sedimentary, volcanic, and intrusive igneous rocks.

Perlite, pumice and pumicite, and scoria and cinders are found in both lava flows and pyroclastic deposits. Expansible shale occurs as special regions within shale strata. Vermiculite is a secondary mineral produced when deep-forming plutonic rock becomes exposed and altered. No indication of vermiculite, perlite, scoria and cinders, or pumice in the literature exists covering this part of Rio Arriba County.

Geology--Generalizations about development potential can be made over the whole county for all lightweight aggregates. These materials are low unit-cost and for most applications have easily available substitutes. If the total cost of one becomes much higher than for the others, another will be used in its place. Although there is potential for only one lightweight aggregate in western Rio Arriba County, the others are present in neighboring counties and can easily be imported. Development potential is thus very dependent on prices of the other aggregates. Transportation costs must be kept low, so development potential is also dependent on nearness of the deposit to end-use centers. Prices in 1983 in New Mexico were as follows: perlite, $34/short ton; scoria, $6/ton (NME&MD, 1984, p. 109, 111). In 1983, pumice was sold for $10/ton, and vermiculite was $96/ton on a national basis (U.S. Bureau of Mines, 1985, p. 120, 172).

The predominance of bedded sediments in the study area makes the overall lightweight aggregate resource potential low, as most varieties are volcanic in origin. Several features that might appear to have potential can be ruled out on the basis of published descriptions. Archuleta Mesa in T. 32 N., R. 1 W. and

R. 2 W. is a sill, rather than a subaerial extrusion (Dane, 1948). Therefore dissolved gases probably did not exsolve and cause vessiculation, and scoria unlikely to be present. The dikes radiating south and west of Archuleta Mesa are genetically closely related to the sill (Dane, 1948), and also are unlikely to be vessiculated. Dane and Bachman (1957) show a rhyolite tuff outcrop at the southeast corner of the study area in T. 23 N., R. 1 E. Reference to the more detailed map of Santos et al.(1975) shows only bedded sediments in this location. The meta-ultramafic rocks necessary for vermiculite occurrence are present in the San Pedro Parks, but do not extend northward into the study area (Woodward et al., 1974; Woodward et al., 1977).

Expansible Shale--Certain shales become useable as lightweight aggregate upon being expanded to reduce their density. The ability to expand depends not on the age or absence of silt in the rock, but rather on the presence and correct chemical binding of water in the clay minerals. The species of clay appears to be important, and montmorillonite-illite clays have been found "more favorable for expansion than kaolinite." Processing involves firing at 1,800° to 2,200°F to achieve bloating. Although some slates have been expanded elsewhere, none occur in western Rio Arriba County. Use of lightweight aggregate in cement block in former years is being surpassed by use as high strength-to-weight ratio aggregate in construction materials (Foster, 1966, p. 3).

There is no simple way to predict whether a particular shaly formation will expand well, because test samples taken only a few

miles apart vary greatly in expansibility, as at Abo Pass (Foster, 1966, p. 12). At a Valencia County site the best shale tested in the state was collected only several miles from an unsuitable shale (Foster, 1966, p. 68).

One site in western Rio Arriba County has been sampled by the New Mexico Bureau of Mines and Mineral Resources. The Lewis Shale of upper Cretaceous age was collected at a roadcut on New Mexico Highway 17, half a mile west of Dulce, sec. 12, T. 31 N., R. 2 W. This shale is light olive gray (5Y6/1), very silty, slightly carbonaceous, and contains a few calcareous fossil fragments (Foster, 1966, p. 77). When fired, it showed moderate to high strength and was suitable for use as lightweight aggregate (Foster, 1966, p. 78, 14). Within a radius of several miles of this site the Lewis Shale is rated high in resource potential. Outside of an indefinite boundary which depends on the area of influence of a single sample, it is of unknown potential. The outcrop map of the Lewis Shale (Fig. 29 as unknown resource potential) is taken from Dane and Bachman (1965) and Dane (1948). Development potential is moderate for the western part of the county, diminishing eastward as the abundant lightweight aggregate resources of the Jemez Mountains are approached.

Limestone (by J. M. Barker)

General description--Limestone includes any rock composed of more than 50% calcium carbonate (Gary et al., 1974). Limestone is a term relatively free of genetic connotations so some classification problems occur. For example, travertine, which is

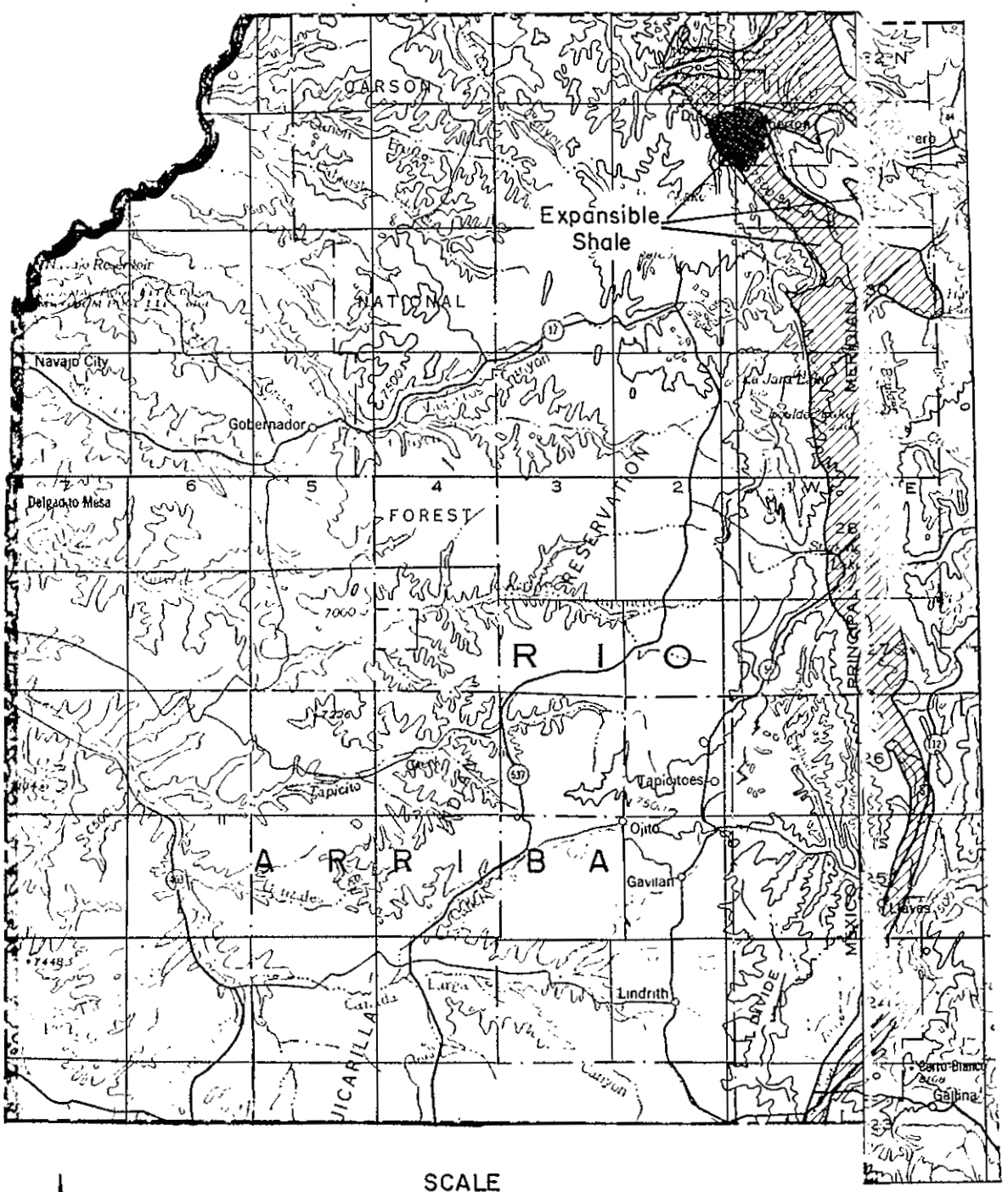


Figure 29. Lightweight aggregate resources in western Rio Arriba County, New Mexico.

typically a thermal-spring deposit, is a limestone as is a deposit composed of marine shells. The following discussion deals primarily with bedded limestones of the Madera Group (Pennsylvanian) and the Todilto Formation (Jurassic), both called simply limestone hereafter. The Yeso and San Andres Formations, along with younger rocks, do not contain significant limestone in western Rio Arriba County (Baars, 1974, p. 168; Fassett, 1974).

Few, if any, industrial minerals have as many end uses as limestone. Limestone comprises over 75% of all stone quarried domestically and makes up about 15% of the sedimentary crust of the earth. Locating limestone deposits typically is not difficult (Scott and Dunham, 1984) compared to locating a market for it. The literature on limestone is voluminous. Carr and Rooney (1983) listed nearly 400 limestone references while noting that this was but a fraction of the total. Limestone has 30 main end-use groups out of literally hundreds of specific end uses (Carr and Rooney, 1983, p. 846, table 7). The basic division is between end uses based on chemical properties and those based on physical properties. Chemical uses are predominantly as raw material for lime (Boynton and Gutschick, 1983) and cement (Ames and Cutcliffe, 1983) manufacture, or stack-gas cleanup. Physical uses include building stone or aggregate. All of these four basic uses, except for lime, are actual uses made of limestone in New Mexico.

Limestone use is generally heavily tied to the relationship of the stone's specifications to the end use contemplated (Power, 1983). The spectrum of limestone specifications is far too detailed to discuss herein. A complex set of standards is in

place exemplified by numerous American Society for Testing and Materials (ASTM) and American Association of State Highway and Transportation Officials (AASHTO) standards.

The calcium carbonate content ($CaCO_3$) of limestone intended for chemical use typically exceeds 95%. The maximum number of chemical end-use specifications can be met by a limestone with the following general composition: $CaO \geq 53.2\%$, $MgO \leq 1.25\%$, $Al_2O_3 \leq 0.75\%$ and minimal Fe_2O_3 with low silica usually favorable (McLemore, W. H., 1983). Variations in limestone chemistry are related to depositional environment so chemical limestones are most likely in coarse, sparry, well sorted limestones in contrast to micritic, muddy, poorly sorted ones (McLemore, W. H., 1983). Physical uses allow a wider range in limestone composition with the low end at about 65-70% $CaCO_3$. Chemical end uses are typically more profitable and are of greater importance in distant trade (Scott and Dunham, 1984) because their value can support higher transportation costs. Physical end uses have less stringent specifications, command a lower price, and hence are more important to regional use.

Limestone is normally quarried but can support underground mining depending on complex interactions between competing economic factors. These factors have limited underground limestone mining primarily to the eastern United States. The current producers of limestone in New Mexico utilize open pit operations supplying cement, stack-gas cleanup, dimension stone, or crushed stone end uses.

The abundance and distribution of limestone in western Rio

Arriba County is greatly reduced compared to the other counties studied in this project. Significant resources are limited to the southeasternmost portion of the study area (Fig. 30). The Todilto Formation is the main resource but potential exists, a few miles south of this portion, in limestone of the Madera Group (Kottlowski, 1962, fig. 3; Austin et al., 1982, p. 14; Kottlowski, 1965, fig. 63; DuChene, 1974, p. 101; Thompson, 1942). Minor limestone occurs in the Mancos Shale and the Lewis Shale (Fassett, 1974).

Todilto Limestone crops out over a small area in the southeasternmost portion of the study area (Fig. 30). The Todilto here is 1-12 ft thick and is impure (Kottlowski, 1965, p. 349). The material is not suitable for high-calcium or chemical end uses. It may be used for physical end uses so resource potential is high. Development potential is moderate based on the relative lack of limestone elsewhere in this portion of Rio Arriba County. Relatively extensive outcrops of Madera Limestone just south of the study area might be used instead of the Todilto if additional transport is warranted for the end use contemplated.

The Madera Group crops out extensively just south of the study area, and is widespread in the subsurface (Thompson, 1942). The Madera limestone crops out on the north flank of San Pedro Mountain (DuChene, 1974). It is 194 ft thick north of San Pedro Mountain (Lookinbill, 1953) and is composed of an arkosic member (Wood and Northrup, 1946). This member consists of arkosic gray limestone and pink arkose intercalated with fossiliferous, calcareous shale (DuChene, 1974). Availability of better quality

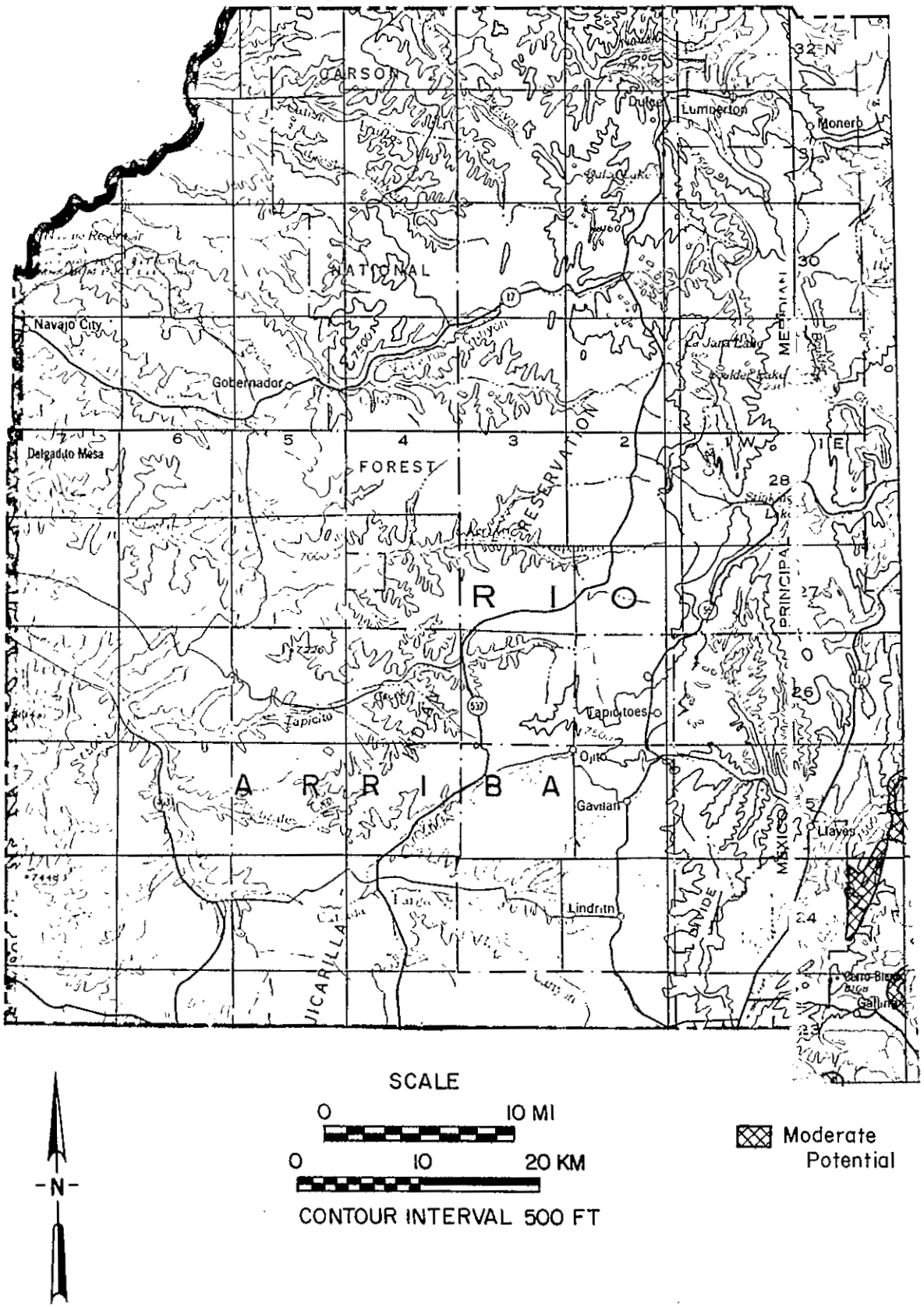


Figure 30. Limestone resource potential in western Rio Arriba County, New Mexico.

limestone in the Madera Group probably precludes use of limestone in the Mancos Shale or the Lewis Shale. Resource and development potential is moderate.

Mancos Shale contains the Greenhorn Limestone Member, a unit up to 78 ft thick (Fassett, 1974, p. 226, fig. 2). The member consists of alternating limestone and calcareous shale. The Greenhorn here is similar to that mapped to the east. Landis et al. (1974) described the Greenhorn, near Tierra Amarilla, as limestone beds a few inches to 2 ft thick alternating with calcareous shale. Limestone comprises about half the lower portion while the upper part is entirely calcareous shale. Resource and development potential is low.

Lewis Shale locally contains limestone concretions and thin limestone beds (Fassett, 1974, p. 227). These have low resource and development potential.

Mica (by M. R. Bowie)

Introduction--In New Mexico, industrial quality mica is restricted to Precambrian rocks in the southern Rocky Mountain area: in pegmatites of the Petaca district, Rio Arriba County and in quartz-muscovite schists of the Picuris Range, Taos County (Northrop, 1959; Lesure, 1965; Beckman, 1982). The only active mica operation in New Mexico is Mineral Industrial Commodities of America's (M.I.C.A.) Tojo mine in the Picuris Range. In 1983, the mine ranked second nationally in order of output of scrap and flake mica and third as a producer of ground mica from scrap and flake mica (New Mexico Energy and Minerals Department, 1984). Material extracted from the Tojo mine is milled at a facility

near Velarde in Rio Arriba County (Eveleth and Bieberman, 1984). The Petaca District lies east of the study area. It is underlain by Precambrian quartzite and quartz-mica schist which has been intruded by a fine- to medium-grained granite. Zoned and unzoned pegmatite dikes cut both the granite and metamorphic rocks. As at the Picuris Range deposits, the quartz-mica schist was probably derived from rhyolite metasomatic recrystallization (Gresens and Stenrud, 1974). Sheet mica was mined from the Petaca district as far back as the early 1700's (Beckman, 1982). About 25,000 tons of scrap mica has also been mined (Jahns, 1946). Current production data are held confidential.

In the area of Rio Arriba County under study here, a swarm of biotite-hornblende lamprophyre dikes and sills, from 1-30 ft thick, crop out in the northeastern part of the San Juan Basin (Dane, 1957; Bingler, 1968; Fassett and Hinds, 1971). These igneous rocks have a low resource potential for mica (Fig. 27, Map 92). Mica also occurs as a disseminated, very minor constituent of the sedimentary units in the study area. These rocks have a very low resource potential for mica. The potential for development of mica occurrences in the study area of the county is low.

Saline Minerals (by K. B. Brown)

There are no reported occurrences of saline minerals in western Rio Arriba County. The Permian beds here equivalent to the halite-bearing Yeso and San Andres Formations are continental deposits of the Cutler Formation and lack the potential for halite. Spring discharges also are barren of saline minerals.

Sand and Gravel (by P. Copeland)

General Description--Sand and gravel is an inert fragmental material used extensively in the construction industry. Sand and gravel is used primarily in the manufacture of concrete and adobe and in highway and railroad construction. The use of sand and gravel is closely tied to the economic activity in an area, because these materials are needed in large quantities during periods of urban expansion. Sand and gravel is very rarely transported long distances to market.

Various uses of sand and gravel may require specific engineering properties. These properties are measured by a series of geotechnical tests. Results of these tests are given for many of the materials pits listed in Appendix 1. These tests, which are performed following procedures listed in American Association of State Highway and Transportation Officials (AASHTO, 1982) include the following:

1. Atterberg limits; water-content boundary between the semiliquid and plastic states (the liquid limit or L.L.), the water-content boundary between the plastic and semisolid state (the plastic limit or P.L.), and the water-content range at which a sediment behaves plastically (the plasticity index or P.I.). Samples with little or no clay or silt will have plasticity indices of zero and are termed "not plastic".
2. Los Angeles Wear; a measure of the resistance to abrasive action determined by tumbling measured portions in a steel cylinder with a number of steel balls. The result is given as the percent of material lost.

3. The Magnesium Soundness Test (Soundness Loss); a measure of the resistance of coarse surfacing aggregate to freeze-thaw damage. This test is performed by soaking samples in a magnesium sulfate solution and drying them repeatedly. The result is given as the percent lost.

Geology--The western half of Rio Arriba County comprises the majority of the outcrop areas of the Tertiary San Jose Formation (Fig. 6). The San Jose consists of interbedded sandstones and siltstones and occupies the center of the asymmetrical San Juan Basin. Other units, which are found in the northeast part of this area, include the Tertiary Animas Formation and the Cretaceous Lewis Shale and Mesaverde Group. Also found in the northeast part of the area are numerous NNE-trending intrusive dikes of Tertiary age. Precambrian granite and metamorphic rocks are found in the southeast part of the area. Almost half of the known sand and gravel pits are producing from the San Jose Formation or alluvium derived directly from the San Jose. The other important source is sand and gravel from dikes in the northeast part of the area. Individual pits are described in Appendix 1. There are no pits known to be operating in 1985 or 1986.

Resource and development potential--Resource potential for sand and gravel in this area is low (Maps 88, 89). No good or excellent sources for this commodity exist in western Rio Arriba County, but there is a high potential for sand along some arroyos (Fig. 31). Consequently, development potential is also low. Any

large construction projects in this area would likely require imported sand and gravel, probably from San Juan County.

Silica Sand (by M. R. Bowie)

Several sedimentary units in the study area contain siliceous zones potentially suitable for use as high silica raw material (Table 19). The extent of highly siliceous material has not been adequately determined nor has much analytical work been done to assess their commercial potential. Although some units are composed dominantly of calcareous or argillaceous material, they often have sandstone beds intercalated with them. Further testing of these sands is required to determine their integrity for use as high silica raw material.

Phelps Dodge Company analyzed selected areas of the Jurassic Summerville, Bluff, and Morrison units in northwest New Mexico in search of high-grade silica flux ($\geq$ 90% SiO_2) for their flash furnace (Tipton, written communication, 1979). They determined that their samples were from sources unsuitable for silica flux, unsuitable primarily due to excessive natural contamination and remoteness of the sampled localities. The units contain variable amounts of calcareous and argillaceous cement, and are generally too arkosic and do not contain enough silica.

Bingler (1968) provided field and petrographic descriptions of the rock units in Rio Arriba County. The most promising units with potentially high silica material are the Entrada and Dakota Sandstones. These units warrant top exploration priority in the study area. The Entrada consists of tan to pinkish-tan to white, well rounded, well sorted, fine- to medium-grained crossbedded,

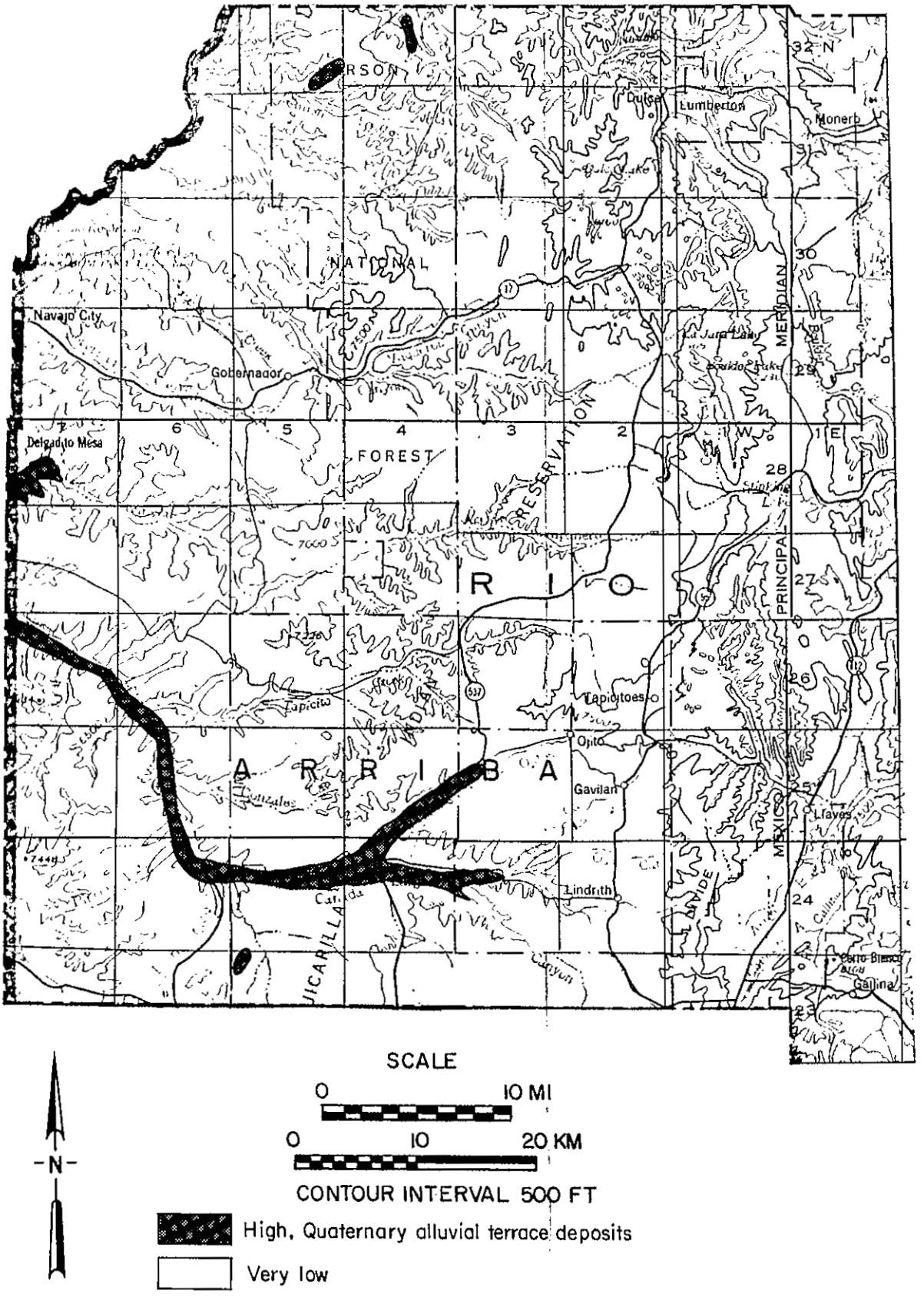


Figure 31. Resource potential for sand and gravel in western Rio Arriba County, New Mexico.

Table 19 - Potential sources of silica sand in Rio Arriba County.

Age	Lithologic Units
Tertiary	San Jose Formation, augite andeiste
Cretaceous-Tertiary	Nacimiento Formation, Animas Formation, Ojo Alamo Sandstone
Cretaceous	Kirtland Shale, Fruitland Formation, Lewis Shale, Mesaverde Group, Mancos Shale, Dakota Sandstone.
Jurassic	Morrison Formation, Todilto Limestone, Entrada Sandstone
Triassic	Chinle Formation
Permian	Cutler Formation

quartz sandstone (Smith et al., 1961). It averages 200 to 250 ft in thickness.

The Late Cretaceous Dakota Sandstone is 180 to 400 ft thick in the county. It consists of a basal zone and an uppermost zone composed dominantly of cliff-forming sandstone, separated by a medial zone of carbonaceous, fissile shale (Bingler, 1968). The basal sandstone consists of pale orange to yellowish-brown, fine- to medium-grained crossbedded, chert-bearing quartz sandstone. Individual sandstone beds contain discontinuous quartz pebble conglomerate zones. The upper sandstone is light-gray, fine- to medium-grained, partially silica-cemented, and is interbedded with shale lenses.

As the extent and quality of the potential resources of silica sand listed in Table 19 have not been adequately determined, the resource potential for silica sand is unknown in most parts of the study area (Fig. 27, Maps 92, 93). The

potential for development of potentially high silica raw material in the study area is only low to moderate, depending on the quality of the material, projected expenses of mining it, and its proximity to major transportation routes and markets.

Zeolites (by M. R. Bowie)

Zeolites have not been found, nor are they likely to occur in economic concentrations, in the study area in the county. Zeolites are speculated to occur in the Brushy Basin Member of the Jurassic Morrison Formation in the southeast corner of the study area (Turner-Peterson, 1985, p. 2004). Here, there is an unknown resource potential for these minerals. There is a very low resource potential for zeolites in the rest of the study area (Fig. 27, Maps 92, 93).

SUMMARY

As is true with all preliminary investigations, additional studies are necessary to assess adequately the mineral-resource potential in western Rio Arriba County. These assessments must be re-evaluated as economic conditions, geologic interpretations, and models change.

The mineral-resource potential for various commodities in western Rio Arriba County are summarized in Table 20 and Figures 19, 20, 22, 25, 27, 28, 29, 30, and 31. The most important commodity is petroleum. Limestone, clays, and crushed and dimension stone resources also have a high potential and are needed to support production of the energy resources. Additional work is necessary to calculate reserves and resources of these commodities in areas of high potential.

TABLE 20 - Summary of mineral-resource potential in western Rio Arriba County.

Commodity	Geologic formation	Geographic area	Mineral-resource potential
Petroleum	Cretaceous, Jurassic, upper Paleozoic	western Rio Arriba County	high
Coal	Cretaceous coal-bearing sequence	Monero field	low
	Cretaceous Fruitland and Menefee Formations (deep coal)	San Juan Basin	very low to moderate
Uranium	Ojo Alamo San Jose	southern Rio Arriba	low
Geothermal	-------	-------	very low
Miscellaneous Metals	Chinle Formation (copper, silver)	Nacinto Mountains	moderate
Barite	stream sediments in Kirtland-Fruitland contact and Nacimiento Formation	northern San Juan and southern Rio Arriba Counties	unknown
CO_2	several units	central San Juan Basin	low to moderate
Clays	Tertiary sediments	eastern fringe of San Juan Basin	low to ~~high~~ moderate
Crushed Stone	sedimentary units of Paleozoic through Cenozoic age, and Cenozoic igneous intrusives	entire study area	high
Dimension Stone	Triassic Chinle and Jurassic Entrada Sandstone		high
	Other rock units		moderate
Helium	Upper Cretaceous sandstones, Entrada Sandstone, Triassic Sandstones, Permian sandstones, Pennsylvanian limestones and sandstones and Mississippian carbonates	central San Juan Basin	moderate
Humate	Cretaceous Menefee Formation	Monero coal field	very low to low
Lightweight Aggregate	shale strata in sedimentary volcanic and igneous intrusive rocks	near Dulce	high in this area unknown elsewhere
Limestone	Todilto	southeastern study area	high
	Madera	north flank of San Pedro Mountain	moderate
	Mancos Shale	near Tierra Amarilla	low
	Lewis Shale		low
Mica	Precambrian rocks	northeastern part of San Juan Basin	low
Saline	Permian	entire study area	very low
Sand and Gravel	Tertiary and Quaternary		low
Silica Sand	Permian to Tertiary	various areas in study area	unknown
Zeolites	Jurassic	southeast corner of study area	unknown

RECOMMENDATIONS

1) Any areas with active claims should be examined (Fig. 11).
2) Isopach facies and structure-contour maps of several formations in Rio Arriba County should be completed to delineate favorable areas for oil and gas accumulations.
3) Analyze the thermal maturity and kerogen content of marine Mancos Shales in the subsurface of western Rio Arriba County.
4) Drill more wells in the Paleozoic section of the San Juan Basin (western Rio Arriba County) to better document reservoir quality of Paleozoic units.
5) Test the Pennsylvanian section in western Rio Arriba County to determine the reservoir quality of Pennsylvanian units.
6) Drill in the Paleozoic section to establish depositionally dependent porosity zonations.
7) Aggregate resources should be mapped and sampled in greater detail prior to extraction of such materials.
8) Examine the belt of anomalous barium values found in the NURE stream-sediment samples along the Kirtland-Fruitland contact in northern San Juan and southern Rio Arriba Counties.
9) Detailed studies of the mineralogy and chemistry of clay deposits are required to fully assess their potential.
10) Exploration and testing of expansible shale regions rated unknown are needed to delineate any economic potential.

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APPENDIX 1

MINERAL AND OTHER COMMODITY OCCURRENCES, DEPOSITS, AND MINES IN WESTERN RIO ARRIBA COUNTY

Introduction

The following compilation of mineral and other commcdity occurrences (excluding oil, gas, and CO_2 tests) is the mcst comprehensive tabulation of mineral occurrences in the area. It is probable that additional occurrences will be discovered in the future. For the purposes of this report, any locality where mineralization or materials prospects are found is considered an occurrence, including sand and gravel (materials) pits.

Each description is a brief account of the location, commodities present, production, and geology of the occurrence that was compiled from the literature, unpublished sources, and field reconnaissance. Each occurrence is plotted on Maps 1-7, 15-20, and 26-30. Metal occurrence are arranged by township and range.

Explanation of descriptions

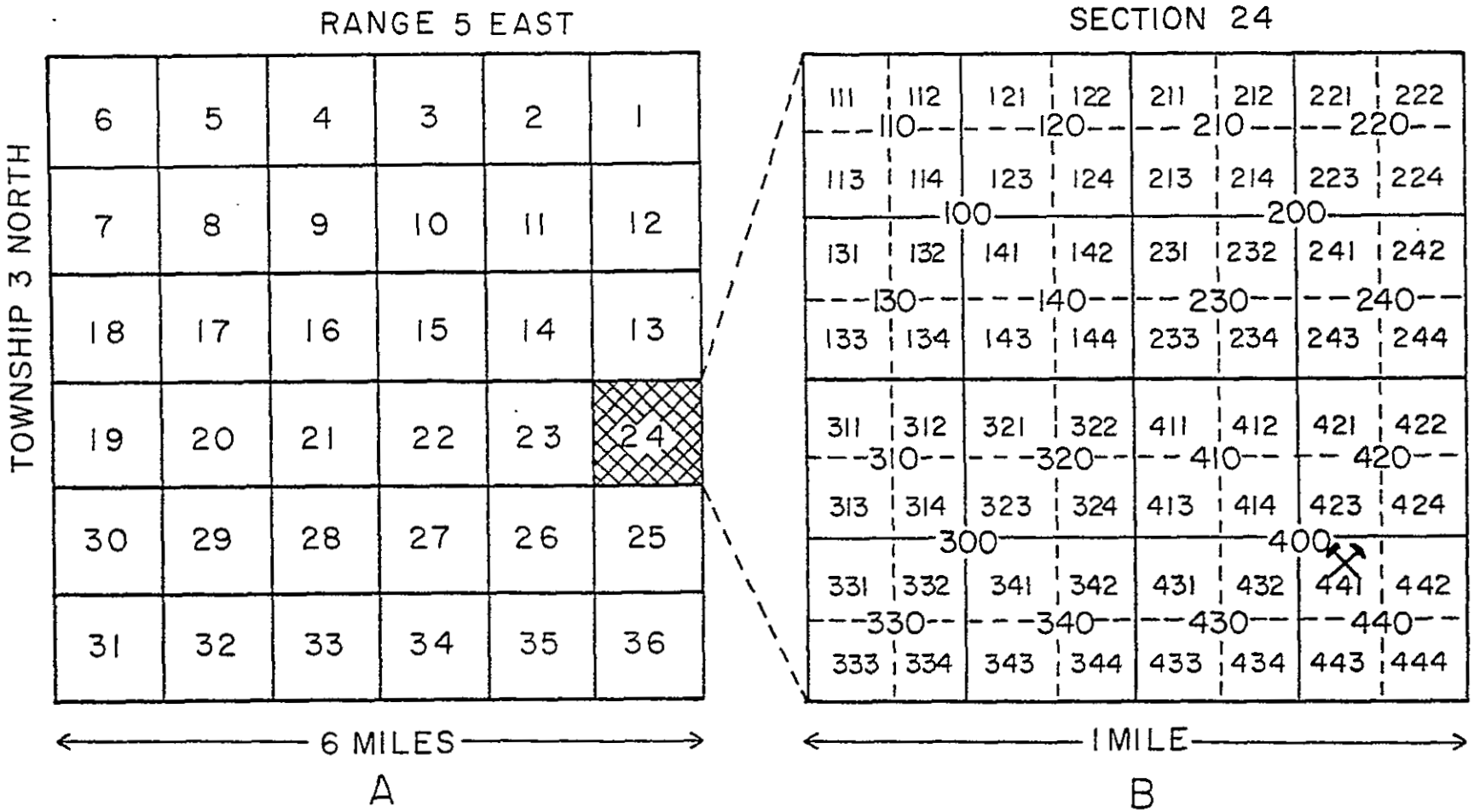
The descriptions of mineral occurrences in this section are brief summaries of published and unpublished information. However, not all of the available information could be included; information for some occurrences is considered confidential by a company or the information is very extensive. Very little information could be obtained for some occurrences. Each description consists of 12 entries or less (depending on available information), and the entries are listed by number as described below.

1: Occurrence number refers to the location or approximate location of each mineral occurrence, prospect, deposit, or mine. The numbering system used is based upon the township, range, and section land-grid system (Fig. 1-1) and is used by the New Mexico State Engineer for numbering water wells and springs. By this system, each occurrence has a unique location number consisting of our parts separated by periods (e.g., 3N.5E.15.441). The first part refers to the township, the second part to the range, and the third part to the section. The fourth part places the occurrence within the nearest quarter-quarter-quarter section block as indicated in Figure 1-1. An occurrence designated 3N.5E.15.441 is located in the NW1/4 SE1/4 SE1/4 of sec. 15, T3N, R5E. Some occurrences are located only to the nearest section, quarter-section, or quarter-quarter section because the occurrence can not be located more accurately or the occurrence extends over the entire given area. Some occurrences are listed by township and range and located in the center of the township. In unsurveyed areas, the locations are approximated by projecting section lines.

2. Name of the occurrence, prospect, deposit, or mine as found in the literature. Aliases are given in parentheses.
3. Location of the occurrence by the section, township, and range and by latitude and longitude.
4. Names of the 7 1/2-minute or 15-minute topographical quadrangle maps; the 30-minute by 60-minute topographical quadrangle map is in parentheses.

5. Mining district or geographical area.
6. Commodities present at the locality.
7. The extent of development or prospecting.
8. Production statistics for various commodites.
9. The formation name and geologic age of the host rock.
10. Brief description of the geology, host rock, and character of the deposit; including chemical analyses and other pertinent information.
11. Comments or additional information.
12. References or sources of information are listed in an abbreviated form and arranged in chronological order. Published reports are listed with last name or author(s) and year of publication in parentheses; the complete citation may be found in the reference section. Unpublished sources are abbreviated as follows: FN (field notes); NMBMMR files (New Mexico Bureau of Mines and Mineral Resources unpublished files); USAEC files (U.S. Atomic Energy Commission files); PRR (Preliminary Reconnaissance Reports of the Atomic Energy Commission); USBM files (U.S. Bureau of Mines files); CRIB (Computerized Resource Information Bank, U.S. Geological Survey); MILS (Mineral Industry Location Survey, U.S. Bureau of Mines); NMSHD (New Mexico State Highway Department files); PC (personal communication); and WC (written communication). Copies of most of these reports are available for inspection at the New Mexico Bureau of Mines and Mineral Resources.

FIGURE 1-1 – Numbering system used in this report.
A – Subdivision of a township into sections.
B – Subdivision of a section into quarter-quarter-quarter section blocks. Mine symbol indicates location of an occurrence numbered 3N.5E.24.441.



Rio Arriba County

Uranium and Metal Occurrences

1: 21N.1E.27
2: Copper City Group
3: 27 T21N R1E (unsurveyed) 36°1'30"N 106°49'10"W
4: Nacimiento Peak 7-1/2
5: Nacimiento Mountains district
6: U, Cu
8: no uranium production
9: Triassic Chinle Formation--Aguas Zarca Sandstone
10: Sandstone
12: Santos et al. (1975); Woodward, et al. (1974); Hilpert and Corey (1955)

1: 21N.1E.32.200
2: Eureka Mine (Nacimiento Mine)
3: NE1/4 32 T21N R1E (unsurveyed) 36°00'35"N 106°51'10"W
4: Nacimiento Peak 7-1/2 Elevation 9,080 ft
5: Nacimiento Mountains district
6: U, Cu, Ag
7: pits, 5 adits
8: no uranium production
9: Triassic Chinle Formation--Agua Zarca Sandstone
10: Sandstone
11: examined by Green et al. (1980a); owned by Earth Resources Co.
12: Green et al. (1980, #61); Santos et al. (1975); Woodward et al. (1974); Soule (1956); Hilpert and Corey (1955); Gott and Erickson (1952,b; 1951); PRR unnumbered (1951)

1: 23N.1E.19.333
2: White Flo #1 (White Flow #1, Corral #3 claim)
3: SW1/4 SW1/4 19 T23N R1E 36°12'15"N 106°53'00"W
4: Regina 7-1/2 Elevation 8,100 ft
5: Vegitas Cluster area-San Pedro Mountains
6: U, Cu, V
7: 125-ft long trench
8: 4 tons ore yielding 7 lbs U_3O_8 (0.08%), 43 lbs V_2O_5
9: Permian Abo Formation
10: sandstone
11: on the Corral #3 claim; examined by Green et al. (1980a)

1: 23N.1E.19.333
2: White Flo #1 (White Flow #1, Corral #3 claim)
3: SW1/4 SW1/4 19 T23N R1E 36°12'15"N 106°53'00"W
4: Regina 7-1/2 Elevation 8,100 ft
5: Vegitas Cluster area-San Pedro Mountains
6: U, Cu, V
7: 125-ft long trench
8: 4 tons ore yielding 7 lbs U_3O_8 (0.08%), 43 lbs V_2O_5
9: Permian Abo Formation
10: Sandstone
11: on the Corral #3 claim; examined by Green et al. (1980a)
12: Merrick and Woodward (1982); Green et al. (1980a, #29); Anderson (1980); Vizcaino et al. (1978); Santos et al. (1975); Woodward et al. (1974); Chenoweth (1974b); Hatson (1958); Brown (1955); PRR-ED-R-610 (1956); USAEC files (1960)

1: 23N.1E.29.144
2: E and B No. 1 (E and B No 3; D.B. Group?)
3: NW1/4 29 T23N R1E 36°11'43"N 106°51'30"W
4: Gallina 7-1/2 Elevation 8,140 ft
5: Vegitas Cluster area-San Pedro Mountains
6: U, Cu
7: several pits and trenches
8: no uranium production
9: Permian Abo Formation
10: Sandstone
11: examined by Green et al. (1980)
12: FN 7/31/82; Green et al. (1980, #31); Woodward et al. (1976); Santos et al. (1975); Chenoweth (1974b); Hilpert (1969, p. 46); Brown (1955); PRR ED-R-513 (1954)

1: 23N.1E.29.340
2: TJBD #1
3: SW1/4 29 T23N R1E 36°11'25"N 106°51'35"W
4: Gallin 7-1/2
5: Vegitas Cluster area-San Pedro Mountains
6: U, Cu
7: no workings found on 7/31/82
8: no production
9: Permian Abo Formation
10: 0.15% U_3O_8 (Hilpert, 1969) in sandstone
12: FN 7/31/82; Green et al. (1980a, #32); Vizcaino et al. (1978); Woodward, et al. (1976); Santos et al. (1975); Chenoweth (1974b); Hilpert (1969, p. 46); Brown, (1955)

1: 23N.1E.30.141
2: Max Jacque and Yellow Bird #2
3: NW1/4 30 T23N R1E 36°11'55"N 106°52'45"W
4: Regina 7-1/2 Elevation 8.070 ft
5: Gallina district-San Pedro Mountains
6: U, Cu
7: large bench cut (300-ft long, 30-ft high)
8: no production known
9: Permian Abo Formation
10: discontinuous and spotty mineralization in fluvial sandstones and conglomerates, 0.05% U_3O_8, 0.26% Cu, 0.3 oz/ton Ag; 0.05% U_3O_8, no Au, Ag, or Cu (NMBMMR chem lab, 10/6/82, #2850, 2853)
12: FN 7/31/82; Merrick and Woodward (1982); Green et al. (1980, #30, #57); Santos et al. (1975, p. 17); Hilpert (1969, p. 46); Hilpert and Corey (1955); Brown (1955)

1: 23N.1E.28.411
2: O'Brien No. 1
3: SE1/4 28 T23N R1E 36°11'40"N 106°50'00"W
4: Gallina 7-1/2 Elevation 8,410 ft
5: Vegitas Cluster area-San Pedro Mountains
6: U, Cu
7: no workings
8: no production
9: Permian Abo Formation
10: 85 ppm U_3O_8 (Green and others, 1980a)
11: examined by Green and others (1980a)
12: Green et al. (1980a, #33); Vizcaino et al. (1978); Woodward, et al. (1976); Santos et al. (1975); Chenoweth (1974b); Hilpert (1969, p. 46); Brown (1955)

1: 23N.1E.31.120
2: Pajarito Azul (La Reina, Pajaro Colorado, Pajaro Azul)
3: 30, 31 T23N R1E 36°11'15"N 106°52'45"W
4: Regina 7-1/2 Elevation 8,400 ft
5: Vegitas Cluster area-San Pedro Mountains
6: U, V, Cu
7: 4 prospect pits
8: no production
9: Permian Abo Formation and Pennsylvanian Madera Formation
10: Sandstone
12: Merrick and Woodward (1982); Green et al. (1980, #34, 73); Vizcaino (1975); Chenoweth (1974b); Brown (1955); USBM files (1945)

1: 23N.1E.32.114
2: Gallina (Sefrina, Unknown, Section 32)
3: NW1/4 32 T23N R1E 36°11'5"N 106°51'50"W
4: Gallina 7-1/2 elevation 8,320 ft
5: Vegitas Cluster area-San Pedro Mountains
6: Cu, U
7: bulldozed area, 2 pits
8: minor copper production, no uranium production
9: Pennsylvanian Madera Formation
10: copper and uranium mineralization in bleached white to gray, coarse-grained fluvial sandstone
12: FN 7/31/82; Green et al. (1980, #73); Woodward et al. (1976); Santos et al. (1975, p. 17); Hilpert (1969, p. 47); Soulé (1956, p. 52); Hilpert and Corey (1955); Brown (1955, p. 10)

1: 23N.1E.32.300
2: Paradise (Sefrina, Gallina)
3: SW1/4 32 T23N R1E 36°10'35"N 106°51'35"W
4: Gallina 7-1/2
5: Vegitas Cluster area-San Pedro Mountains
6: U, Cu
7: no workings found on 7/31/82
8: no production
9: Permian Abo Formation and Pennsylvanian Madera Formation
10: copper oxides in sandstone
11: small ore pile found in NW1/4 32 T23N R1E on 7/31/82, no workings found in area
12: FN 7/31/82; Green et al. (1980, #d67); Woodward et al. (1976); Santos et al. (1975); Chenoweth (1974b); Hilpert (1969, p. 46); Brown (1955)

1: 23N.1W.16.340
2: State Lease (Little Prospect)
3: SE1/4 SW1/4 16 T23N R1W 36°13'00"N 106°56'47"W
4: Regina 7-1/2 Eleation 7,550 ft
5: west of Gallina district-San Pedro Mountains
6: U
7: no workings
8: no production
9: Tertiary San Jose Formation
10: mineralized gray sandstone and mudstone 0.08% U_3O_8 (Chenoweth, 1975b)
11: could not locate on 7/31/82; examined by Green et al. (1980)
12: FN 7/31/82; Green et al. (1980, #16); Chenoweth (1974a; 1957b); Hilpert (1969); PRR ED-R-492 (1954)

1: 23N.2W.15
2: Unknown
3: 15 T23N R2W (unsurveyed)
4: Five Lakes Canyon NE 7-1/2
6: U
7: no workings
8: no production
9: Jurassic Todilto Limestone
10: Limestone
12: Green et al. (1980a, #65); Hilpert and Corey (1955)

1: 24N.1W.36.222
2: Anomaly NA-17 (Unnamed)
3: NE1/4 NE1/4 36 T24N R1W
4: Llaves 15
5: Llaves area
6: U
7: no workings
8: no production
9: Eocene Ojo Alamo Sandstone(?) or Nacimiento Formation(?)
10: radioactive zone in coarse sandstone with wood fragments, 0.02% U_3O_8 (PRR)
12: McLemore (1983a); Green et al. (1980, #15); Vizcaino and O'Neill (1977); Chenoweth (1974b; 1957b, p. 15-16); Hilpert (1969, p. 46); Easton (1955b); PRR ED-R-1465 (1954)

1: 25N.1E.30.320
2: Coy Claims (Z.O. Young)
3: NE1/4 SW1/4 30 T25N R1E
4: Llaves 15
5: Llaves area
8: no production
9: Eocene San Jose Formation--Llaves Member
10: radioactive zone in sandstone, 0.04% U_3O_8 (Chenoweth, 1957b)
11: occurrence could not be located by Green et al. (1980)
12: McLemore (1983a); Green et al. (1980, #8); Vizcaino and O'Neill (1977); Chenoweth (1974b; 1957b, p. 15-17); Hilpert (1969, p. 47); PRR ED-R-623 (1956); ED-R-602 (1956)

1: 25N.1W.11.220
2: Carbon and Log
3: N1/2 NE1/4 11 T25N R1W (unsurveyed) 36°25'5"N 106°54'25"W
4: Llaves 15 Elevation 7,600 ft
5: Llaves area
6: U
7: no workings
8: no production
9: Eocene San Jose Formation-Llaves Member
10: radioactive lignite zones in channel sandstone, 62.8 ppm U_3O_8 (Green et al. 1980)
11: examined by Green et al. (1980); PRR incorrectly locates this prospect in R1E
12: Green et al. (1980, #7); Vizcaino and O'Neil (1977); Chenoweth (1974b; 1957b, p. 15-16); Hilpert (1969, p. 47); PRR ED-R-619 (1956)

1: 25N.1W.19
2: Young prospect
3: 19 T25N R1W
4: Llaves 15
5: Llaves area
6: U
7: no workings
8: no production
9: Eocene San Jose Formation
10: 0.04% U_3O_8 (Hilpert, 1969) in sandstone
12: Hilpert (1969, p. 47)

1: 26N. 1W.33.330
2: Princess Claims
3: SW1/4 SW1/4 33 T26N R1W
4: Llaes 15
5: Llaves area
6: U
7: no workings
8: no production
9: Eocene San Jose Formation-Llaves Member
10: radioactive zone at base of sandstone
11: Green et al. (1980) could not locate described occurrence; PRR incorrently locates occurrence in Section 31
12: Green et al. (1980, #6); Vizcaino and O'Neill (1977); Chenoweth (1974b; 1957b, p. 15-16); PRR ED-R-622 (1956)

1: 27N.1E.2.420
2: Airbourne Anomaly No. 3
3: NE1/4 SE1/4 2 T27N R1E
4: Boulder Lake 15
6: U, Th, Ti
7: no workings
8: no production
9: Cretaceous Point Lookout Sandstone
10: 1,000-ft long; 5-ft thick beach-placer sandstone
11: inaccessible on 9/1/81
12: McLemore (1983a); Bingler (1968); Chenoweth (1957a, c); PRR ED-R-606 (1956)

1: 28N.1E.3.311
2: Airbourne Anomaly No. 1 (Stinking Lake, Jicarilla Reservation)
3: NW1/4 SW1/4 3 T28N R1E
4: Boulder Lake 15
6: U, Th, Ti
7: no workings
8: no production
9: Cretaceous Point Lookout Sandstone
10: 700-ft long, 5-ft thick reddish brown beach-placer sandstone, 0.01% U_3O_8 (PRR)
12: McLemore (1983a); Bingler (1968); Chenoweth (1957a, b); PRR ED-R-604 (1956)

1: 28N.1E.3.323
2: Airbourne Anomaly No. 2 (Stinking Lake, Jicarilla Reservation)
3: E1/2 SW1/4 3 T28N R1E
6: U, Th, Ti
7: no workings
8: no production-5,000,000 tons of ore in reserve
9: Cretaceous Point Lookout Sandstone
10: 300-ft long; 5-ft thick red-brown beach-placer sandstone deposit, 5.73% TiO_2
12: McLemore (1983a); Bingler (1968); Chenoweth (1957a, c); PRR ED-R-606 (1956)

MATERIALS PITS

WESTERN RIO ARRIBA COUNTY

1: 21N.1E.15.330
2: Pit 0897
3: SW1/4 SW1/4 sec 15, T21N, R1E
4: Nacimiento Peak 7.5 (Abiquiu)
6: "granite"
7: prospect pit
9: Precambrian quartz monzonite
10: good quality, 100+ ft thick, unlimited volume, LA wear 52.6, soundness loss 4.1, P.I. not plastic
12: NMSHD (1974)

1: 23N.2W.11
2: Pit 5972
3: Sec 11, T23N, R2W (projected)
4: Five Lakes Canyon 7.5 (Chaco Canyon)
6: sand
7: developed pit
9: Tertiary San Jose Formation
10: good quality, 1 ft thick, 100,000+ cu yds P.E. S.N.P.
12: NMSHD (1974)

1: 23N.4W.4
2: Pit 6121
3: Sec 4, T23N, R4@ (projected)
4: Tomcosa Windmill 7.5 (Chaco Canyon)
6: sand
7: developed pit
9: Tertiary San Jose Formation
10: fair quality, 9+ ft thick, 200,000 cu yds, P.I. not plastic
12: NMSHD (1974)

1: 24N.1E.21.222
2: Pit 0887
3: NE1/4 NE1/4 NE1/4 sec 21, T24N, R1E
4: French Mesa 7.5 (Abiquiu)
6: sand
7: prospect pit
9: Quaternary alluvium
10: fair quality, 10 ft thick, 1,000+ cu yds, P.I. not plastic
12: NMSHD (1974)

1: 24N.4W.8
2: Pit 6122
3: Sec 8, T24N, R4W (projected)
4: Tamcosa Windmill 7.5 (Chaco Canyon)
6: sand
7: developed pit
9: Quaternary alluvium
10: fair quality, 6 ft thick, 155,000+ cu yds, P.I. not plastic
12: NMSHD (1974)

1: 24N.4W.33
2: Pit 6222
3: Sec 33, T24N, R4W (projected)
4: Tamcosa Windmill 7.5 (Chaco Canyon)
6: sand
7: developed pit
9: Tertiary San Jose Formation
10: fair quality, 5 ft thick, 100,000+ cu yds, P.I. not plastic
12: NMSHD (1974)

1: 26N.1W.27.430
2: Pit 0883
3: SW1/4 SE1/4 Sec 27, T26N, R1W
4: Cañada Ojito 7.5 (Abiquiu)
6: sand
7: prospect pit
9: Tertiary San Jose Formation
10: poor quality, 2-4 ft thick, 50,000 cu yds, P.I. not plastic
12: NMSHD (1974)

1: 26N.3W.13
2: Pit 0874
3: Sec 13, T26N, R3W (projected)
4: Ojito 7.5 (Chaco Canyon)
6: lamprophyre
7: prospect pit
9: Tertiary intrusive dike
10: good quality, 35+ ft thick, 100,000 cu yds, LA wear 34.3, soundness loss 40.0, P.I. not plastic
12: NMSHD (1974)

1: 26N.3W.18
2: Pit 6503
3: Sec 18, T26N, R3W (projected)
4: Schmitz Ranch 7.5 (Chaco Canyon)
6: sand
7: developed pit
9: Tertiary San Jose Formation
10: fiar quality, 12+ ft thick, 300,000+ cu yds, P.I. not plastic
12: NMSHD (1974)

1: 28N.3W.5.330
2: Pit 6713
3: SW1/4 SW1/4 sec 5, T28N, R3W
4: Leandro Canyon 7.5 (Navajo Reservoir)
6: sandstone
7: developed pit
9: Tertiary San Jose Foremation
10: fair quality, 4+ ft thick, 290,000 cu yds, P.I. not plastic
12: NMSHD (1974)

1: 29N.3W.20.200
2: Pit 6712
3: NE1/4 sec 20, T29N, R3W
4: Leandro Canyon 7.5 (Navajo Reservoir)
6: sand and sandstone
7: developed pit
9: Tertiary San Jose Formation
10: fair quality, 8-15 ft thick, 700,000 cu yds, P.I. not plastic
12: NMSHD (1974)

1: 30N.2W.20.140
2: Pit 0672
3: SE1/4 NW1/4 sec 20, T30N, R2W
4: John Mills Lake 7.5 (Navajo Reservoir)
6: sand and sandstone
7: prospect pit
9: Tertiary San Jose Formation
10: fair quality, 20+ ft thick, 440,000+ cu yds, P.I. not plastic
12: NMSHD (1974)

1: 30N.2W.22.140
2: Pit 5932
3: SE1/5 NW1/4 sec 22, T30N, R2W
4: John Mills Lake 7.5 (Navajo Reservoir)
6: sand
7: developed pit
9: Quaternary alluvium
10: fair quality, 18 ft thick, 40,000 cu yds, P.I. not plastic
12: NMSHD (1974)

1: 30N.2W.30.412
2: Pit 5931
3: SE1/4 sec 30, T30N, R2W
4: Cement Lake 7.5 (Navajo Reservoir)
6: monzonite
7: developed pit
9: Tertiary intrusive dike
10: fair quality, 10,000+ cu yds, LA wear 19.2, soundness loss 19.9, P.I. 8
12: NMSHD (1974)

1: 30N.3W.12.400
2: Pit 7013
3: SE1/4 sec 12, T30N, R3W
4: John Mills Lake 7.5 (Navajo Reservoir)
7: developed pit
9: Tertiary intrusive dike
12: NMSHD (1974)

1: 30N.3W.25.130
2: Pit 5860
3: SW1/4 NW1/4 sec 25, T30N, R3W
4: Cement Lake 7.5 (Navajo Reservoir)
6: sand
7: developed pit
9: Quaternary alluvium
10: good quality, 12 ft thick, 60,000 cu yds, P.I. not plastic
12: NMSHD (1974)

1: 30N.3W.27.310
2: Pit 5859
3: NW1/4 SW1/4 sec 27, T30N, R3W
4: Bixler Ranch 7.5 (Navajo Reservoir)
6: sand
7: developed pit
9: Quaternary alluvium
10: fair quality, 15 ft thick, 20,000 cu yds, P.I. not plastic
12: NMSHD (1974)

1: 31N.1W.17.210
2: Pit 0869
3: NW1/4 NE1/4 sec 17, T31N, R1W
4: Dulce 7.5 (Aztec)
6: lamprophyre
7: prospect pit
9: Tertiary intrusive dike
10: fair quality, 4+ ft thick, 10,000+ cu yds, LA wear 21.8, soundness loss 7.2, P.I. not plastic
12: NMSHD (1974)

1: 32N.1W.19.440
2: Pit 5863
3: SE1/4 SE1/4 sec 30, T32N, R1W
4: Dulce 7.5 (Aztec)
6: gravel
7: developed pit
9: Quaternary alluvium
10: good quality, 4+ ft thick, 50,000 cu yds, LA wear 20.8, soundness loss 9.9, P.I. not plastic
12: NMSHD (1974)

1: 32N.1W.20.412
2: Pit 58136
3: NE1/4 NW1/4 sec 20, T32N, R1W
4: Dulce 7.5 (Aztec)
6: sand and gravel
7: developed pit
9: Quaternary alluvium
10: good quality, 6+ ft thick, 100,000 cu yds, LA wear 20, soundness loss 11.3, P.I. not plastic
12: NMSHD (1974)

1: 32N.1W.29.120
2: Pit 59111
3: NE1/4 NW1/4 sec 29, T32N, R1W
4: Dulce 7.5 (Aztec)
6: sand and gravel
7: developed pit
9: Quaternary alluvium
10: good quality, 7+ ft thick, 100,000 cu yes, LA wear 21.2, soundness loss 3.4, P.I. not plastic
12: NMSHD (1974)

1: 32N.1W.30.220
2: Pit 6454
3: NE1/4 NE1/4 sec 30, T32N, R1W
4: Dulce 7.5 (Aztec)
6: sand and gravel
7: developed pit
9: Quaternary alluvium
10: good quality, 6+ ft thick, 50,000 cu yds, LA wear 20.4, soundness loss 8.4, P.I. not plastic
12: NMSHD (1974)

1: 32N.2W.13.120
2: Pit 0671
3: NE1/4 NW1/4 sec 13, T32N, R2W
4: Dulce 7.5 (Aztec)
6: andesite
7: prospect pit
9: Tertiary andesite sill
10: good quality, 40 ft thick, 200,000 cu yds, LA wear 21.4, soundness loss 3.8, P.I. not plastic
12: NMSHD (1974)

1: 32N.1W.22
2: Pit 76-16-S
3: Sec 22, T32N, R1W 36°58'00"N 106°55'00"W
4: Dulce 7.5 (Aztec)
6: sand and gravel
12: MILS (1980)

1: 32N.1W.32
2: Pit 64-54-S
3: Sec 32, T32N, R1W 36°57'00"N 106°58'00"W
4: Dulce 7.5 (Aztec)
6: sand and gravel
12: MILS (1980)

1: 32N.2W.28.333
2: Pit 58137
3: SW1/4 SW1/4 SW1/4 sec. 28, T32N, R2W
4: Wirt Canyon 7.5 (Navajo Reservoir)
6: sand and gravel
7: developed pit
9: Quaternary alluvium
10: good quality, 6 ft thick, 40,000 cu yds, LA wear 24.4, soundness loss 12.2, P.I. not plastic
12: NMSHD (1974)

1: 32N.6W.27.220
2: Pit 0670
3: NE1/4 NE1/4 sec 27, T32N, R6W
4: Bancos Mesa NW 7.5 (Navajo Reservoir)
6: gravel
7: prospect pit
9: Quaternary terrace deposits (Pinedale)
10: good quality, 10 ft thick, 475,000 cu yds, LA wear 24.8, soundness loss 13.4, P.I. 12
12: NMSHD (1974)

1: 32N.1W.32
2: Pit 64-54-S
3: Sec 32, T32N, R1W 36°57'00"N 106°58'00"W
4: Dulce 7.5 (Aztec)
6: sand and gravel
12: MILS (1980)

1: 32N.2W.28.333
2: Pit 58137
3: SW1/4 SW1/4 SW1/4 sec 28, T32N, R2W
4: Wirt Canyon 7.5 (Navajo Reservoir)
6: sand and gravel
7: developed pit
9: Quaternary alluvium
10: good quality, 6 ft thick, 40,000 cu yds, LA wear 24.4, soundness loss 12 2. P.I. not plastic
12: NMSHD (1974)

1: 32N.6W.27.220
2: Pit 0670
3: NE1/4 NE1/4 sec 27, T32N, R6W
4: Bancos Mesa NW 7.5 (Navajo Reservoir)
6: gravel
7: prospect pit
9: Quaternary terrace deposits (Pinedale)
10: good quality, 10 ft thick, 475,000 cu yds, LA wear 24.8, soundness loss 13.4, P.I. 12
12: NMSHD (1974)

1: 31N.1E.7.224
2: Angel Mine (2 owners)
3: SE1/4 sec 7, T31N, R1E 36°52'52"N 106°51'37"W Elev. 7240'
4: Lumberton 15'
5: Monero
6: coal
7: mine opened by a drift driven 300 ft at 7 degrees
8: total 4600 tons (1909-1911)
9: Menefee Formation
10: 3 ft coal bed--upper bed of the Amargo coal sequence
11: 1890-1909 San Luis Coal Co. abandoned 1909 A. Luchetti (1909-1011). 3300NL, 0EL
12: Nickelson's notes

1: 31N.1E.7.221
2: Kutz-Luchetti Peacock Mine
3: NW1/4 sec 7, T31N, R1E 36°55'18"N 106°52'32"W Elev. 7250'
4: Lumberton 15'
5: Monero
6: coal
7: by 1900 slope reached 400 ft, 1900, ventilation shaft
8: 222,637 tons 1890-1930
9: Menefee Formation
10: Lower bed dip 11° west. Both beds approx. 4 ft with ss roofs
11: Opened 1899 by G. W. Kutz, had problems with gas and flooding; timbering and ventilation were poor. From 1910-1913 mine was idle; obtained by A. Luchetti in 1912-13?, 1920 Luchetti organized Peacock Coal Co.
12: Nickelson

1: 31N.1E.7.212
2: Laing Mine
3: NE1/4 sec 7, T31N, R1E 36°55'22"N, 106°51'53"W Elev. 7280'
4: Lumberton 15'
5: Monero
6: coal
7: Mine opened along strike of bed for 250 ft
8: 5674 tons
9: Menefee Formation
10: Lower bed of Monero coal bed; coal of coking quality with sandstone roof. Measured section: 1.5 in. coal, 3 in. ss, 15 in. coal, 11 in. shale, 14 in. coal.
11: Burros used to haul coal to surface. Operated by Monero Coal Co.; most of the coal sold in San Luis Valley. Closed 1908. *100NL, 2300EL
12: Nickelson

1: 31N.1E.7.224
2: Ray Mine
3: SE1/4 sec 7, T31N, R1E 36°54'54"N 106°51'37"W Elev. 7280'
4: Lumberton 15'
5: Monero
6: coal
7: Slope driven 300 ft, S45W. Ventilation aided by furnace
8: 3500 tons (1894-95)
9: Menefee Formation
10: 3 ft bed of coal
11: Mine was closed 1896, but was merged into the Monero mine. Coal sold to D&RG RR., owned by Monero Coal and Coke Co. 2900NL, 100EL
12: Nickelson

1: 31N.1E.7.144
2: Walker-Caranta Mine
3: SE1/4 sec 7, T31N R1E 36°54'43"N 106°51'40"W Elev. 7285'
4: Lumberton 15'
5: Monero
6: coal
7: wagon mine
8: approximately 1 railroad car/week
9: Menefee Formation
11: 1917 opened by M. C. Walker, 1918-19 Barne Caranta, closed 1919 with property in litigation. 4000NL, 300EL
12: Nickelson

1: 31N.1E.7.114
2: unknown
3: SE1/4 sec. 7, T31N, R1E 36°54'49"N 106°51'36"W Elev. ?
4: Lumberton 15'
5: Monero
6: coal
7: Portal bearing N86W, within few ft of creek
9: Menefee Formation
10: Coal bed well exposed in creek
11: One of five small mines along west bank of Amargo Creek within 1.25 mi of Monero. 3400NL, 0EL
12: Nickelson

1: 31N.1E.7.214
2: unknown
3: SE1/4 sec 7, T31N, R1E 36°54'49"N 106°51'47"W Elev. 7280'
4: Lumberton 15'
5: Monero
6: coal
7: Two entries, S44W and S56W, 40 ft south of first
9: Menefee Formation
11: 2900NL, 100EL
12: Nickelson

1: 31N.1E.7.342
2: unknown
3: NE1/4 sec. 7, T31N, R1E 36°55'00"N 106°51'48"W Elev. 7300'
4: Lumberton 15'
5: Monero
6: coal
7: Two entries approx. 70 ft apart, bearing S44W
9: Menefee Formation
11: One of the small mines or prospects along the west side of Amargo Creek, below Monero. 2200NL, 800EL
12: Nickelson

1: 31N.1E.7.142
2: unknown
3: NE1/4 sec 7, T31N, R1E 36°55'09"N 106°51'45"W Elev. 7195'
4: Lumberton 15'
5: Monero
6: coal
7: Two entries bearing S66W
9: Menefee Formation
11: Mine on west side of Amargo Creek. 1400NL, 800EL
12: Nickelson

1: 31N.1E.8.313
2: Barne Caranta Mine
3: SW1/4 sec 8, T31N, R1E 36°54'49"N 106°51'15"W Elev. 7390'
4: Lumberton 15'
5: Monero
6: coal
7: Two openings, haulage entry and airshaft
8: 17,899 tons (1927-38)
9: Menefee Formation
10: 3-3 ft 8 in. thick, clean, high quality coal between sandstone roof and fireclay floor. Upper bed of coal was mined. Three faults encountered. Coal dipped 8° S80W Monero fault has 200 ft displacement, upthrown block to SW.
11: 1927 Caranta applied for competitive lease, operated until 1938. 3500NL, 3500EL
12: Nickelson

1: 31N.1E.8.233
2: Tomacino-Davito Mine
3: SW1/4 sec 8, T31N, R1E 36°54'42"N 106°51'27"W Elev. 7320'
4: Lumberton 15'
5: Monero
6: coal
7: Entry bearing S60E, airshaft and furnace for ventilation
8: 6280 tons (1922)
9: Menefee Formation
11: Coal hauled by wagon to railroad at Monero. John Tomacino and Joe Davito, owners, 1922. 4200NL, 4500EL
12: Nickelson

1: 31N.1E.8.33.133
2: Monero mines
3: SW1/4 sec 8, T31N, R1E 36°54'36"N 106°51'34"W Elev. 7280'
4: Lumberton 15'
5: Monero
6: coal
7: no. 1 slope 1700 ft., no. 2 slope, 600 ft
8: Total: 359-808 tons (incl. 2,588 from McBroom mine)
9: Menefee Formation
10: In 1897, Rio Arriba Coal Co. acquired the Monero mine, and named the Willis Mine the Monero no. 2. M. F. Simers mine became the Monero no. 3. Coal was sold to the D&RG. Mines were closed in 1908, some production in 1909.
12: Nickelson
*no. 1 sec 8, 400SL, 100WL, no. 2; sec. 8, 1250SL, 150WL

1: 31N.1E.17.443
2: McBroom Mine
3: SW1/4 sec 17, T31N, R1E 36°53'44"N 106°51'05"W Elev. 7400'
4: Lumberton 15'
5: Monero
6: coal
7: Single 200 ft entry by 1905 1600 ft slope
8: 32,646 tons (1899-1911)
9: Menefee Formation
10: 3 ft 8 in. coal bed dipping 8°, sandstone roof
11: 1899 McBroom Bros. opened mine. Coal was sold at Creede. In 1901 or '02 owned by Rio Arriba Coal Co., 1905 coal sold to D&RG and nearby lumber company 1910. Production by year in text. 4700NL, 2800EL
12: Nickelson
*1921 mine map shows 3 openings on upper bed, two on SW side of gulch, 2 on other side of gulch in lower bed.

1: 31N.1E.17.411
2: Peacock Coal Co. Prospect
3: NW1/4 sec 17, T31N, R1E 36°54'26"N 106°51'27"W Elev. 7320'
4: Lumberton 15'
5: Monero
6: coal
7: Four development entries on steep side of hill.
9: Menefee Formation
10: Two beds of coal separated by 40 ft. Upper bed thickness ranges from 2'-10". roof-shale, floors-shale and fire clay. Lower bed thickness 2'-9" with shale roof and floor.
11: Opened Dec. 26, 1928, Peacock Coal Co. Lease relinquished in 1937. 600NL, 4600EL
12: Nickelson

1: 31N.1E.17.443
2: unknown (Christ)
3: SW1/4 sec 17, T31N, R1E 36°53'40"N 106°51'03"W Elev. 7320'
4: Lumberton 15'
5: Monero
6: coal
7: 1905-1906
8: 4061 tons
9: Menefee Formation
11: Trespassed into sec 20 NE1/4, NW1/4, owner J. H. Christ
12: Nickelson (under Monero and Erler mine).

1: 31N.1E.18.232
2: Caranta Mines (no. 1 & 4 3)
3: NE1/4 sec 18, T31N, R1E 36°54'15"N 106°51'05"W Elev. 7880'
4: Lumberton 15'
5: Monero
6: coal
7: Slope 420', S62W, dip 4°, rooms off main slope
8: 185,238 tons, McElroy 7,940, Idzior 4,401 tons
9: Menefee Formation
10: Two beds of coal separated by 40 ft, faulting prevalent. Bed varies from 2'8" to 3'5". Roof and floor of sandstone dip 3° S17E. No. 3 mine coal bed 3.5'.
11: Permit 1940, no. 1 worked out by 1943. Development started on 2-4 mines, no. 2 opened on upper bed, no. 3 on lower. In 1951, developed no. 5 mine. In 1961, McElroy Bros. bought mine. Mine fire in 1963, and lease cancelled in 1971.
12: Nickelson
*1500WL, 1300EL

1: 31N.1E.18.312
2: Caranta Mines
3: NE1/4 sec 18, T31N, R1E 36°54'18"N 106°51'59"W Elev. 8000'
4: Lumberton 15'
5: Monero
6: coal
9: Menefee Formation
11: Locations of no. 2 and no. 3 mines. 1300NL, 1500EL
12: Nickelson

1: 31N.1E.7.443
2: Caranta Mine No. 5
3: SW1/4 sec 7, T31N, R1E 36°54'33'N 106°52'07"W Elev. 7920'
4: Lumberton 15'
5: Monero
6: coal
11: Location of no. 5 5000NL, 2400EL
12: Nickelson

1: 31N.1E.20.112.312
2: Monero and Erler mines
3: NE1/4 sec 20, T31N, R1E 36°53'37"N 106°51'01"W Elev. 7520'
4: Lumberton 15'
5: Monero
6: coal
7: Nine prospects driven in 1925, entries drive to SE
8: 1921-'24, 26,360 tons closed 1940. Total 142,133 tons
9: Menefee Formation
10: Monero fault on west side of mine. Trend NW-SE through sec 20 and upthrown 200 ft. No coal south of fault. Water problems in mine. Coal mined was 4-4.5' with 2-4" parting. Shale roof with sandstaone above shale SW dip 6-12°.
11: Caranta issued a lease in 1921. A. Luchetti in 1923 applied for a competitive lease on land adjoining Caranta's lease--Caranta was highest bidder. In 1924 he sold to Western Fuel Co. Erler no. 1 and 2 mined during 1929.
12: Nickelson, USBM Tec. Paper 569
*300NL, 2500El analyses in USBM 565
*900NL, 2300EL @ 7480 ft 36°53'30"N, 106°50'58"W

1: 31N.1E.21.331
2: unknown (Sterling Mine?)
3: NW1/4 sec 21, T31N, R1E 36°53'13"N 106°50'23"W Elev. 7680'
4: Lumberton 15'
5: Monero
6: coal
7: Two drifts, one driven N45W, other N55E
9: Menefee Formation
11: Found in abandoned mine study of 1979 (AML); small dumps left. *2700NL, 4700EL
12: Nickelson, AML

1: 31N.1E.30.321.121,121
2: Rainbow Mine
3: NW1/4 sec 30, T31N, R1E 36°52'37"N 106°52'16"W Elev. 7480'
4: Lumberton 15'
5: Monero
6: coal
7: Six prospects drive, 4 adits on upper, 2 on lower coal bed.
8: 144,281 tons from 4 adits
9: Menefee Formation
10: Lower bed 2.5', dip 2-4° S80E.
11: Inez Erler, owner on 1939 permit lease assigned to Carrillo Bros. Lease relinquished in 1966. *no. 1 800NL, 3300EL, no. 3, 500NL, 3300EL, no. 4 100NL, 3200EL
12: Nickelson

1: 31N.1E.30.431
2: unknown
3: NW1/4 sec 30, T31N, R1E 36°52'25"N 106°52'28"W Elev. 7420'
4: Lumberton 15'
5: Monero
6: coal
7: Double entry system bearing S13E
9: Menefee Formation
11: South across draw from Erler Mine
*2100NL, 4200EL
12: Nickelson

1: 31N.1W.1.232
2: unknown
3: NE1/4 sec 1, T31N, R1W 36°55'58"N 106°53'07"W Elev. 7030'
4: Lumberton 15'
5: Monero
6: coal
7: Single adit driven at edge of a hill; coal dump.
9: Menefee Formation
11: Driven at edge of hill south of Highway 17
*1600NL, 2000EL
12: Nickelson

1: 31N.1W.1.241
2: Tafoya Prospect
3: NW1/4 sec 1, T31N, R1W 36°55'59"N 106°53'22"W Elev. 7020'
4: Lumberton 15'
5: Monero
6: coal
7: Six adits
9: Menefee Formation
11: Juan A. Tafoya made permit application May to August 1938.
12: Nickelson, Location from AML map

1: 31N.1W.1.113.313
2: Amargo knot no. 2 mine
3: SW/14 sec 1, T31N, R1W Elev. 7090'
4: Lumberton 15'
5: Monero
6: coal
7: Two entries, 250' to the East, and 700' to the South, aircourse 280'W
8: 15,643 and 10,007 tons after resurvey
9: Menefee Formation
10: Coal 4'-4'4" thick, clean coal with sandstone roof and floor.
11: 1940's--Juan Tafoya, owner, sold coal to Indian Agency in Dulce. Ceased operations in 1959. Reopened by Joe Salazar in 1960. Coal reserves depleted by 1962. *no. 1 elev. 7090', 3000NL, 5000EL, no. 2 elev. 7090', 3800NL, 4900EL.

1: 31N.1W.8.314
2: Burns and Biggs Lumber Co. Mine
3: SE1/4 sec 8, T31N, R1W 36°54'42"N 106°47'10"W Elev. 7000'
4: Lumberton 15'
5: Monero
6: coal
7: Single entry room and pillar slope 600 ft.
8: Total 21,709 tons 1906-1911
9: Menefee Formation
10: Clean bed of coking coal 32" thick, dip 6° SW. Referred to as coal bed no. 1 in USGM 569. Roof of sandstone, floor of clay shale.
11: Sample for analyses taken by Gardner 1908: moisture 1.7%, vm 36.3%, fc 44.1%, ash 6.9%, sulpher 0.7%, hydrogen 5.2%, carbon 75.4%, nitrogen 1.6%, oxygen 10.2%.
12: Nickelson, USBM Tech. Paper 569 *4000NL, 800EL

1: 31N.1W.8.314
2: Peisker Prospect
3: SE1/4 sec 8, T31N, R1W 36°54'46"N 106°57'12"W Elev. 7000'
4: Lumberton 15'
5: Monero
6: coal
7: Slope N70W 203 ft, aircourse 51 ft long, 5 rooms
8: 385 tons
9: Menefee Formation
10: Upper coal bed mined. On west side of Milelr Creek, 1.5' coal 3" ss, 2'3" coal. Roof and floor of shale. Dip 5° N67W
11: Peisker permit 1939 lease cancelled in 1951. *3600NL, 900EL
12: Nickelson

1: 31N.1W.8.314
2: unknown
3: SE1/4 sec 8, T31N, R1W 36°54'44"N 106°57'12"W Elev. 7000'
4: Lumberton 15'
5: Monero
6: coal
7: Single adit bearing N66W and tipple and chute.
9: Menefee Formation
11: Mine is down Miller Creek about 700 ft from Burns and Briggs mine. *3600NL, 900EL
12: Nickelson

1: 31N.1W.9.132
2: Lobato Prospect
3: NE1/4 sec 9, T31N, R1W 36°55'05"N 106°56'20"W Elev. 7080'
4: Lumberton 15'
5: Monero
6: coal
7: Entry S30E, 140 ft
8: 136 tons
9: Menefee Formation
10: Coal bed had sandstone roof and shale floor. 1'3" coal, 4" ss, 1'3" coal. Dip 9° N60E.
11: Permit issued to Francisco Lobato 1924; expire 1926. Reapplied 1927, closed mine 1928.
*1800NL, 1900EL
12: Nickelson

1: 31N.1W.8.243
2: Miller Mine
3: NE1/4 sec 8, T31N, R1W 36°55'05"N 106°56'57"W Elev. 7020'
4: Lumberton 15'
5: Monero
6: coal
7: extensive?
8: 107,290 tons
9: Menefee Formation
10: Two beds of coal, upper containd 1-2 ptgs. 40 ft separated the two beds. Dip to the NW. Mine plagued with small faults and rolls. Coal at entry 70" with two ptgs, 4" and 14" thick. Average coal thickness 3'10", with 4" ptg. Lower coal 2'2".
11: E. G. Miller and D. G. Kutz, owners, 1921-1930. Sold coal as steam coal because coal slacked easy. Leased assigned to Navajo Mercantile in 1930. Closed in 1936.
12: Nickelson, USBM Tech. Paper 569
*1800NL, 500EL went into sec 9
*coal analyses in USBM 569

1: 31N.1W.10.312.132.221
2: Lumberton-Kutz-Garcia Mine
3: NE1/4 sec 10, T31N, R1W 36°55'10"N 106°55'22"W Elev. 7040'
4: Lumberton 15'
5: Monero
6: coal
7: Operation 1898-1947. Drift 250 ft 3 entries, 3rd for vent.
8: 45,957 tons
9: Menefee Formation
10: 2'8" coal bed which thinned quickly. In Kutz mine coal bed dipped 12°N. Coal bed 32". Bed mined had shale roof and floor. Several faults were encountered. In Garcia mine, 4 ft of coal were mined.
11: Lumberton mine--J. Corrigan 1989--ceased operations in 1899. Kutz-1924 preference lease acquired by Kutz. In 1930 had water problems. Garcia mine--1937 Mr. Blunt, owner, 340 ft s of Kutz mine. Most coal sold to D&RG RR.
12: Nickelson, USBM Tech. Paper 569
*Lumberton 1300NL, 2600EL
*Kutz-SE, sec 3, NE sec 10, 300-1800NL, 2400-2900EL

1: 31N.1W.12.431
2: Castelone Prospect
3: NW1/4 sec 12, T31N, R1W 36°54'58"N 106°53'33"W Elev. 7080'
4: Lumberton 15'
5: Monero
6: coal
7: An entry 85 ft on a S20W course.
9: Menefee Formation
10: Coal at face of entry 4', but was soft and of poor quality.
11: Abandoned Mine Survey (AML) could not find given locality. Prospecting permit 1925--Samuel Castelone. Relinquished permit in 1926.
*1100N & 300E from W corner of sec 12
12: Nickelson, USBM Tech. Paper 569

1: 31N.1W.17.242
2: unknown
3: NE1/4 sec 17, T31N, R1W 36°54'14"N 106°57'05"W Elev. 7040'
4: Lumberton 15'
5: Monero
6: coal
7: An adit bearing N65E
9: Menefee Formation
10: Coal outcrop exposed in the creek.
11: Old sealed adit found in Abandoned Mine Survey (AML) 1979 on Federal land. *1600NL, 300EL
12: Nickelson, AML

1: 31N.1W.17.443
2: Cornell Prospect
3: NE1/4 sec 17, T31N, R1W 36°54'05"N 106°57'06"W Elev. 7080'
4: Lumberton 15'
5: Monero
6: coal
7: Prospect entry diven along bed 47' S10W
9: Menefee Formation
10: 8" of rock and bone separated 2.5' of coal and bottom bed of 4". Sandstone roof and shale floor. Coal thins to 8" at face. Coal bed cut by fault trending along stream course.
11: Old workings found in AML study. Permittee H. M. Cornell 1926-28. *1300NL, 400EL
12: Nickelson, AML

1: 31N.1W.17.22
2: Bellino Prospect
3: NE1/4 sec 17, T31N, R1W 36°54'24"N 106°57'07"W Elev. 7000'
4: Lumberton 15'
5: Monero
6: coal
7: 165 ft initial entry. Second entry on sec 8 SW,SE1/4
8: 260 tons up to 1925
9: Menefee Formation
10: Two beds of approximately 2 ft separated by 5 ft of shale. Back entry driven on upper bed. Second entry S8W along lower bed. Lower bed 35-38". 45 ft between two coal beds.
11: Prospecting and mining on fee lands. Permittee Frank Bellino 1924-25. *400NL, 500EL.
12: Nickelson

1: 31N.1W.8.444
2: Bellino-Peisker Mine
3: SE1/4 sec 8, T31N, R1W 36°54'33"N 106°57'05"W Elev. 7000'
4: Lumberton 15'
5: Monero
6: coal
7: Two entries on SE, SE1/4 sec 8, later on sec 17.
8: total production 32,438 tons
9: Menefee Formation
10: Coal bed 2.5 to 3 ft thick and generally a 3-6" parting near middle of bed. Roof of sandstone with thin shale bed between ss and coal. Shale was later removed. Dip 30 to 7 deg. westerly. *400SL, 300EL
11: Bellino mined prior to 1927, sold to Emmet Wirt 1927???
12: Nickelson

1: 25N.1E.21.112
2: Kern Mine
3: NE1/4 sec 21, T25N, R1E 36°23'17"N 106°50'21"W Elev. 7060'
4: Llaves 15'
5: Monero
6: coal
7: entry driven along side old prospect
8: 2,500 tons 1942-59
9: Menefee Formation
10: Bed of clean coal 5 ft. Dip of beds 25-30° NW
11: Kern permitted 1942, leased in 1951. Sold in 1956 to Simmons, who operated until 1960. *800NL, 2100EL
12: Nickelson

1:
2: Caranta Prospect
3: 1/2 sec 7, 18, T31N, R1E,1W
4: Lumberton 15'
5: Monero
6: coal
7: 3 openings: 1st S23W for 80 ft; 2nd S52W for 60 ft, 3rd S72E
8: Not reported, chute never completed
9: Menefee Formation
10: Faulting between permit and lease land, but same coal bed existed on both sides
11: Permittees Joseph and Barne Caranta allowed permit to expire at end of two year period (1945-47).
Location: lots 2, 3, & 4, SE1/4 SW1/4, NW1/4 NE1/4, sec 7, and lot 1, NE1/4 NW1/4, sec 18, T31N, R1E; N1/2 SE1/4, NE1/4 SW1/4, E1/2 NW1/4, sec 12, T31N, R1W.
12: Nickelson

1:
2: Isadore Erler Prospect
3: SW1/4 sec 28, T31N, R1E
4: Lumberton 15'
5: Monero
6: coal
7: Three short prospect drifts off permit land
9: Menefee Formation
10: Coal bed at face 2'2" thick, with shale roof and floor. Bed dipped 22° S80W.
*3 mi east of Monero
11: Permittee Isadore Erler 1937, permit expired by law.
12: Nickelson

1:
2: Sterling Mine
3:
4: Lumberton 15'
5: Monero
6: coal
7: Drift 200' in length along coal bed
8: 750 tons (1895-1896)
9: Menefee Formation
10: 3.5 ft of coal
11: Coal sold to D&RG RR. Owner Fred Sterling (1895-96)
12: Nickelson

1: 31N.1E.6.211
2: Sczerbiak Prospect
3: NW1/4 sec 6, T31N, R1E 36°57'47"N 106°49'09"W
4: Lumberton 15'
5: Monero
6: coal
7: Two prospect slopes on N1/2, NW1/4 sec 6
9: Menefee Formation
10: Upper bed 18" thick, lower 23" thick > coal to thin
11: Wasyl Sczerbiak permittee 1927. Permit expired with no production. *4 mi east of Lumberton *slope on upper bed 25 ft long. Slope on lower bed 20 ft.
12: Nickelson

1:
2: Simers Mine
3:
4: Lumberton 15'
5: Monero
6: coal
7: Slope 350 ft
8: 4,195 tons (1893-96)
9: Menefee Formation
10: 3'4" of coal
11: F. M. Simers, owner prior to 1893-97, purchased by Rio Arriba Coal Co. and renamed Monero #3 (1897-98). Sold coal to D&RG RR.
12: Nickelson

1: 31N.1W.8.421
2: prospect
3: NE1/4 sec 8, T31N, R1W 36°55'05"N 106°55'05"W Elev. 6880'
4: Lumberton 15'
5: Monero
6: coal
7: prospect
9: Menefee Formation
10: Coal 2 ft 9 in. Separated by 4" from 2'2" of coal. Bed has little or no dip.
12: USBM Tech Paper 569--analyses reported may be from a weathered coal

1: 31N.1E.18.143
2: Old Sims Mine
3: SW1/4 sec 18, T31N, R1E Elev. 7000'
4: Lumberton 15'
5: Monero
6: coal
7: Entry driven in 1899
9: Menefee Formation
10: Upper coal bed 3.5 ft
*3400NL, 4150EL
11: Sampled in 1917, 135 ft from mine mouth--sample of weathered coal
12: USBM Tech. paper 569

2: Caranta Brothers Prospect
3: 1/4 sec, T31N, R1E
4: Lumberton 15'
5: Monero
6: coal
7: Entry opening near center of NE,NW1/4S sec 21
8: 100 tons mined, not sold
9: Menefee Formation
10: Coal bed 3'10" thick at portal but thinned to 22" at face.
11: Joseph and Barne Caranta permittees 1941. *sec 17, 20, 21, slope 454 ft long is SE direction following coal bed. Problem of no available transportation or labor.
12: Nickelson

1:
2: Rio Arriba Mine
3: 1/4 sec 7, T31N, R1E
4: Lumberton 15'
5: Monero
6: coal
8: 1906 production 26,000 tons
9: Menefee Formation
10: Lower coal bed 2'9.5"
11: Most production sold to D&RG RR. Analyses: mois. 4%, vol. mat. 39%, fixed carbon 51.1%, ash 5.9%, sulphur 1.0%
12: USBM Tech. Paper 569

1: 31n.1E.7.132.,6.443
2: Martinez Prospect
3: NW1/4 sec 7, T31N, R1E Elev. 7280'
4: Lumberton 15'
5: Monero
6: coal
7: A number of short entries were made (4 entries)
9: Menefee Formation
10: Opening #2 2'8" thick coal at face opening 3 2' of coal at face opening #4 2' of coal
11: Lease applied for by Levi Martinez (1927-30), but determined that coal not found in commercial quantity. Closed 1930. *#2 36°57'04"N 106°48'55"W, #1 36°56'47"N 106°49'10"W
12: Nickelson

Appendix 2 - Summary sheets of oil and gas pools in Rio Arriba County. IP, initial potential; IPF, initial potential flowing; IPP, initial potential pumping; BOPD, bbls oil per day; MCFGPD, thousand ft^3 gas per day; MCFG, thousand ft^3 gas; MMCFG, million ft^3 gas; BO, bbls oil; BW, bbls water; BC, bbls condensate; BCPD, bbls condensate per day.

POOL NAME: Gavilan Nacimiento Gas Pool

LOCATION: T. 24 N., R. 2 W., Rio Arriba County

PRODUCING UNIT(S): Nacimiento Formation (Tertiary)

DISCOVERY WELL: Kenai Oil and Gas No. 12 Federal 31, located in Sec. 12, T. 24 N., R. 2 W. Completed 2/9/80 through perforations from 2,380 to 2,395 ft. Total depth 3,575 ft. IP 3,600 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fine- to medium-grained sandstone, 15-20 ft thick, 14-15% porosity.

TYPE OF TRAP: Stratigraphic, formed by laterally discontinuous sandstones.

PROPERTIES OF OIL AND GAS: Gas is 95.86% hydrocarbons.

ANNUAL PRODUCTION, 1984: 17,858 MCFG

CUMULATIVE PRODUCTION TO 12/31/84: 337,966 MCFG + 179 BO

NUMBER PRODUCING WELLS, 12/31/84: 2

ESTIMATED ULTIMATE RECOVERY: 350,000 MCFG

REFERENCES: Dugan (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Cottonwood Fruitland Gas Pool

LOCATION: T. 32 N., R. 5 W., Rio Arriba County

PRODUCING UNIT(S): Fruitland Formation (Cretaceous)

DISCOVERY WELL: Stanolind No. 2 San Juan 32-5 unit, located in Sec. 35, T. 32 N., R. 5 W. Completed 11/21/53 through perforations from 2,875 to 2,894 ft, 2,920 to 2,956 ft, and 3,040 to 3,064 ft. Total depth 5,884 ft. IP 396 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstone, siltstone, and shale, approximately 310 ft thick; 45 ft average net pay.

TYPE OF TRAP: Stratigraphic, formed by discontinuous channel sandstones.

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 0

CUMULATIVE PRODUCTION TO 12/31/84: 0, pool abandoned without attaining commercial production.

NUMBER PRODUCING WELLS, 12/31/84: 0

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Edmister (1983)

POOL NAME: La Jara Fruitland Gas Pool

LOCATION: T. 30 N., R. 5-6 W., Rio Arriba County

PRODUCING UNIT(S): Fruitland Formation (Cretaceous)

DISCOVERY WELL: El Paso Natural Gas Co. No. 1 Abraham, located in Sec. 13, T. 30 N., R. 6 W. Completed 6/15/55 through perforations from 3,092 to 3,110 ft. Total depth 3,485 ft. IP 2,530 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Thinly bedded coal and sandstone, 10 ft net pay.

TYPE OF TRAP: Stratigraphic

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 0

CUMULATIVE PRODUCTION TO 12/31/84: 0, pool abandoned without attaining commercial production.

NUMBER PRODUCING WELLS, 12/31/84: 0

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Malone (1978)

POOL NAME: Ballard Pictured Cliffs Gas Pool

LOCATION: T. 22-27 N., R. 2-9 W., Rio Arriba, San Juan, and Sandoval Counties.

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: Jack Foster Trust No. 1 Riddle A, located in Sec. 4, T. 25 N., R. 7 W. Completed 5/8/53 through an open-hole interval from 2,202 to 2,304 ft; artificially fractured. Total depth 2,304 ft. IP 396 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Very fine- to medium-grained sandstone, 30-80 ft thick; 25 ft average net pay, 15% average porosity, 5.4 millidarcies average permeability.

TYPE OF TRAP: Stratigraphic, formed by lenticular bar and beach sandstones; possible hydrodynamic modifications.

PROPERTIES OF OIL AND GAS: Gas is more than 98% hydrocarbons

ANNUAL PRODUCTION, 1984: 2,935,757 MCFG + 2,129 BW (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 146,169,541 MCFG + 5,186 BO (Rio Arriba County part of pool)

NUMBER PRODUCING WELLS, 12/31/84: 384

ESTIMATED ULTIMATE RECOVERY: 479,412,454 MCFG from Rio Arriba, San Juan, and Sandoval Counties.

REFERENCES: Brown (1978e); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Blanco Pictured Cliffs Gas Pool

LOCATION: T. 28-32 N., R. 7-12 W., Rio Arriba and San Juan Counties.

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: Huntington Park Oil Co. No. 1 Goede, located in Sec. 29, T. 30 N., R. 9 W. Completed 12/27 through an open-hole interval from 2,190 to 4,550 ft. Total depth 4,550 ft.

LITHOLOGY AND THICKNESS OF RESERVOIR: Very fine- to medium-grained sandstone, 60-150 ft thick; 40 ft average net pay, 15% porosity.

TYPE OF TRAP: Stratigraphic, formed by lenticular bar and beach sandstones; possible hydrodynamic modifications.

PROPERTIES OF OIL AND GAS: Gas is more than 98% hydrocarbons.

ANNUAL PRODUCTION, 1984: 286,119 MCFG + 9 BO (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 1,942,709 MCFG + 33 BO (Rio Arriba County part of pool).

NUMBER PRODUCING WELLS, 12/31/84: 12

ESTIMATED ULTIMATE RECOVERY: 818,357,633 MCFG

REFERENCES: Brown (1978b); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: East Blanco Pictured Cliffs Gas Pool

LOCATION: T. 29-30 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: Blackwood and Nichols No. 1 Alsup, located in Sec. 18, T. 30 N., R. 4 W. Completed 2/13/52 through an open-hole interval from 4,140 to 4,355 ft; artificially fractured. Total depth 4,355 ft. IP 750 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstone, siltstone, and shale, 300 ft thick; 150 ft net pay, 0-22% porosity, 0-0.70 millidarcy permeability.

TYPE OF TRAP: Stratigraphic, formed by lenticular bar and beach sandstones; possibly hydrodynamic modifications.

PROPERTIES OF OIL AND GAS: Gas is more than 99% hydrocarbons.

ANNUAL PRODUCTION, 1984: 507,684 MCFG + 281 BO + 6,032 BW

CUMULATIVE PRODUCTION TO 12/31/84: 15,752,376 MCFG + 1,560 BO

NUMBER PRODUCING WELLS, 12/31/84: 32

ESTIMATED ULTIMATE RECOVERY: 32,535,172 MCFG

REFERENCES: Brown (1978a); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: South Blanco Pictured Cliffs Gas Pool

LOCATION: T. 23-28 N., R. 1-9 W., Rio Arriba, San Juan, and Sandoval Counties.

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: Doswell Federal No. 1-B, located in Sec. 15, T. 26 N., R. 6 W. Completed 6/19/51 through an open-hole interval from 2,861 to 2,929 ft. Total depth 2,929 ft. IP 1,900 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fine- to medium-grained sandstone, 60-100 ft thick; 30 ft average net pay, 15% porosity, 0-5.5 millidarcies permeability.

TYPE OF TRAP: Stratigraphic, formed by lenticular bar and beach sandstones; possible hydrodynamic modification.

PROPERTIES OF OIL AND GAS: Gas is more than 99% hydrocarbons.

ANNUAL PRODUCTION, 1984: 13,216,773 MCFG + 167 BO + 3,052 BW (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 715,625,174 MCFG + 49,430 BO (Rio Arriba County part of pool)

NUMBER PRODUCING WELLS, 12/31/84: 1,330

ESTIMATED ULTIMATE RECOVERY: 1,377,618 MMCFG from Rio Arriba, San Juan, and Sandoval Counties

REFERENCES: Brown (1978f); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Choza Mesa Pictured Cliffs Gas Pool

LOCATION: T. 28-29 N., R. 3-4 W., Rio Arriba County

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: El Paso Natural Gas No. 2 San Juan 29-4, located in Section 35, T. 29 N., R. 4 W. Completed 10/22/53 through perforations from 3,850 to 3,980 ft. Total depth 6,445 ft.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstone, shale, and coal, 270 ft thick; 130 ft average net pay, 0-16% porosity, 0.15 millidarcy average matrix permeability; sandstones are fractured.

TYPE OF TRAP: Stratigraphic, formed by lenticular bar and beach sandstones; possible hydrodynamic modifications.

PROPERTIES OF OIL AND GAS: Gas is more than 97% hydrocarbons.

ANNUAL PRODUCTION, 1984: 792,662 MCFG + 4,679 BO + 5,602 BW

CUMULATIVE PRODUCTION TO 12/31/84: 13,664,467 MCFG

NUMBER PRODUCING WELLS, 12/31/84: 50

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Brown (1978c); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Gavilan Pictured Cliffs Gas Pool

LOCATION: T. 24-28 N., R. 2-3 W., Rio Arriba County

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: Gardner Petroleum Co. No. 1 Durham, located in Sec. 14, T. 25 N., R. 2 W. Completed 7/15/49 through an open-hole interval from 3,426 to 3,492 ft; artificially fractured. Total depth 3,492 ft. IP 277 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Argillaceous, medium-grained sandstone, 110 ft thick; 25 ft average net pay, 13.5% porosity, 1 millidarcy permeability.

TYPE OF TRAP: Stratigraphic, formed by lenticular sandstone bodies; possible hydrodynamic modifications.

PROPERTIES OF OIL AND GAS: Oil gravity is 60° API. Gas is at least 98% hydrocarbons.

ANNUAL PRODUCTION, 1984: 608,764 MCFG + 3,447 BO + 617 BW

CUMULATIVE PRODUCTION TO 12/31/84: 48,198,100 MCFG + 145,329 BO

NUMBER PRODUCING WELLS, 12/31/84: 100

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Conyers (1978); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Gavilan Pictured Cliffs Gas Pool

LOCATION: T. 24-28 N., R. 2-3 W., Rio Arriba County

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: Gardner Petroleum Co. No. 1 Durham, located in Sec. 14, T. 25 N., R. 2 W. Completed 7/15/49 through an open-hole interval from 3,426 to 3,492 ft; artificially fractured. Total depth 3,492 ft. IP 277 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Argillaceous, medium-grained sandstone, 110 ft thick; 25 ft average net pay, 13.5% porosity, 1 millidarcy permeability.

TYPE OF TRAP: Stratigraphic, formed by lenticular sandstone bodies; possible hydrodynamic modifications.

PROPERTIES OF OIL AND GAS: Oil gravity is 60° API. Gas is at least 98% hydrocarbons.

ANNUAL PRODUCTION, 1984: 608,764 MCFG + 3,447 BO + 617 BW

CUMULATIVE PRODUCTION TO 12/31/84: 48,198,100 MCFG + 145,329 BO

NUMBER PRODUCING WELLS, 12/31/84: 100

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Conyers (1978); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Gobernador Pictured Cliffs Gas Pool

LOCATION: T. 29-30 N., R. 4-6 W., Rio Arriba County

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: John Schalk No. 1 Schalk 52, located in Sec. 24, T. 29 N., R. 5 W. Completed 3/11/73 through perforations from 3,483 to 3,526 ft; artificially fractured. Total depth 5,810 ft.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstone, shale, and coal, 300 ft thick; 130 ft net pay, 0-16% porosity, 0.15 millidarcy permeability; sandstones are fractured.

TYPE OF TRAP: Stratigraphic, formed by lenticular bar and beach sandstones; possible hydrodynamic modifications.

PROPERTIES OF OIL AND GAS: Gas is more than 90% hydrocarbons.

ANNUAL PRODUCTION, 1984: 898,100 MCFG + 715 BO + 828 BW

CUMULATIVE PRODUCTION TO 12/31/84: 6,743,351 MCFG + 5,208 BO

NUMBER PRODUCING WELLS, 12/31/84: 38

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: M. L. Matheny (1978); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Tapacito Pictured Cliffs Gas Pool

LOCATION: T. 25-27 N., R. 3-5 W., Rio Arriba County

PRODUCING UNIT(S): Pictured Cliffs Sandstone (Cretaceous)

DISCOVERY WELL: Southern Union Gas Co. No. 2A Jicarilla, located in Sec. 14, T. 26 N., R. 4 W. Completed 5/5/54 through an open-hole interval from 3,557 to 3,619 ft; artificially fractured. Total depth 3,619 ft. IP 4,955 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Sandstone, 40-100 ft thick; 60 ft average net pay, 15% porosity, 5.5 millidarcies average permeability.

TYPE OF TRAP: Stratigraphic, formed by lenticular bar and beach sandstones; possible hydrodynamic modifications.

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 3,070,561 MCFG + 584 BO + 2,018 BW

CUMULATIVE PRODUCTION TO 12/31/84: 234,809,430 MCFG + 15,900 BO

NUMBER PRODUCING WELLS, 12/31/84: 322

ESTIMATED ULTIMATE RECOVERY: 392,798 MMCFG

REFERENCES: Brown (1978d); Silver (1968); Brown (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Blanco Mesaverde Gas Pool

LOCATION: T. 25-32 N., R. 2-13 W., Rio Arriba and San Juan Counties

PRODUCING UNIT(S): Mesaverde Group (Cretaceous)

DISCOVERY WELL: Huntington Park Oil Co. No. 1 Goede, located in Sec. 29, T. 30 N., R. 9 W. Completed 12/27 through an open-hole interval from 4,130 to 4,550 ft. Total depth 4,550 ft. IP 600 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstone, shale, and coal, 700-1,000 ft thick; 80-200 ft net pay, 10-16% porosity. Reservoirs are mostly northwest-trending shoreline sandstones. Reservoirs are naturally fractured.

TYPE OF TRAP: Combination stratigraphic and hydrodynamic trap.

PROPERTIES OF OIL AND GAS: Oil gravity is 33-30° API. Gas is 98.88% hydrocarbons.

ANNUAL PRODUCTION, 1984: 53,981,193 MCFG + 245,332 BO + 83,423 BW (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 1,793,617,410 MCFG + 5,142,665 BO (Rio Arriba County part of pool)

NUMBER PRODUCING WELLS, 12/31/84: 1,577

ESTIMATED ULTIMATE RECOVERY: 12,000,000 MMCFG from Rio Arriba and San Juan Counties.

REFERENCES: Pritchard (1978); Silver (1968); Hollenshead and Pritchard (1961); Pritchard (1973); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Devils Fork Mesaverde Oil Pool

LOCATION: T. 24 N., R. 6 W., Rio Arriba County

PRODUCING UNIT(S): Point Lookout Sandstone of Mesaverde Group (Cretaceous)

DISCOVERY WELL: J. Gregory Merrion No. 3 NCRA State, located in Sec. 16, T. 24 N., R. 6 W. Completed 6/20/68 through perforations from 4,541 to 4,547 ft; acidized, artificially fractured. Total depth 5,865 ft. IPP 17 BOPD + 10 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fine- to medium-grained sandstone, 20 ft thick; 14 ft average net pay, 20% porosity.

TYPE OF TRAP: Stratigraphic

PROPERTIES OF OIL AND GAS: Oil gravity is 42° API.

ANNUAL PRODUCTION, 1984: 11,707 BO + 36 MCFG + 7,003 BW

CUMULATIVE PRODUCTION TO 12/31/84: 181,757 BO

NUMBER PRODUCING WELLS, 12/31/84: 6

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Dunn (1978a); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Adobe Chacra Gas Pool

LOCATION: T. 24 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Chacra (Cretaceous)

DISCOVERY WELL: Cotton Petroleum Corp. No. 26 Apache, located in Sec. 13, T. 24 N., R. 4 W. Completed 1/15/81 through perforations from 3,809 to 3,914 ft; artificially fractured. Total depth 4,120 ft. IPF 325 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Very fine-grained sandstone and shaly sandstone, 30-40 ft thick; 20-30 ft net pay.

TYPE OF TRAP: Stratigraphic, formed by northwest-trending bar-shaped sandstone.

PROPERTIES OF OIL AND GAS: Gas is 98.48% hydrocarbons.

ANNUAL PRODUCTION, 1984: 4,758 MCFG

CUMULATIVE PRODUCTION TO 12/31/84: 83,688 MCFG

NUMBER PRODUCING WELLS, 12/31/84: 2

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Mannick (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Otero Chacra Gas Pool

LOCATION: T. 24-26 N., R. 4-7 W., Rio Arriba County

PRODUCING UNIT(S): Chacra (Cretaceous)

DISCOVERY WELL: Amerada Petroleum Corp. No. 3 Jicarilla Apache A, located in Sec. 23, T. 25 N., R. 5 W. Completed 12/5/55 through perforations from 3,784 to 3,815 ft; artificially fractured. Total depth 7,505 ft. IP 600 MDFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fine-grained shaly sandstone, 10-45 ft thick; 20-30 ft net pay, 6-12% porosity, 0.15-0.3 millidarcy permeability.

TYPE OF TRAP: Stratigraphic

PROPERTIES OF OIL AND GAS: Gas is more than 94% hydrocarbons.

ANNUAL PRODUCTION, 1984: 3,585,228 MCFG + 547 BO + 795 BW

CUMULATIVE PRODUCTION TO 12/31/84: 106,016,850 MCFG + 15,284 BO

NUMBER PRODUCING WELLS, 12/31/84: 298

ESTIMATED ULTIMATE RECOVERY: 172,000 MMCFG

REFERENCES: Hoppe (1978b); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Gavilan Niobrara Mancos Oil Pool

LOCATION: T. 24-25 N., R. 2 W., Rio Arriba County

PRODUCING UNIT(S): Upper Mancos Shale (Cretaceous)

DISCOVERY WELL:

LITHOLOGY AND THICKNESS OF RESERVOIR:

TYPE OF TRAP:

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 454 BO + 1,290 MCFG + 70 BW

CUMULATIVE PRODUCTION TO 12/31/84: 454 BO

NUMBER PRODUCING WELLS, 12/31/84: 1

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: East Puerto Chiquito Mancos Oil Pool

LOCATION: T. 25-27 N., R. 1 E., Rio Arriba County

PRODUCING UNIT(S): Upper Mancos Shale (Cretaceous)

DISCOVERY WELL: Intex Oil Co. No. 1 Alto, located in Sec. 5, T. 26 N., R. 1 E. Completed 2/1/60 through an open-hole interval from 1,783 to 1,958 ft. Total depth 1,958 ft. IPP 130 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fractured shale, approximately 250 ft thick. Production if from 3 separate zones that have a combined thickness of approximately 150 ft.

TYPE OF TRAP: Fractured trap, formed by fractured shales on a west-dipping monocline.

PROPERTIES OF OIL AND GAS: Oil gravity is 34° API.

ANNUAL PRODUCTION, 1984: 74,469 BO + 23,252 MCFG + 1,635 BW

CUMULATIVE PRODUCTION TO 12/31/84: 3,989,271 BO

NUMBER PRODUCING WELLS, 12/31/84: 21

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Greer (1978a); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: West Puerto Chiquito Mancos Oil Pool

LOCATION: T. 25-27 N., R. 1 E., R. 1 W., Rio Arriba County

PRODUCING UNIT(S): Upper Mancos Shale (Cretaceous)

DISCOVERY WELL: Bolack-Greer No. 2 Bolack, located in Sec. 13, T. 25 N., R. 1 W. Completed 7/23/63 through an open-hole interval from 5,976 to 6,022 ft; acidized, artificially fractured. Total depth 6,022 ft. IPP 95 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fractured shale, approximately 250 ft thick. Production is from 3 separate zones that have a combined thickness of approximately 150 ft.

TYPE OF TRAP: Fractured trap, formed by fractured shales on a west-dipping monocline.

PROPERTIES OF OIL AND GAS: Oil gravity is 39-40° API.

ANNUAL PRODUCTION, 1984: 222,196 BO + 481,888 MCFG + 2,311 BW

CUMULATIVE PRODUCTION TO 12/31/84: 7,724,364 BO

NUMBER PRODUCING WELLS, 12/31/84: 14

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Greer (1978b); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: South Blanco Tocito Oil Pool

LOCATION: T. 26 N., R. 5-6 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Tocito Sandstone Lentil and El Vado Sandstone Member of Mancos Shale, Cretaceous)

DISCOVERY WELL: Caulkins Oil Co. No. 679 Breech A, located in Sec. 9, T. 26 N., R. 6 W. Completed 7/26/51 through an open-hole interval from 6,622 to 6,638 ft. Total depth 6,692 ft. IPF 1,900 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Tocito is very fine- to coarse-grained sandstone, 0-35 ft thick; 30 ft average net pay. El Vado is very fine-grained thinly bedded sandstone and siltstone, 500 ft thick; 50 ft average net pay.

TYPE OF TRAP: Stratigraphic. Most production is from the Tocito. Tocito trap formed by two northwest-trending bar-shaped sandstones.

PROPERTIES OF OIL AND GAS: Oil gravity is 43-44° API. Gas is 99.82% hydrocarbons.

ANNUAL PRODUCTION, 1984: 4,999 BO + 35,373 MCFG + 618 BW

CUMULATIVE PRODUCTION TO 12/31/84: 3,902,977 BO

NUMBER PRODUCING WELLS, 12/31/84: 3

ESTIMATED ULTIMATE RECOVERY: 5,600,000 BO

REFERENCES: Fassett and Jentgen (1978c); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: BS Mesa Gallup Gas Pool

LOCATION: T. 26-27 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Consolidated No. 1-5 Hoyt, located in Sec. 5, T. 26 N., R. 4 W. Completed 2/6/64 through perforations from 7,772 to 7,805 ft; artificially fractured. Total depth 8,524 ft. IPF 4,566 MCFGPD + 45 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fine- to medium-grained sandstone, 10 ft thick; 15% porosity, 83 millidarcies permeability.

TYPE OF TRAP: Stratigraphic, formed by northwest-trending bar-shaped sandstone.

PROPERTIES OF OIL AND GAS: Oil gravity is 65° API. Gas is 98.99% hydrocarbons. Gas is sweet.

ANNUAL PRODUCTION, 1984: 347,109 MCFG + 2,879 BO + 219 BW

CUMULATIVE PRODUCTION TO 12/31/84: 10,950,331 MCFG + 99,943 BO

NUMBER PRODUCING WELLS, 12/31/84: 21

ESTIMATED ULTIMATE RECOVERY: 10,000 MMCFG + 77,500 BO

REFERENCES: Matheny and Matheny (1978a); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Cabrestro Gallup Gas Pool

LOCATION: Sec. 13, T. 30 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S):

DISCOVERY WELL:

LITHOLOGY AND THICKNESS OF RESERVOIR:

TYPE OF TRAP:

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984:

CUMULATIVE PRODUCTION TO 12/31/84:

NUMBER PRODUCING WELLS, 12/31/84:

ESTIMATED ULTIMATE RECOVERY:

REFERENCES:

POOL NAME: Campo Gallup Gas Pool

LOCATION: T. 29 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Continental Oil Co. No. 2 Conoco 29-4, located in Sec. 11, T. 29 N., R. 4 W. Completed 10/24/73 through perforations from 7,380 to 7,412 ft; artificially fractured. Total depth 8,475 ft. IP 1,078 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded dark-gray to black shales, siltstones, and fine-grained sandstones; 800 ft thick. Porosity and permeability are mostly due to fractures.

TYPE OF TRAP: Fracture trap; fractures formed by synclinal flexure.

PROPERTIES OF OIL AND GAS: Gas is at least 98.29% hydrocarbons.

ANNUAL PRODUCTION, 1984: 8,199 MCFG

CUMULATIVE PRODUCTION TO 12/31/84: 59,500 MCFG + 210 BO

NUMBER PRODUCING WELLS, 12/31/84: 2

ESTIMATED ULTIMATE RECOVERY: 117 MMCFG

REFERENCES: Middleman (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Choza Mesa Gallup Gas Pool

LOCATION: T. 28 N., R. 3 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Phillips Petroleum Co. No. 1 Jicarilla 28-3, located in Sec. 6, T. 28 N., R. 3 W. Completed 9/19/75 through perforations from 7,069 to 7,740 ft; artificially fractured. Total depth 8,603 ft. IPF 749 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstone and silty shale, approximately 800 ft thick; fractured, 25 ft net pay; 11% porosity, 0.02 millidarcy matrix permeability.

TYPE OF TRAP: Combination stratigraphic and fractured trap; formed by sandstones and interbedded fractured shales.

PROPERTIES OF OIL AND GAS: Oil gravity is 40° API. Gas is 98.85% hydrocarbons.

ANNUAL PRODUCTION, 1984: 3,004 MCFG + 508 BW

CUMULATIVE PRODUCTION TO 12/31/84: 30,565 MCFG

NUMBER PRODUCING WELLS, 12/31/84: 1

ESTIMATED ULTIMATE RECOVERY: 44,000 MCFG

REFERENCES: Roe (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Counselors Gallup Oil Pool

LOCATION: T. 23 N., R. 6 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Southern Union Exploration No. 1 Yarborough Federal, located in Sec. 3, T. 23 N., R. 6 W. Completed 7/26/81 through perforations from 5,304 to 5,618 ft; acidized, artificially fractured. Total depth 6,885 ft. IPF 38 BOPD + 70 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded fine-grained sandstones and shales, approximately 250 ft thick; 125 ft net pay, 9% porosity, 0.5 millidarcy permeability.

TYPE OF TRAP: Stratigraphic, formed by northwest-trending lenticular sandstones.

PROPERTIES OF OIL AND GAS: Oil gravity is 40-45° API. Gas is 98.22% hydrocarbons.

ANNUAL PRODUCTION, 1984: 47,247 BO + 203,132 MCFG + 5,681 BW (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 127,987 BO (Rio Arriba County part of pool)

NUMBER PRODUCING WELLS, 12/31/84: 27

ESTIMATED ULTIMATE RECOVERY: 575,000 BO + 251 MMCFG

REFERENCES: J. K. Folk (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Devils Fork Gallup Oil Pool

LOCATION: T. 24 N., R. 6-7 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Val R. Reese and Assoc. No. 1 Reynolds-Killarney, located in Sec. 24, T. 24 N., R. 7 W. Completed 8/25/58 through perforations from 5,246 to 5,520 ft; artificially fractured. Total depth 5,623 ft. IP 1,757 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fine- to medium-grained sandstone, 18 ft thick; 13% porosity, 22 millidarcies permeability.

TYPE OF TRAP: Stratigraphic, formed by lenticular deltaic sandstone.

PROPERTIES OF OIL AND GAS: Oil gravity is 39° API.

ANNUAL PRODUCTION, 1984: 375,368 BO + 1,893,905 MCFG + 773 BW

CUMULATIVE PRODUCTION TO 12/31/84: 3,069,016 BO

NUMBER PRODUCING WELLS, 12/31/84: 90

ESTIMATED ULTIMATE RECOVERY: 2,170,000 BO + 35,760 MMCFG

REFERENCES: Dunn (1978b); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Escrito Gallup Oil Pool

LOCATION: T. 24 N., R. 6-8 W., Rio Arriba and San Juan Counties

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Standard of Texas No. 1 Federal 1-27, located in Sec. 27, T. 24 N., R. 7 W. Completed 6/10/57 through perforations from 5,700 to 5,713 ft and 5,757 to 5,768 ft; artificially fractured. Total depth 6,956 ft. IPF 70 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstone and shale, 400 ft thick; 80 ft net pay, 10% porosity, 1.3 millidarcies permeability. Reservoir is fractured.

TYPE OF TRAP: Stratigraphic

PROPERTIES OF OIL AND GAS: Oil gravity is 40° API. Gas is more than 90% methane. Gas is sweet.

ANNUAL PRODUCTION, 1984: 87,884 BO + 440,638 MCFG + 3,763 BW (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 2,810,950 BO (Rio Arriba County part of pool)

NUMBER PRODUCING WELLS, 12/31/84: 51

ESTIMATED ULTIMATE RECOVERY: 3,546,931 BO + 18,718,545 MCFG.

REFERENCES: Reese (1978a); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Laguna Seca Gallup Gas Pool

LOCATION:

PRODUCING UNIT(S):

DISCOVERY WELL:

LITHOLOGY AND THICKNESS OF RESERVOIR:

TYPE OF TRAP:

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 17,623 MCFG

CUMULATIVE PRODUCTION TO 12/31/84: 72,938 MCFG

NUMBER PRODUCING WELLS, 12/31/84: 1

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Largo Gallup Gas Pool

LOCATION: T. 26 N., R. 7 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Ladd Petroleum Corp. No. 13 Lindrith, located in Sec. 3, T. 26 N., R. 7 W. Completed 9/12/61 through perforations from 6,592 to 6,598 ft; artificially fractured. Total depth 7,420 ft. IP 3,058 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Very fine- to coarse-grained sandstone, 0-18 ft thick, 2 sand beds; 6 ft average net pay, 18% average porosity, 250 millidarcies permeability.

TYPE OF TRAP: Stratigraphic, formed by northwest-trending bar-shaped sandstones.

PROPERTIES OF OIL AND GAS: Gas is 98.68% hydrocarbons.

ANNUAL PRODUCTION, 1984: 465,917 MCFG + 1,117 BO + 493 BW

CUMULATIVE PRODUCTION TO 12/31/84: 13,699,301 MCFG + 97,660 BW

NUMBER PRODUCING WELLS, 12/31/84: 6

ESTIMATED ULTIMATE RECOVERY: 13,600 MMCFG + 104,900 BC

REFERENCES: Fassett and Jentgen (1978a); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Lindrith Gallup Gas Pool

LOCATION: T. 24 N., r. 2 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Frank Yockey No. 4 Ingwerson Federal, located in Sec. 20, T. 24 N., R. 2 W. Completed 7/15/66 through perforations from 6,520 to 6,555 ft; artificially fractured. Total depth 8,464 ft. IP 3,282 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded fine-grained sandstones and siltstones, approximately 35 ft thick; 11 ft net pay.

TYPE OF TRAP: Stratigraphic, formed by lenticular offshore marine bars.

PROPERTIES OF OIL AND GAS: Oil is paraffin based and sweet; oil gravity is 38-40° API.

ANNUAL PRODUCTION, 1984: 22,540 MCFG + 5,071 BO

CUMULATIVE PRODUCTION TO 12/31/84: 561,055 MCFG + 62,621 BO

NUMBER PRODUCING WELLS, 12/31/84: 1

ESTIMATED ULTIMATE RECOVERY: 750,000 MCFG + 75,000 BO

REFERENCES: Hornbeck (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Lybrook Gallup Oil Pool

LOCATION: T. 23-24 N., R. 6-7 W., Sandoval and Rio Arriba Counties

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Harrell Budd No. 1 Dunn, located in Sec. 9, T. 23 N., R. 7 W. Completed 3/11/57 through perforations from 5,716 to 5,846 ft; artificially fractured.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded sandstones and shales, 400 ft thick; 73 ft average net pay, 9.9% average porosity, 0.56 millidarcy average permeability. Production is mostly from three 10-20 ft thick sandstone beds.

TYPE OF TRAP: Stratigraphic, formed by northwest-trending offshore marine bars.

PROPERTIES OF OIL AND GAS: Oil gravity is 40° API. Gas is more than 90% methane.

ANNUAL PRODUCTION, 1984: 97,763 BO + 508,419 MCFG + 1,310 BW (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 494,271 BO (Rio Arriba County part of pool)

NUMBER PRODUCING WELLS, 12/31/84: 60

ESTIMATED ULTIMATE RECOVERY: 700,000 BO + 5,141 MMCFG

REFERENCES: Reese (1978b); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Otero Gallup Oil Pool

LOCATION: T. 24-25 N., R. 4-6 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Amerada Petroleum Corp. No. 5 Jicarilla Apache A, located in Sec. 25, T. 25 N., R. 5 W. Completed 8/4/56 through perforations from 6,550 to 6,560 ft; artificially fractured. Total depth 7,743 ft. IPP 13 BOPD + 45 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Two beds of fine-grained, fractured sandstone; 14 ft net pay.

TYPE OF TRAP: Stratigraphic

PROPERTIES OF OIL AND GAS: Oil gravity is 41° API

ANNUAL PRODUCTION, 1984: 46,504 BO + 400,648 MCFG + 3,992 BW

CUMULATIVE PRODUCTION TO 12/31/84: 2,475,478 BO

NUMBER PRODUCING WELLS, 12/31/84: 60

ESTIMATED ULTIMATE RECOVERY: Not available

REFERENCES: Brown (1978g); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Regina Gallup Oil Pool

LOCATION: T. 24 N., R. 1 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Southern Union Exploration No. 1 Mobil Federal, located in Sec. 36, T. 24 N., R. 1 W. Completed 6/12/79 through perforations from 3,845 to 4,123 ft. IPF 6 BOPD + 108 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded fractured shale and thin siltstones and sandstones, approximately 80 ft thick; 6% porosity.

TYPE OF TRAP: Combination stratigraphic and fractured trap, formed by a fractured reservoir zone that pinches out to the south.

PROPERTIES OF OIL AND GAS: Oil is paraffin based. Oil gravity is 46° API. Gas is 99.06% hydrocarbons.

ANNUAL PRODUCTION, 1984: 1,174 BO + 2,186 MCFG

CUMULATIVE PRODUCTION TO 12/31/84: 4,070 BO

NUMBER PRODUCING WELLS, 12/31/84: 1

ESTIMATED ULTIMATE RECOVERY: 11,600 BO + 73,000 MCFG

REFERENCES: Davies and Folk (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Rosa Gallup Gas Pool

LOCATION: T. 32 N., R. 5 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Merrion and Bayless No. 1 Gibbons, located in Sec. 20, T. 32 N., R. 5 W. Completed 11/1/71 through perforations from 6,600 to 6,616 ft and 7,080 to 7,176 ft; artificially fractured. Total depth 7,980 ft. IP 500 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Siltstone and very fine-grained sandstone, 96 ft thick; 10% porosity. Reservoir is fractured.

TYPE OF TRAP: Stratigraphic, formed by porosity and permeability variations within a tabular unit of siltstones and sandstones.

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 3,972 MCFG + 8 BW

CUMULATIVE PRODUCTION TO 12/31/84: 177,387 MCFG

NUMBER PRODUCING WELLS, 12/31/84: 2

ESTIMATED ULTIMATE RECOVERY: 120,000 MCFG

REFERENCES: Endsley (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Tapacito Gallup Oil Pool

LOCATION: T. 26 N., R. 4-6 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Tenneco Oil Co. No. 2 Jicarilla A, located in Sec. 18, T. 26 N., R. 5 W. Completed 2/22/65 through perforations from 6,917 to 6,919 ft; artificially fractured. Total depth 7,750 ft. IPF 47 BOPD + 183 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Very fine- to coarse-grained sandstone, 0-34 ft thick; 5-15 ft net pay, 18% porosity, 250 millidarcies permeability.

TYPE OF TRAP: Stratigraphic, formed by northwest-trending bar-shaped sandstones.

PROPERTIES OF OIL AND GAS: Oil gravity is 43-44° API. Gas is 98.92% hydrocarbons.

ANNUAL PRODUCTION, 1984: 3,714 BO + 230,434 MCFG + 793 BW

CUMULATIVE PRODUCTION TO 12/31/84: 476,709 BO

NUMBER PRODUCING WELLS, 12/31/84: 8

ESTIMATED ULTIMATE RECOVERY: 560,000 BO + 24,611 MCFG

REFERENCES: Fassett and Jentgen (1978b); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Wildhorse Gallup Gas Pool

LOCATION: T. 26 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone (Cretaceous)

DISCOVERY WELL: Southern Union No. 6 Jicarilla E, located in Sec. 21, T. 26 N., R. 4 W. Completed 1/6/57 through perforations from 7,140 to 7,153 ft. Total depth 8,023 ft. IP 5,663 MCFGPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fine- to medium-grained sandstone, 20 ft thick; 15% average porosity, 82 millidarcies average permeability.

TYPE OF TRAP: Stratigraphic, formed by northwest-trending shoestring sand.

PROPERTIES OF OIL AND GAS: Oil gravity is 65° API. Gas is 98.99% hydrocarbons.

ANNUAL PRODUCTION, 1984: 276,509 MCFG + 4,323 BO + 394 BW

CUMULATIVE PRODUCTION TO 12/31/84: 34,580,202 MCFG + 179,934 BO

NUMBER PRODUCING WELLS, 12/31/84: 14

ESTIMATED ULTIMATE RECOVERY: 37,000 MMCFG + 190,000 BO

REFERENCES: Matheny and Matheny (1978b); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Boulder Mancos Oil Pool

LOCATION: T. 28 N., R. 1 W., Rio Arriba County

PRODUCING UNIT(S): lower Mancos Shale (Cretaceous)

DISCOVERY WELL: P-M Drilling Co. No. 1 Bayless, located in Sec. 15, T. 28 N., R. 1 W. Completed 5/15/61 through an open-hole interval from 4,150 to 4,429 ft; artificially fractured. Total depth 4,429 ft. IPP 85 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Fractured shale. Gross productive zone is 51-642 ft thick.

TYPE OF TRAP: Fractured trap, formed by fractured shales on a west-dipping monocline.

PROPERTIES OF OIL AND GAS: Oil gravity is 37° API.

ANNUAL PRODUCTION, 1984: 7,771 BO + 307 MCFG + 1,307 BW

CUMULATIVE PRODUCTION TO 12/31/84: 1,793,176 BO

NUMBER PRODUCING WELLS, 12/31/84: 4

ESTIMATED ULTIMATE RECOVERY: 1,700,000 BO + 1,500 MMCFG

REFERENCES: Needham (1978); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Basin Dakota Gas Pool

LOCATION: T. 23-32 N., R. 3-14 W., Rio Arriba, San Juan, and Sandoval Counties.

PRODUCING UNIT(S): Dakota Sandstone and Graneros Shale

DISCOVERY WELL: Byrd, Frost Inc. No. 1 Hargrave, located in Sec. 4, T. 27 N., R. 10 W. Completed 4/12/47 through liner from 6,410 to 6,538 ft; artificially fractured. Total depth 6,745 ft. IP 1,200 MCFGPD + 10 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded fine-grained sandstones, shales, conglomerates, and coals, 200-350 ft thick; 50-70 ft net pay; 5-15% porosity; 0.1-0.25 millidarcy matrix permeability, enhanced by natural fractures.

TYPE OF TRAP: Combination stratigraphic and hydrodynamic trap. Reservoirs are northwest-trending shallow-marine and beach sandstones. Hydrodynamic forces confine the Basin Dakota pool to the deeper, central part of the San Juan Basin.

PROPERTIES OF OIL AND GAS: Oil gravity is 50° API. Gas is at least 94% hydrocarbons.

ANNUAL PRODUCTION, 1984: 47,693,932 MCFG + 323,984 BO + 78,345 BW (Rio Arriba County part of pool)

CUMULATIVE PRODUCTION TO 12/31/84: 1,085,141,456 MCFG + 8,892,690 BO (Rio Arriba County part of pool)

NUMBER PRODUCING WELLS, 12/31/84: 1,172

ESTIMATED ULTIMATE RECOVERY: 5,000,000 MMCFG from Rio Arriba, San Juan, and Sandoval Counties.

REFERENCES: Hoppe (1978a); Deischl (1973); Silver (1968); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Gallo Dakota Oil Pool

LOCATION: T. 24 N., R. 5 W., Rio Arriba County

PRODUCING UNIT(S):

DISCOVERY WELL:

LITHOLOGY AND THICKNESS OF RESERVOIR:

TYPE OF TRAP:

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 0

CUMULATIVE PRODUCTION TO 12/31/84: 4,762 BO

NUMBER PRODUCING WELLS, 12/31/84: 0

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Lindrith Dakota Oil Pool

LOCATION: T. 24 N., R. 2 W., Rio Arriba County

PRODUCING UNIT(S):

DISCOVERY WELL:

LITHOLOGY AND THICKNESS OF RESERVOIR:

TYPE OF TRAP:

PROPERTIES OF OIL AND GAS:

ANNUAL PRODUCTION, 1984: 0

CUMULATIVE PRODUCTION TO 12/31/84: 27,141 BO

NUMBER PRODUCING WELLS, 12/31/84: 0

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Wildhorse Dakota Oil Pool

LOCATION: T. 26 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Dakota Sandstone (Cretaceous)

DISCOVERY WELL: Southern Union Gas Co. No. 1 Jicarilla F, located in SEc. 27, T. 26 N., R. 4 W. Completed 1/27/60 through perforations from 8,151 to 8,325 ft; artificially fractured. Total depth 8,350 ft. IPF 84 BOPD + 109 MCFGPD + 20 BWPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Interbedded fine- to medium-grained sandstone and shale, 285-300 ft thick; approximately 100 ft net pay, 5% porosity.

TYPE OF TRAP: Combination structural and stratigraphic, formed by northwest-trending marine sand bars that have been folded into a structural syncline. The syncline has caused localization of oil beneath a gas-oil contact. The Basin Dakota gas pool is present above the gas-oil contact.

PROPERTIES OF OIL AND GAS: Oil gravity is 42-44° API. Gas is 99.07% hydrocarbons.

ANNUAL PRODUCTION, 1984: 703 BO + 24,093 MCFG

CUMULATIVE PRODUCTION TO 12/31/84: 96,852 BO

NUMBER PRODUCING WELLS, 12/31/84: 1

ESTIMATED ULTIMATE RECOVERY: 97,000 BO + 1,500 MMCFG

REFERENCES: J. P. Matheny (1978); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Gavilan Gallup Oil Pool

LOCATION: T. 25 N., R. 2 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone, Juana Lopez sandstone, Graneros Shale, and Dakota Sandstone (Cretaceous).

DISCOVERY WELL: Northwest Exploration Co. No. 1 Gavilan, located in Sec. 26, T. 25 N., R. 2 W. Completed 3/21/82 through perforations from 6,821 to 7,161 ft (Gallup), 7,466 to 7,562 ft (Juana Lopez), 7,880 to 7,910 ft (Graneros), and 8,004 to 8,026 ft (Dakota); artificially fractured. Total depth 8,241 ft. IPF 62 BOPD + 545 MCFGPD + 3 BWPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Gallup is interbedded fine-grained dolomitic sandstone, siltstone, and shale, 350 ft thick; 108 ft net pay. Juana Lopez is interbedded very fine-grained sandstone, siltstone, and shale, 102 ft thick; 36 ft net pay. Graneros is interbedded siltstone and shale, 30 ft thick; 20 ft net pay. Dakota is interbedded fine-grained sandstone and shale, 30 ft thick; 15 ft net pay.

TYPE OF TRAP: Combination stratigraphic, structural, and fractured. Reservoir permeability enhanced by fractures formed during structural doming.

PROPERTIES OF OIL AND GAS: Gravity of Gallup and Juana Lopez oil is 41° API. Gravity of Graneros and Dakota oil is 40° API.

ANNUAL PRODUCTION, 1984: 484,448 BO + 498,426 MCFG + 3,126 BW

CUMULATIVE PRODUCTION TO 12/31/84: 580,123 BO

NUMBER PRODUCING WELLS, 12/31/84: 13

ESTIMATED ULTIMATE RECOVERY: 7,500,000 BO + 37,500 MMCFG

REFERENCES: Bowman (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: South Lindrith Gallup-Dakota Oil Pool

LOCATION: T. 23-24 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone, Greenhorn Limestone, and Dakota Sandstone (Cretaceous)

DISCOVERY WELL: Skelly Oil Co. No. 2 Jicarilla D, located in Sec. 5, T. 23 N., R. 4 W. Completed 1/29/58 through perforations from 5,962 to 6,149 ft; artificially fractured. Total depth 6,208 ft. IPF 36 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Gallup is shaly sandstone, 200 ft thick; 90 ft net pay. Greenhorn is marly limestone, 60 ft thick; 10 ft net pay. Dakota is sandstone, 200 ft thick; 40 ft net pay.

TYPE OF TRAP: Stratigraphic

PROPERTIES OF OIL AND GAS: Oil gravity is 43° API.

ANNUAL PRODUCTION, 1984: 449,863 BO + 428,216 MCFG + 512 BW

CUMULATIVE PRODUCTION TO 12/31/84: 1,041,613 BO

NUMBER PRODUCING WELLS, 12/31/84: 79

ESTIMATED ULTIMATE RECOVERY: 3,200,000 BO

REFERENCES: Matheny (1983); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: West Lindrith Gallup-Dakota Oil Pool

LOCATION: T. 24-26 N., R. 4 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone and Dakota Sandstone (Cretaceous)

DISCOVERY WELL: Gallup: Continental Oil Co. No. 2-20 Jicarilla, located in Sec. 20, T. 25 N., R. 4 W. Completed 4/16/59 through perforations from 6,870 to 6,980 ft; artificially fractured. Total depth 7,020 ft. IPP 41 BOPD.
Dakota: Johnston & Shear No. 1-1 Jicarilla, located in Sec. 1, T. 24 N., R. 4 W. Completed 3/21/59 through perforations from 7,312 to 7,512 ft; artificially fractured. Total depth 7,695 ft. IP 1,914 MCFGPD + 21 BCPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Gallup is very fine- to fine-grained sandstone, 55 ft thick; 32 ft average net pay, 12% porosity. Dakota is very fine- to fine-grained calcareous sandstone, 40 ft thick; 9% porosity. Matrix permeability of Gallup and Dakota is less than 0.1 millidarcy, but is enhanced by natural fracturing.

TYPE OF TRAP: Stratigraphic

PROPERTIES OF OIL AND GAS: Gravity of Gallup oil is 44° API. Gravity of Dakota oil is 46° API.

ANNUAL PRODUCTION, 1984: 847,121 BO + 9,929,169 MCFG + 139,606 BW

CUMULATIVE PRODUCTION TO 12/31/84: 7,702,843 BO

NUMBER PRODUCING WELLS, 12/31/84: 266

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Attebery (1978); New Mexico Oil & Gas Engineering Committee (1985)

POOL NAME: Ojito Gallup-Dakota Oil Pool

LOCATION: T. 25-26 N., R. 3 W., Rio Arriba County

PRODUCING UNIT(S): Gallup sandstone and Dakota Sandstone (Cretaceous)

DISCOVERY WELL: Gallup: Skelly Oil Co. No. 4 C. W. Roberts, located in Sec. 17, T. 25 N., R. 3 W. Completed 6/13/74 through perforations from 6,960 to 7,250 ft; artificially fractured. Total depth 8,220 ft. IPP 9 BOPD + 110 MCFGPD.
Dakota: Skelly Oil Co. No. 3 C. W. Roberts, located in Sec. 18, T. 25 N., R. 3 W. Completed 1/30/58 through perforations from 7,936 to 8,077 ft; artificially fractured. Total depth 8,180 ft. IPP 171 BOPD.

LITHOLOGY AND THICKNESS OF RESERVOIR: Gallup is interbedded sandstone, siltstone, and shale, 300 ft thick; 8-10% porosity. Dakota is sandstone, 50 ft thick; 45 ft net pay in 2 zones, 10% porosity.

TYPE OF TRAP: Stratigraphic, formed by lenticular sandstones in the Gallup and in the Dakota.

PROPERTIES OF OIL AND GAS: Gravity of Dakota oil is 72° API.

ANNUAL PRODUCTION, 1984: 60,514 BO + 233,629 MCFG + 2,694 BW

CUMULATIVE PRODUCTION TO 12/31/84: 207,008 BO

NUMBER PRODUCING WELLS, 12/31/84: 16

ESTIMATED ULTIMATE RECOVERY:

REFERENCES: Matheny and Folk (1978); R. J. Folk (1978); New Mexico Oil & Gas Engineering Committee (1985)

Appendix 3 Coal Resource Data

The data for calculating coal resources according to Wood and others (1983) has been entered on the form shown below. Data contained in this appendix is non-confidential data and may or may not reflect the entire data set used to obtain the resource/reserve figures given in the text.

```
WELL NUMBER \\\\\\\\\\\\\\\\\\ COUNTY \\\\\\\\\\\\\\
QUADRANGLE \\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\\
\\ 1/4 \\ 1/4 \\ 1/4 SEC \\ T \\\ R \\\ FIELD: \\\\\\\\\\\\\\\\\\\\
FORMATION: \\\\\\\\\\\\\\\\ COAL THICKNESS: \\\\ DEPTH: \\\\\\
ACRES: MEASURED \\\\\ INDICATED \\\\\\ INFERRED \\\\\\\
SOURCE: \\\\\\\\\\\\\\\\\\\\
```

INDICATED - 3/4 mi. circle from the drill hole/measured section

INFERRED - 1 1/4 mi. circle from the drill hole/measured section

CONF. - Confidential or non-confidential status of the data

REC NUM - The record number in the NMBMMR data file.

LAT-LONG - Latitude and longitude of the drill hole/measured section

MEMBER - Member of the geologic formation in which the coal bed occurs.

ZONE - Zone of the geologic formation in which the coal bed occurs.

Coal Resources for the Monero Field

WELL NUMBER ms-5 COUNTY rio arriba
QUADRANGLE chama
1/4 1/4 1/4 SEC T R FIELD: monero
FORMATION: menefee COAL THICKNESS: 5.0 DEPTH: 50.0
ACRES: MEASURED 58.1 INDICATED 401.7 INFERRED
SOURCE: bull 89 n.m.b.m.m.r Conf n
REC NUM: LAT-LONG - MEMBER
ZONE

WELL NUMBER COUNTY rio arriba
QUADRANGLE lumberton
1/4 nw 1/4 sw 1/4 SEC 12 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 4.0 DEPTH: 256.5
ACRES: MEASURED 72.6 INDICATED INFERRED
SOURCE: usbm-569 Conf n
REC NUM: LAT-LONG - MEMBER
ZONE

WELL NUMBER 31076 COUNTY rio arriba
QUADRANGLE lumberton
1/4 sw 1/4 ne 1/4 SEC 8 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 6.5 DEPTH: 0.0
ACRES: MEASURED 77.4 INDICATED 242.0 INFERRED
SOURCE: usbm-569 Conf n
REC NUM: 129 LAT-LONG - MEMBER
ZONE

WELL NUMBER 2122 COUNTY rio arriba
QUADRANGLE lumberton
ne 1/4 ne 1/4 sw 1/4 SEC 7 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 2.8 DEPTH: 0.0
ACRES: MEASURED 106.5 INDICATED 493.7 INFERRED
SOURCE: usbm-569 Conf n
REC NUM: 130 LAT-LONG 365054 -1065712 MEMBER
ZONE

WELL NUMBER 2121 COUNTY rio arriba
QUADRANGLE lumberton
ne 1/4 sw 1/4 ne 1/4 SEC 10 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 3.9 DEPTH: 0.0
ACRES: MEASURED 67.8 INDICATED 266.2 INFERRED
SOURCE: usbm - 569 Conf n

WELL NUMBER ms-5 COUNTY rio arriba
QUADRANGLE chama
1/4 1/4 1/4 SEC T R FIELD: monero
FORMATION: menefee COAL THICKNESS: 5.0 DEPTH: 50.0
ACRES: MEASURED 58.1 INDICATED 401.7 INFERRED
SOURCE: bull 89 n.m.b.m.m.r Conf n
REC NUM: LAT-LONG - MEMBER
ZONE

WELL NUMBER COUNTY rio arriba
QUADRANGLE lumberton
1/4 nw 1/4 sw 1/4 SEC 12 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 4.0 DEPTH: 256.5
ACRES: MEASURED 72.6 INDICATED INFERRED
SOURCE: usbm-569 Conf n
REC NUM: LAT-LONG - MEMBER
ZONE

WELL NUMBER 31076 COUNTY rio arriba
QUADRANGLE lumberton
1/4 sw 1/4 ne 1/4 SEC 8 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 6.5 DEPTH: 0.0
ACRES: MEASURED 77.4 INDICATED 242.0 INFERRED
SOURCE: usbm-569 Conf n
REC NUM: 129 LAT-LONG - MEMBER
ZONE

WELL NUMBER 2122 COUNTY rio arriba
QUADRANGLE lumberton
ne 1/4 ne 1/4 sw 1/4 SEC 7 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 2.8 DEPTH: 0.0
ACRES: MEASURED 106.5 INDICATED 493.7 INFERRED
SOURCE: usbm-569 Conf n
REC NUM: 130 LAT-LONG 365054 -1065712 MEMBER
ZONE

WELL NUMBER 2121 COUNTY rio arriba
QUADRANGLE lumberton
ne 1/4 sw 1/4 ne 1/4 SEC 10 T 31n R lw FIELD: monero
FORMATION: menefee COAL THICKNESS: 3.9 DEPTH: 0.0
ACRES: MEASURED 67.8 INDICATED 266.2 INFERRED
SOURCE: usbm - 569 Conf n
REC NUM: LAT-LONG - MEMBER
ZONE

APPENDIX 4

Coal Resources for Deep Coals in Rio Arriba County

WELL NUMBER 12285-53 COUNTY rio arriba
QUADRANGLE bancos mesa
nw 1/4 se 1/4 nw 1/4 SEC 26 T 32n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 3764.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: belco petrol. corp.; carracas mesa unit 1 Conf

WELL NUMBER 12285-53 COUNTY rio arriba
QUADRANGLE bancos mesa
nw 1/4 se 1/4 nw 1/4 SEC 26 T 32n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.5 DEPTH: 3798.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: belco petrol. corp.; carracas mesa unit 1 Conf

WELL NUMBER 9289-54 COUNTY rio arriba
QUADRANGLE bancos mesa
sw 1/4 ne 1/4 sw 1/4 SEC 29 T 32n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 4004.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: phillips petrol. mesa unit 32-4 well i-29 Conf

WELL NUMBER 12281-56 COUNTY rio arriba
QUADRANGLE wirt canyon
se 1/4 nw 1/4 nw 1/4 SEC 23 T 32n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 7.0 DEPTH: 1030.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pan am. pet. co.; pagosa-jicarilla #1 Conf

WELL NUMBER 12278-69 COUNTY rio arriba
QUADRANGLE navajo dam
sw 1/4 ne 1/4 sw 1/4 SEC 31 T 31n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 2354.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeling; sj 31-6, mesa 5-31 Conf

WELL NUMBER 12278-69 COUNTY rio arriba
QUADRANGLE navajo dam
sw 1/4 ne 1/4 sw 1/4 SEC 31 T 31n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 6.0 DEPTH: 2364.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline; sj-31-6, mesa 5-31 Conf

WELL NUMBER 12278-69 COUNTY rio arriba
QUADRANGLE navajo dam
sw 1/4 ne 1/4 sw 1/4 SEC 31 T 31n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 2382.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline; sj 31-6 Conf

WELL NUMBER 9394-71 COUNTY rio arriba
QUADRANGLE gemez ranch
nw 1/4 se 1/4 ne 1/4 SEC 29 T 31n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3157.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline, rosa unit 15-29 Conf

WELL NUMBER 9394-71 COUNTY rio arriba
QUADRANGLE gemez ranch
nw 1/4 se 1/4 ne 1/4 SEC 29 T 31n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.0 DEPTH: 3200.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline, rosa unit 15-29 Conf

WELL NUMBER 9394-71 COUNTY rio arriba
QUADRANGLE gemez ranch
nw 1/4 se 1/4 ne 1/4 SEC 29 T 31n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3207.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline, rosa unit 15-29 Conf

WELL NUMBER 9394-71 COUNTY rio arriba
QUADRANGLE gemez ranch
nw 1/4 se 1/4 ne 1/4 SEC 29 T 31n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.0 DEPTH: 3238.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline, rosa unit 15-29 Conf

WELL NUMBER 9394-71 COUNTY rio arriba
QUADRANGLE gemez ranch
nw 1/4 se 1/4 ne 1/4 SEC 29 T 31n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 3247.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline, rosa unit 15-29 Conf

WELL NUMBER 9394-71 COUNTY rio arriba
QUADRANGLE gemez ranch
nw 1/4 se 1/4 ne 1/4 SEC 29 T 31n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 6.0 DEPTH: 3264.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw pipeline, rosa unit 15-29 Conf

WELL NUMBER 9020-90 COUNTY rio arriba
QUADRANGLE gomez ranch
se 1/4 nw 1/4 sw 1/4 SEC 20 T 30n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 11.0 DEPTH: 3068.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: el paso natl gas Conf

WELL NUMBER 9020-90 COUNTY rio arriba
QUADRANGLE gomez ranch
se 1/4 nw 1/4 sw 1/4 SEC 20 T 30n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 7.0 DEPTH: 3112.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: el paso nat'l gas; manning #1-a Conf

WELL NUMBER 14581-111 COUNTY rio arriba
QUADRANGLE gobernador
sw 1/4 se 1/4 ne 1/4 SEC 30 T 29n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 12.0 DEPTH: 3573.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw, san juan 29-5, 13-30 Conf

WELL NUMBER 14581-111 COUNTY rio arriba
QUADRANGLE gobernador
sw 1/4 se 1/4 ne 1/4 SEC 30 T 29n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 8.0 DEPTH: 3537.0
ACRES: MEASURED 125.7 INDICATED 994.3 INFERRED
SOURCE: pacific nw, san juan 29-5, 13-30 Conf

WELL NUMBER 12120-116 COUNTY rio arriba
QUADRANGLE leandro canyon
sw 1/4 nw 1/4 se 1/4 SEC 30 T 29n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 6.0 DEPTH: 3533.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: pacific nw, jicarilla indian a-2 Conf

WELL NUMBER 12120-116 COUNTY rio arriba
QUADRANGLE leandro canyon
sw 1/4 nw 1/4 se 1/4 SEC 30 T 29n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3591.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: pacific nw, jicarilla indian a-2 Conf

WELL NUMBER 12120-116 COUNTY rio arriba
QUADRANGLE leandro canyon
sw 1/4 nw 1/4 se 1/4 SEC 30 T 29n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.5 DEPTH: 3540.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: pacific nw, jicarilla indian a-2 Conf

WELL NUMBER 17877-194 COUNTY rio arriba
QUADRANGLE gonzales mesa
ne 1/4 sw 1/4 sw 1/4 SEC 7 T 26n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 2946.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: nw production; w#1-7 Conf

WELL NUMBER 17877-194 COUNTY rio arriba
QUADRANGLE gonzales mesa
ne 1/4 sw 1/4 sw 1/4 SEC 7 T 26n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 2960.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: nw production; w#1-7 Conf

WELL NUMBER 17877-194 COUNTY rio arriba
QUADRANGLE gonzales mesa
ne 1/4 sw 1/4 sw 1/4 SEC 7 T 26n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3044.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: nw production; w#1-7 Conf

WELL NUMBER 11463-199 COUNTY rio arriba
QUADRANGLE ojito
sw 1/4 ne 1/4 ne 1/4 SEC 14 T 26n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3555.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: magnolia pet., jicarilla d#2 Conf

WELL NUMBER 11463-199 COUNTY rio arriba
QUADRANGLE ojito
sw 1/4 ne 1/4 ne 1/4 SEC 14 T 26n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 7.0 DEPTH: 3595.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: magnolia pet., jicarilla d#2 Conf

WELL NUMBER 22382-163 COUNTY rio arriba
QUADRANGLE gould pass
nw 1/4 se 1/4 sw 1/4 SEC 9 T 27n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 2956.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj28-7 #93 (pm) Conf

WELL NUMBER 22382-163 COUNTY rio arriba
QUADRANGLE gould pass
nw 1/4 se 1/4 sw 1/4 SEC 9 T 27n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 2980.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj28-7 #93 (pm) Conf

WELL NUMBER 22382-163 COUNTY rio arriba
QUADRANGLE gould pass
nw 1/4 se 1/4 sw 1/4 SEC 9 T 27n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3055.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj28-7 #93 (pm) Conf

WELL NUMBER 22480-165 COUNTY rio arriba
QUADRANGLE gould pass
se 1/4 nw 1/4 sw 1/4 SEC 18 T 27n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3066.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, rincon #97 pm Conf

WELL NUMBER 22480-165 COUNTY rio arriba
QUADRANGLE gould pass
se 1/4 nw 1/4 sw 1/4 SEC 18 T 27n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 6.0 DEPTH: 3137.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, rincon #97 pm Conf

WELL NUMBER 22480-165 COUNTY rio arriba
QUADRANGLE gould pass
se 1/4 nw 1/4 sw 1/4 SEC 18 T 27n R 6w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 6.0 DEPTH: 3158.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, rincon #97 pm Conf

WELL NUMBER 8151-167 COUNTY rio arriba
QUADRANGLE santos peak
nw 1/4 se 1/4 sw 1/4 SEC 20 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 1.5 DEPTH: 3273.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #19 Conf

WELL NUMBER 8151-167 COUNTY rio arriba
QUADRANGLE santos peak
nw 1/4 se 1/4 sw 1/4 SEC 20 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3278.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #19 Conf

WELL NUMBER 8151-167 COUNTY rio arriba
QUADRANGLE santos peak
nw 1/4 se 1/4 sw 1/4 SEC 20 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3296.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #19 Conf

WELL NUMBER 8151-167 COUNTY rio arriba
QUADRANGLE santos peak
nw 1/4 se 1/4 sw 1/4 SEC 20 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 3346.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #19 Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3080.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.5 DEPTH: 3152.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 12.5 DEPTH: 3236.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.0 DEPTH: 3254.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3271.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 3289.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 3355.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 19300 COUNTY rio arriba
QUADRANGLE navajo dam
ne 1/4 sw 1/4 ne 1/4 SEC 36 T 31n R 7w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 12.0 DEPTH: 3373.0
ACRES: MEASURED 125.7 INDICATED INFERRED
SOURCE: blackwood and nichols, nebu 22-a Conf

WELL NUMBER 22397-168 COUNTY rio arriba
QUADRANGLE vigas canyon
se 1/4 nw 1/4 ne 1/4 SEC 3 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3361.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #21 Conf

WELL NUMBER 22397-168 COUNTY rio arriba
QUADRANGLE vigas canyon
se 1/4 nw 1/4 ne 1/4 SEC 3 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.0 DEPTH: 3368.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #21 Conf

WELL NUMBER 22397-168 COUNTY rio arriba
QUADRANGLE vigas canyon
se 1/4 nw 1/4 ne 1/4 SEC 3 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.0 DEPTH: 3374.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #21 Conf

WELL NUMBER 22397-168 COUNTY rio arriba
QUADRANGLE vigas canyon
se 1/4 nw 1/4 ne 1/4 SEC 3 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3383.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #21 Conf

WELL NUMBER 22397-168 COUNTY rio arriba
QUADRANGLE vigas canyon
se 1/4 nw 1/4 ne 1/4 SEC 3 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3431.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng, sj 27-5 #21 Conf

WELL NUMBER 8156-169 COUNTY rio arriba
QUADRANGLE vigas canyon
nw 1/4 se 1/4 ne 1/4 SEC 26 T 27n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3236.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: epng; sj 27-5 #33 Conf

WELL NUMBER 11901-173 COUNTY rio arriba
QUADRANGLE leavry canyon
sw 1/4 ne 1/4 ne 1/4 SEC 25 T 27n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 3587.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: magnolia pet, jicarilla g 2 Conf

WELL NUMBER 11901-173 COUNTY rio arriba
QUADRANGLE leavry canyon
sw 1/4 ne 1/4 ne 1/4 SEC 25 T 27n R 3w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3369.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: magnolia pet. jicarilla g 2 Conf

WELL NUMBER 11781-225 COUNTY rio arriba
QUADRANGLE gonzales mesa
nw 1/4 se 1/4 se 1/4 SEC 6 T 25n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.0 DEPTH: 2719.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: humble oil jicarilla j4 Conf

WELL NUMBER 11781-225 COUNTY rio arriba
QUADRANGLE gonzales mesa
nw 1/4 se 1/4 se 1/4 SEC 6 T 25n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.5 DEPTH: 2767.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: humble oil jicarilla j4 Conf

WELL NUMBER 11781-225 COUNTY rio arriba
QUADRANGLE gonzales mesa
nw 1/4 se 1/4 se 1/4 SEC 6 T 25n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.5 DEPTH: 2788.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: humble oil jicarilla j4 Conf

WELL NUMBER 11781-225 COUNTY rio arriba
QUADRANGLE gonzales mesa
nw 1/4 se 1/4 se 1/4 SEC 6 T 25n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 2314.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: humble oil jicarilla j4 Conf

WELL NUMBER 19851-228 COUNTY rio arriba
QUADRANGLE otero sttore
nw 1/4 se 1/4 se 1/4 SEC 25 T 25n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 6.0 DEPTH: 3076.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: amerada pet, jicarilla apache a5 Conf

WELL NUMBER 19851-228 COUNTY rio arriba
QUADRANGLE otero store
nw 1/4 se 1/4 se 1/4 SEC 25 T 25n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.5 DEPTH: 3110.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: amerada pet. jicarilla apache Conf

WELL NUMBER 19851-228 COUNTY rio arriba
QUADRANGLE otero store
nw 1/4 se 1/4 se 1/4 SEC 25 T 25n R 5w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 2.0 DEPTH: 3118.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: amerada pet. jicarilla apache a5 Conf

WELL NUMBER 24811 COUNTY rio arriba
QUADRANGLE bancos mesa
sw 1/4 ne 1/4 ne 1/4 SEC 7 T 31n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 4.0 DEPTH: 3209.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: mitchell energy rosa unit 81 Conf

WELL NUMBER 24811 COUNTY rio arriba
QUADRANGLE bancos mesa
sw 1/4 ne 1/4 ne 1/4 SEC 7 T 31n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 9.0 DEPTH: 3314.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: mitchell energy rosa unit 81 Conf

WELL NUMBER 23149 COUNTY rio arriba
QUADRANGLE carracus canyon
sw 1/4 ne 1/4 nw 1/4 SEC 15 T 31n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 13.0 DEPTH: 3535.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: mitchell energy rosa unit 83 Conf

WELL NUMBER 25729 COUNTY rio arriba
QUADRANGLE espinosa ranch
nw 1/4 se 1/4 ne 1/4 SEC 28 T 31n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 13.0 DEPTH: 3752.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: amoco rosa unit 86 Conf

WELL NUMBER 25729 COUNTY rio arriba
QUADRANGLE espinosa ranch
nw 1/4 se 1/4 ne 1/4 SEC 28 T 31n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 5.0 DEPTH: 3770.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: amoco rosa unit 86 Conf

WELL NUMBER 26001 COUNTY rio arriba
QUADRANGLE carracus canyon
se 1/4 nw 1/4 nw 1/4 SEC 12 T 31n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 3.5 DEPTH: 3892.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: amoco rosa unit 87 Conf

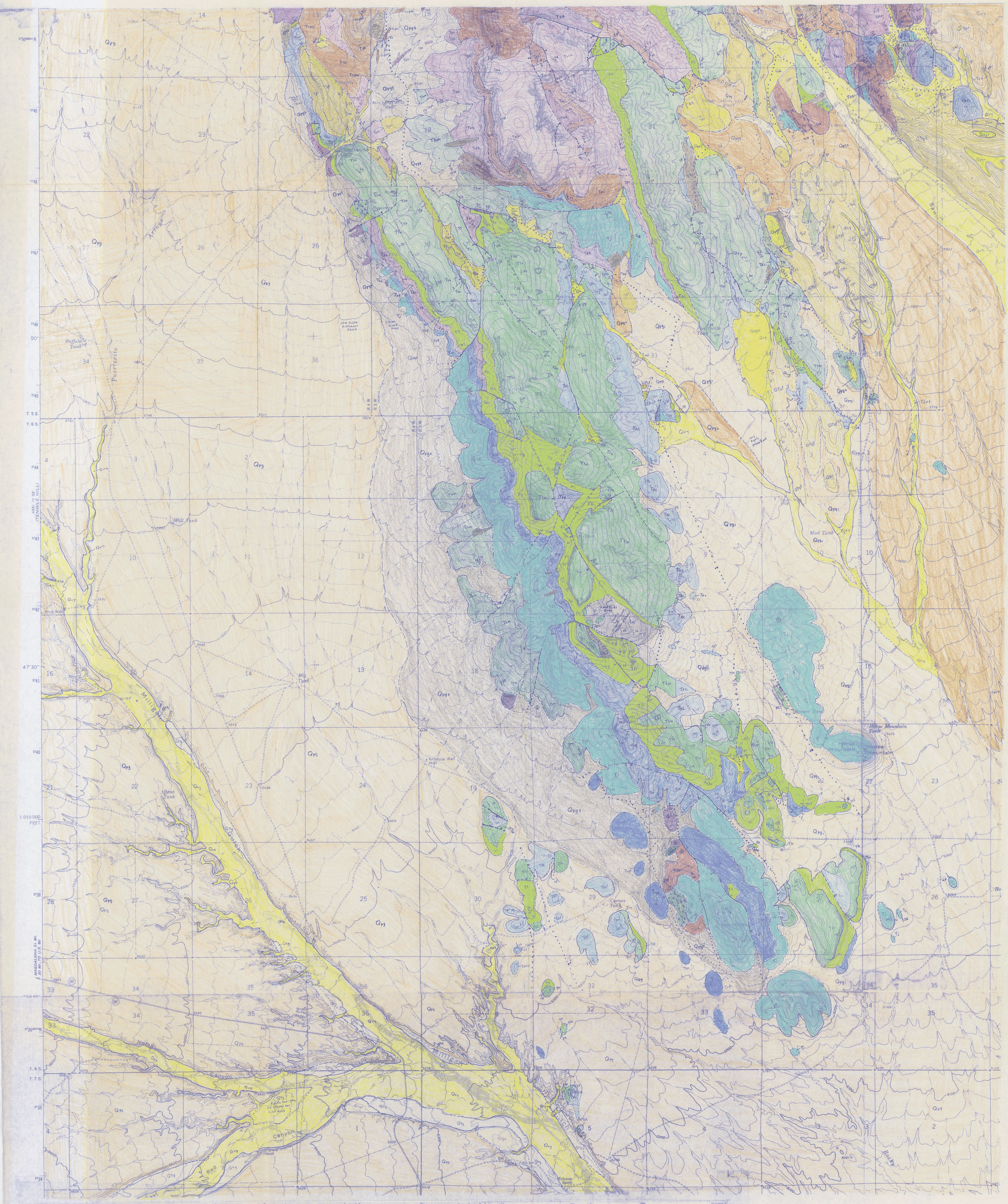
WELL NUMBER 26001 COUNTY rio arriba
QUADRANGLE carracus canyon
se 1/4 nw 1/4 nw 1/4 SEC 12 T 31n R 4w FIELD: san juan
FORMATION: fruitland COAL THICKNESS: 18.0 DEPTH: 3912.0
ACRES: MEASURED 125.7 INDICATED 1005.3 INFERRED
SOURCE: amoco rosa unit 87 Conf

GEOLOGIC MAP OF THE PUERTECITO GAP QUADRANGLE AND VICINITY

by

G. R. OSBURN, S.A. BOWRING, LARS NELSON, S. J. ROTH AND OTHERS

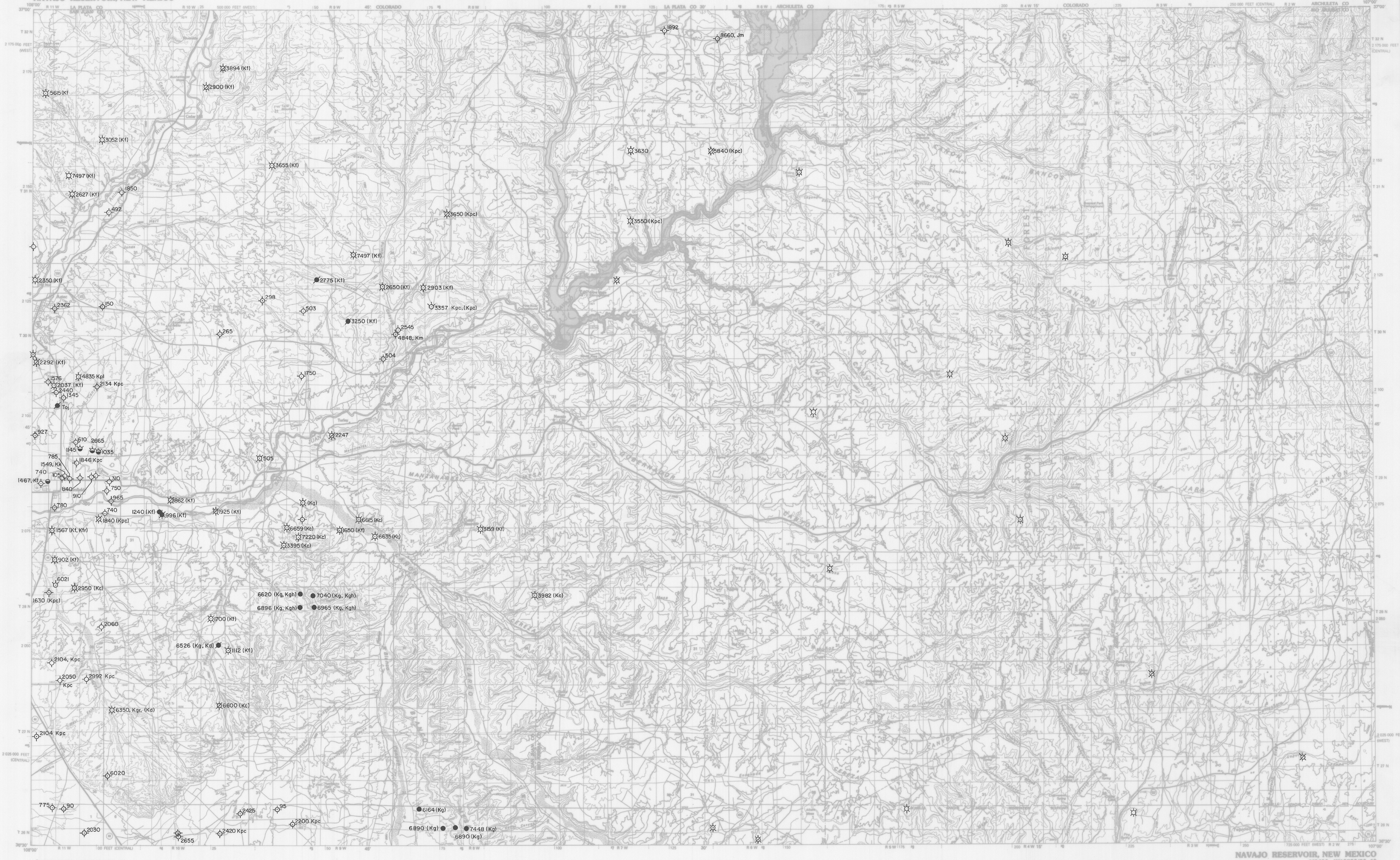
1985



OF-232, 233
Map 65.

NAVAJO RESERVOIR, NEW MEXICO

30X60 MINUTE SERIES (TOPOGRAPHIC)



SCALE 1:100 000

1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND

CONTOUR INTERVAL 50 METERS

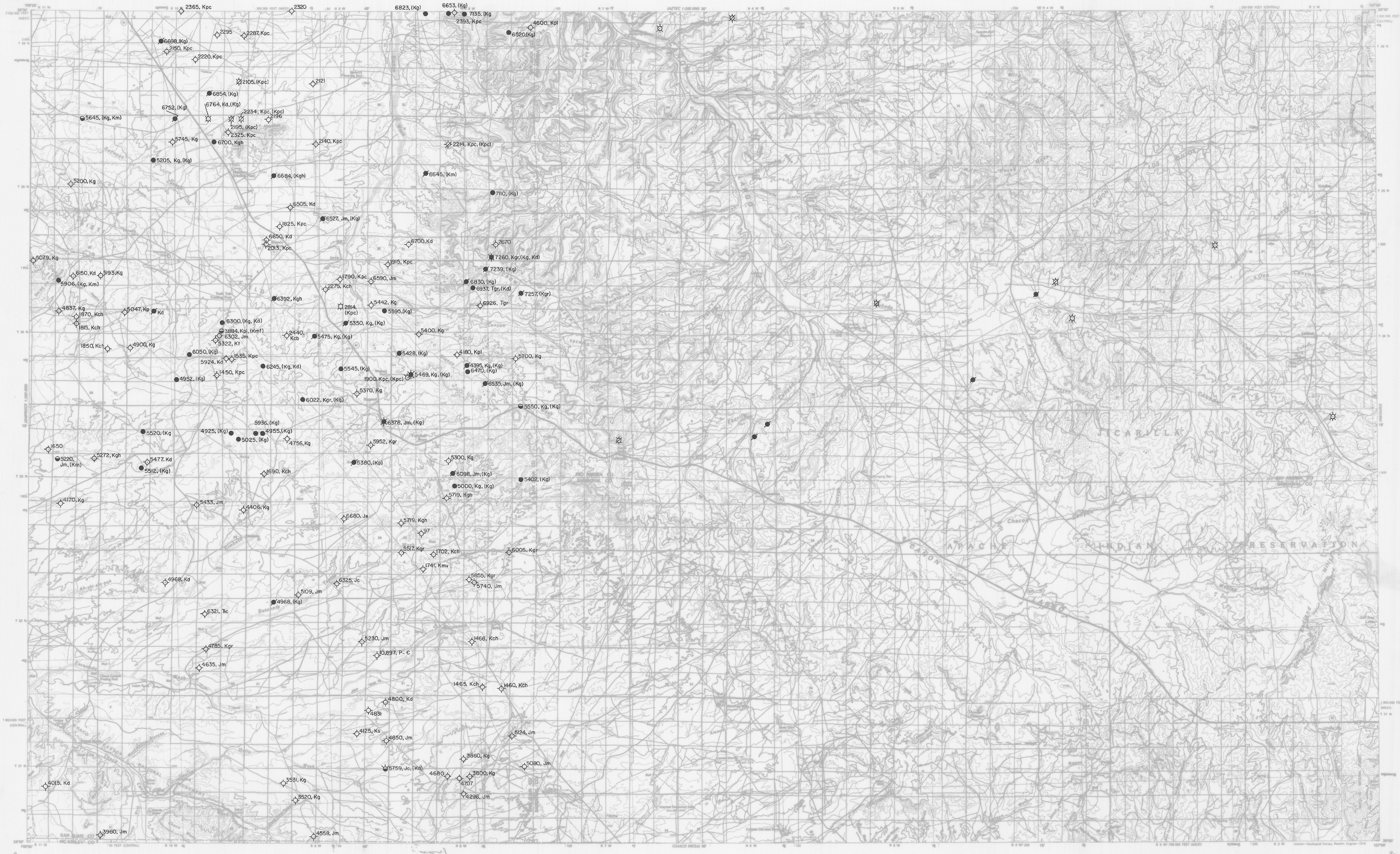
NAVAJO RESERVOIR, NEW MEXICO
N3630—W10700/30x60
1980

MAP 65 **Petroleum tests in the Navajo Reservoir 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.**

OF-232, 233
Map 66.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHACO CANYON QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES



Mapped, edited, and published by the Geological Survey

Compiled in 1976 from USGS 1:24 000 and 1:62 500-scale topographic maps dated 1959–1967. See index for dates of individual maps

Partially revised from aerial photographs taken 1975–1976 and from other official sources. Revised information not field checked

Projection and 10 000-meter grid, zone 13: Universal Transverse Mercator
50 000-foot grid ticks based on New Mexico coordinate system, central and west zones. 1927 North American datum

Areas covered by dashed light-blue pattern are subject to controlled inundation

INDEX TO 1:24 000 AND 1:62 500-SCALE MAPS

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1 Huerfano Trading Post NW–1966
2 Huerfano Trading Post–1967
3 Chaco Canyon–1959
4 Gobernador Mesa–1963
5 Lapis Point–1963
6 Schmitz Ranch–1963
7 Otero–1963
8 Huerfano Trading Post SW–1966
9 Burro Trading Post–1966
10 Tohlakai Canyon–1963
11 Cherry Shale–1963
12 Billy Rice Canyon–1963
13 Pueblo Bonito–1963
14 Pueblo Bonito NW–1966
15 Kinlichee–1967
16 Lybrook NW–1966
17 Lybrook–1959
18 Lybrook SW–1966
19 Tsoodzil Mesa–1966
20 Five Lakes Canyon NW–1963
21 Five Lakes Canyon NE–1963
22 Pueblo Bonito–1959
23 Pueblo Bonito–1966
24 Fire Rock Wash–1966
25 Lybrook SE–1966
26 Mule Dam–1966
27 Door Mesa–1966
28 Taylor Ranch–1963
29 Arroyo Chijuilla–1963

UTM GRID AND 1976 MAGNETIC NORTH DECLINATION AT CENTER OF MAP

SCALE 1:100 000

KILOMETERS 0 1 2 3 4 5 6 7 8 9 10
MILES 0 1 2 3 4 5
FEET 5000 0 5000 10000 15000 20000 25000

NATIONAL GEODETIC VERTICAL DATUM OF 1929

NEW MEXICO
QUADRANGLE LOCATION

LEGEND

Perennial stream, lake
Intermittent stream, lake
Village or locality
Landmark structure
Public park or recreation area
Forest or game land area
Other public area or Military or Indian reservation

ROAD CLASSIFICATION

Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Street or unimproved road
Trail
Interstate route
U.S. route
State route

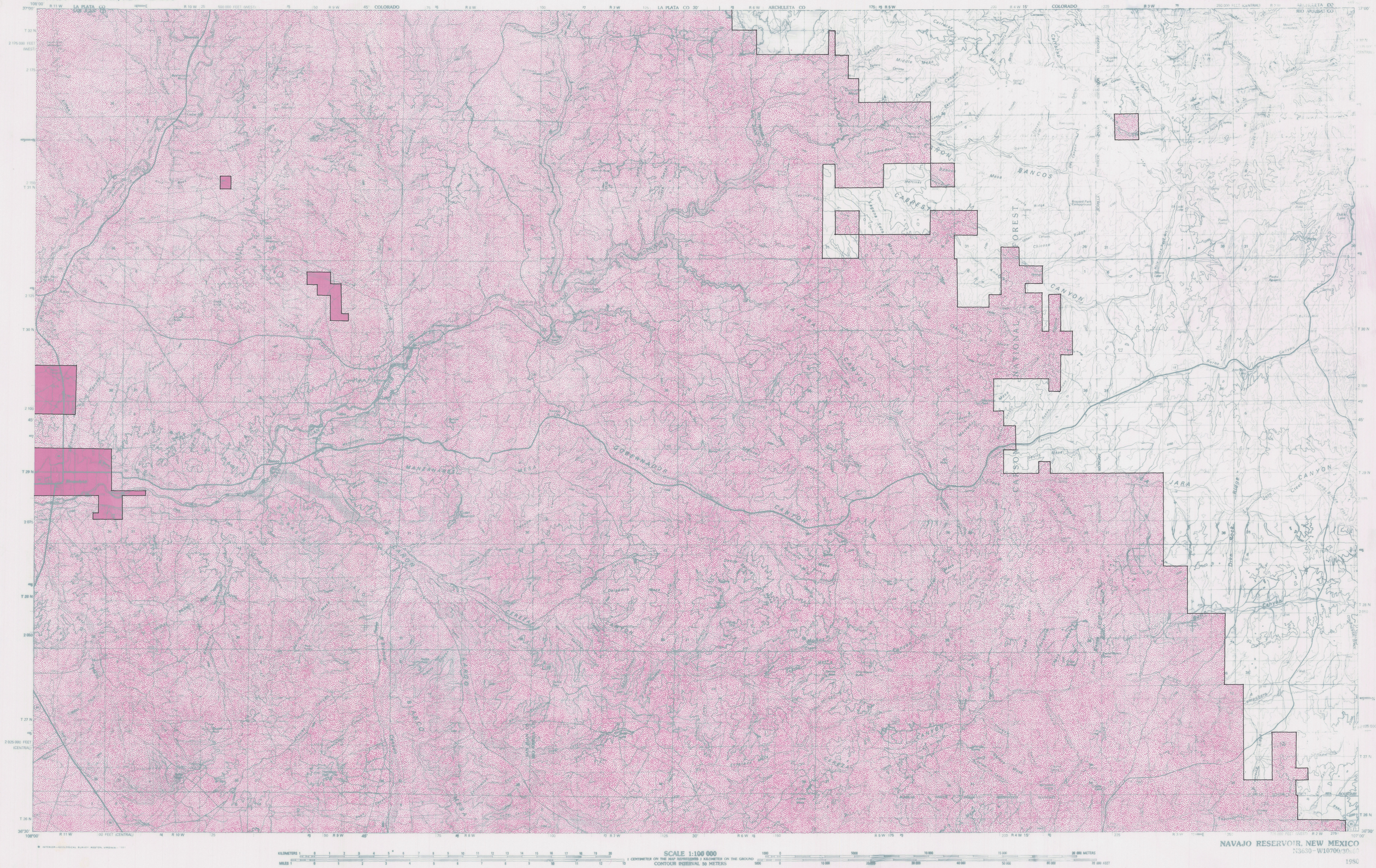
CHACO CANYON, NEW MEXICO
SW/4 AZTEC (NJ 13-10) 1:250 000-SCALE MAP
N3600–W10700/30x60
1976

MAP 66 Petroleum tests in the Chaco Canyon 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.

OF-232, 233
Map 69.

NAVAJO RESERVOIR, NEW MEXICO

30X60 MINUTE SERIES (TOPOGRAPHIC)



SCALE 1:100 000
1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 50 METERS

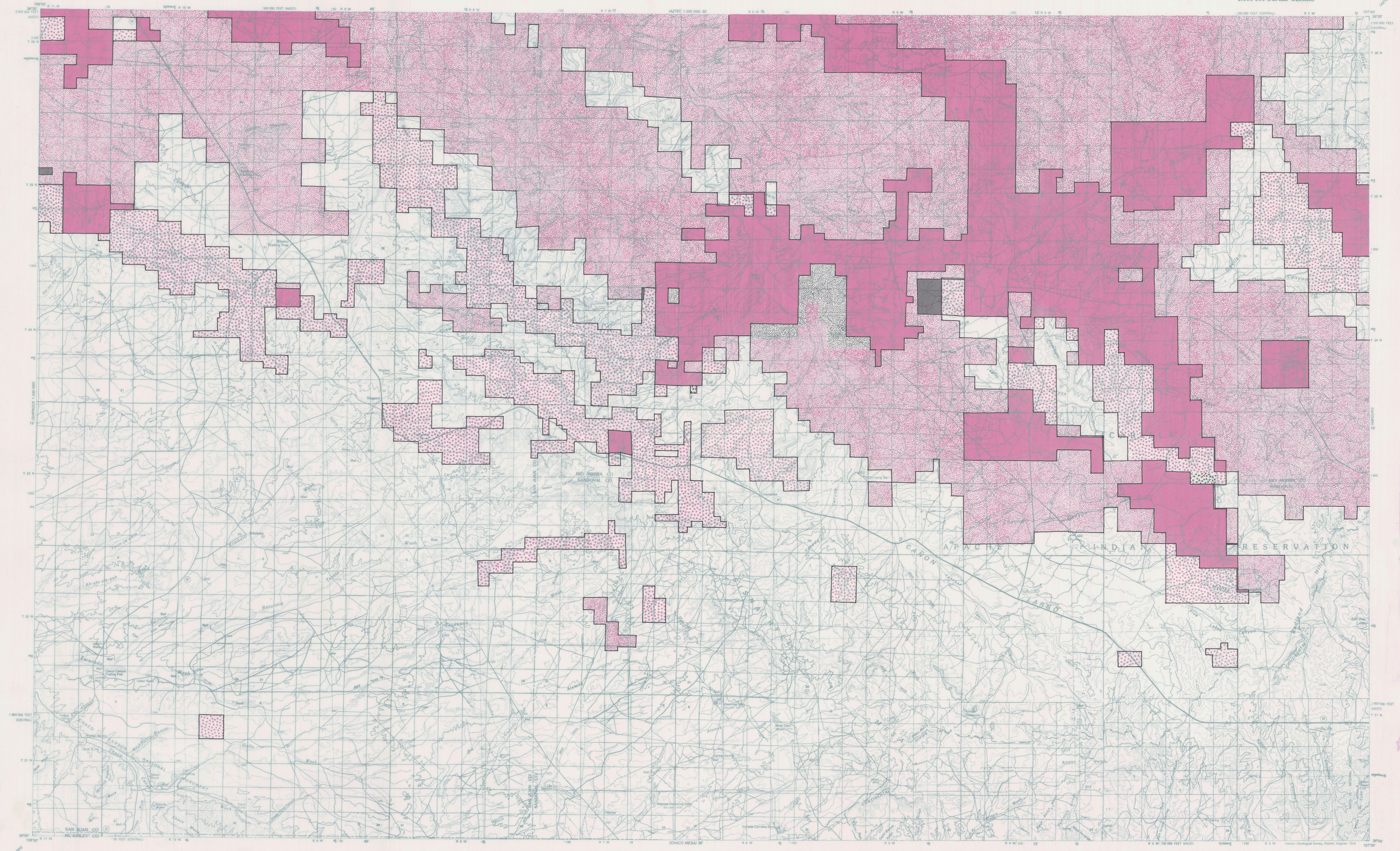
Oil Field
Gas Field
Combination Oil & Gas Field

MAP 69 **Oil and gas fields in the Navajo Reservoir 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.**

OF-232, 233
Map 70.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHACO CANYON QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES



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Projection and 10 000-meter grid, zone 13: Universal Transverse Mercator

50 000-foot grid ticks based on New Mexico coordinate system, central and west zones. 1927 North American datum

Areas covered by dashed light-blue pattern are subject to controlled inundation

INDEX TO 1:24 000 AND 1:62 500-SCALE MAPS

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1 Huerfano Trading Post NW-1966
2 Huerfano Trading Post-1967
3 Nageezi-1959
4 Lybrook NW-1962
5 Lapis Point-1963
6 Schmitz Ranch-1963
7 Otto-1963
8 Huerfano Trading Post SW-1966
9 Billy Rock Canyon-1966
10 Tiffany Canyon-1963
11 Otero Sinks-1962
12 Billy Rock Canyon-1963
13 Landusky-1963
14 Kimbeto Bonito NW-1966
15 Kimbeto-1967
16 Lybrook-1966
17 Lybrook-1966
18 Chinlee-1966
19 Fort Lewis Canyon-1966
20 Fort Lewis Canyon NW-1963
21 Fort Lewis Canyon NE-1963
22 Pueblo Bonito-1966
23 Sargent Ranch-1966
24 Fort Lewis Canyon-1966
25 Lybrook SE-1962
26 Mule Dam-1966
27 Deer Mesa-1966
28 Taylor Ranch-1962
29 Arroyo Chijuilla-1963

GN MN
12½° 27 MILS
12½° 222 MILS
UTM GRID AND 1976 MAGNETIC NORTH DECLINATION AT CENTER OF MAP

SCALE 1:100 000
KILOMETERS 0 1 2 3 4 5 6 7 8 9 10
MILES 0 1 2 3 4 5
FEET 5000 0 5000 10000 15000 20000 25000

NATIONAL GEODETIC VERTICAL DATUM OF 1929

NEW MEXICO
QUADRANGLE LOCATION

Oil Field
Gas Field
Combination Oil & Gas Field

LEGEND

Perennial stream, lake
Intermittent stream, lake
Village or locality
Landmark structure
Public park or recreation area
Forest or game land area
Other public area or Military or Indian reservation

ROAD CLASSIFICATION

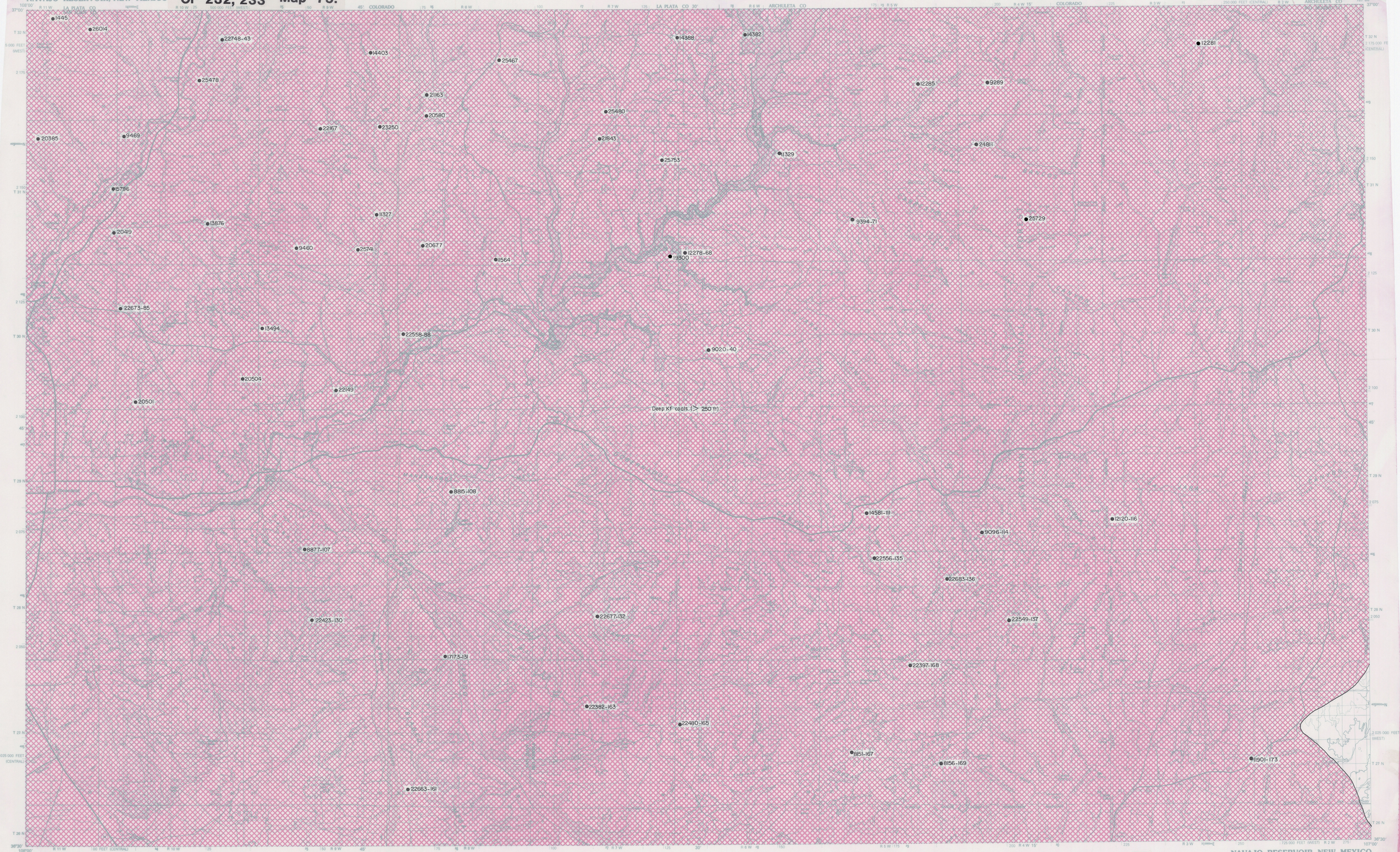
Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Street or unimproved road
Trail
Interstate route
U.S. route
State route

CHACO CANYON, NEW MEXICO
SW/4 AZTEC (NJ 13-10) 1:250 000-SCALE MAP
N3600—W10700/30x60
1976

MAP 70 Oil and gas fields in the Chaco Canyon 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.

NAVAJO RESERVOIR, NEW MEXICO **OF-232, 233** **Map 75.**

30X60 MINUTE SERIES (TOPOGRAPHIC)



SCALE 1:100 000
1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 50 METERS

Moderate
Very low
Kf - Fruitland Formation
●20677 Drill hole & drill hole number

NAVAJO RESERVOIR, NEW MEXICO
N3630–W10700/30x60
1980

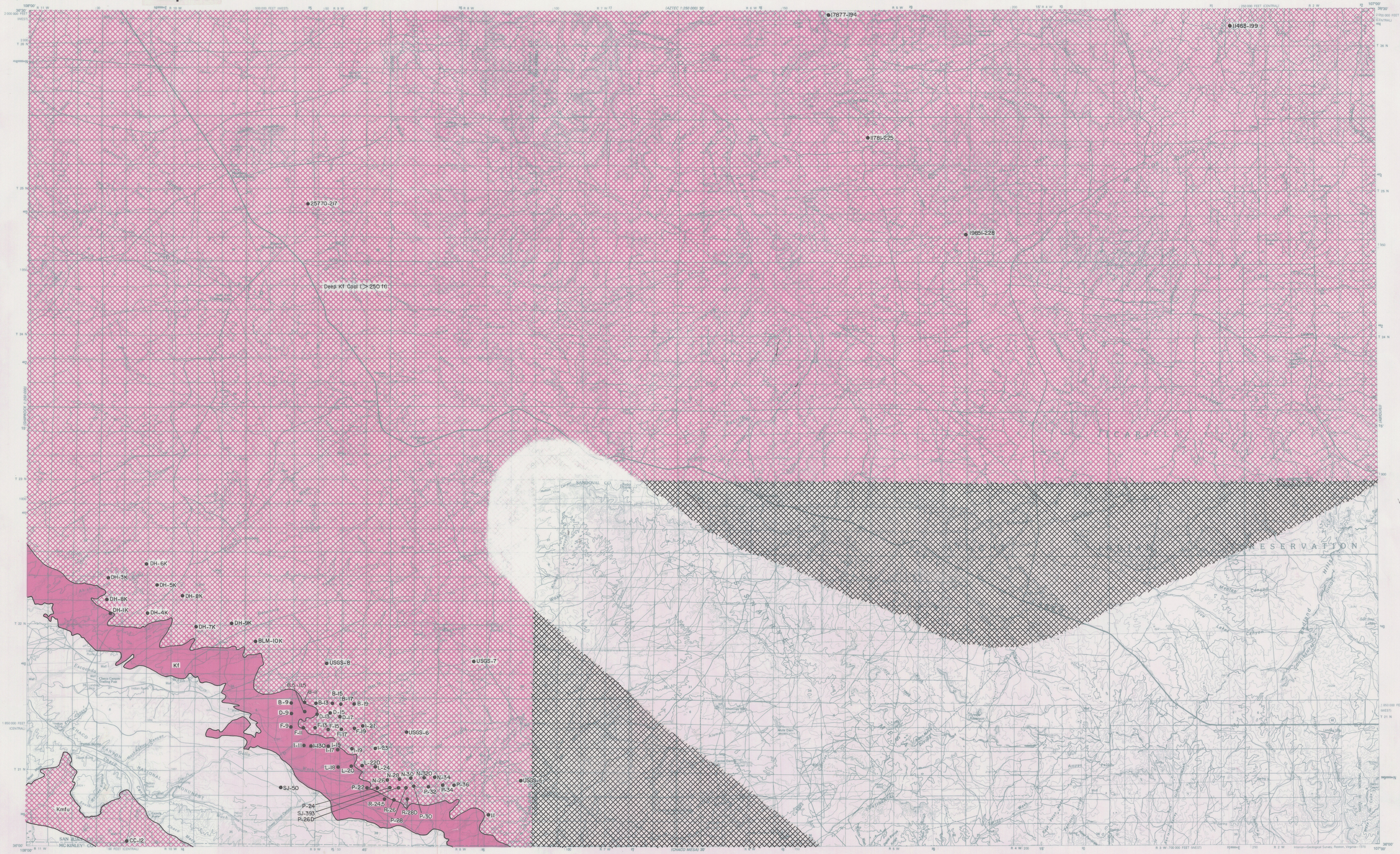
INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1981

MAP 75 **Coal occurrences, prospects, mines, and resource potential for Navajo Reservoir 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.**

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OF-232, 233
Map 76.

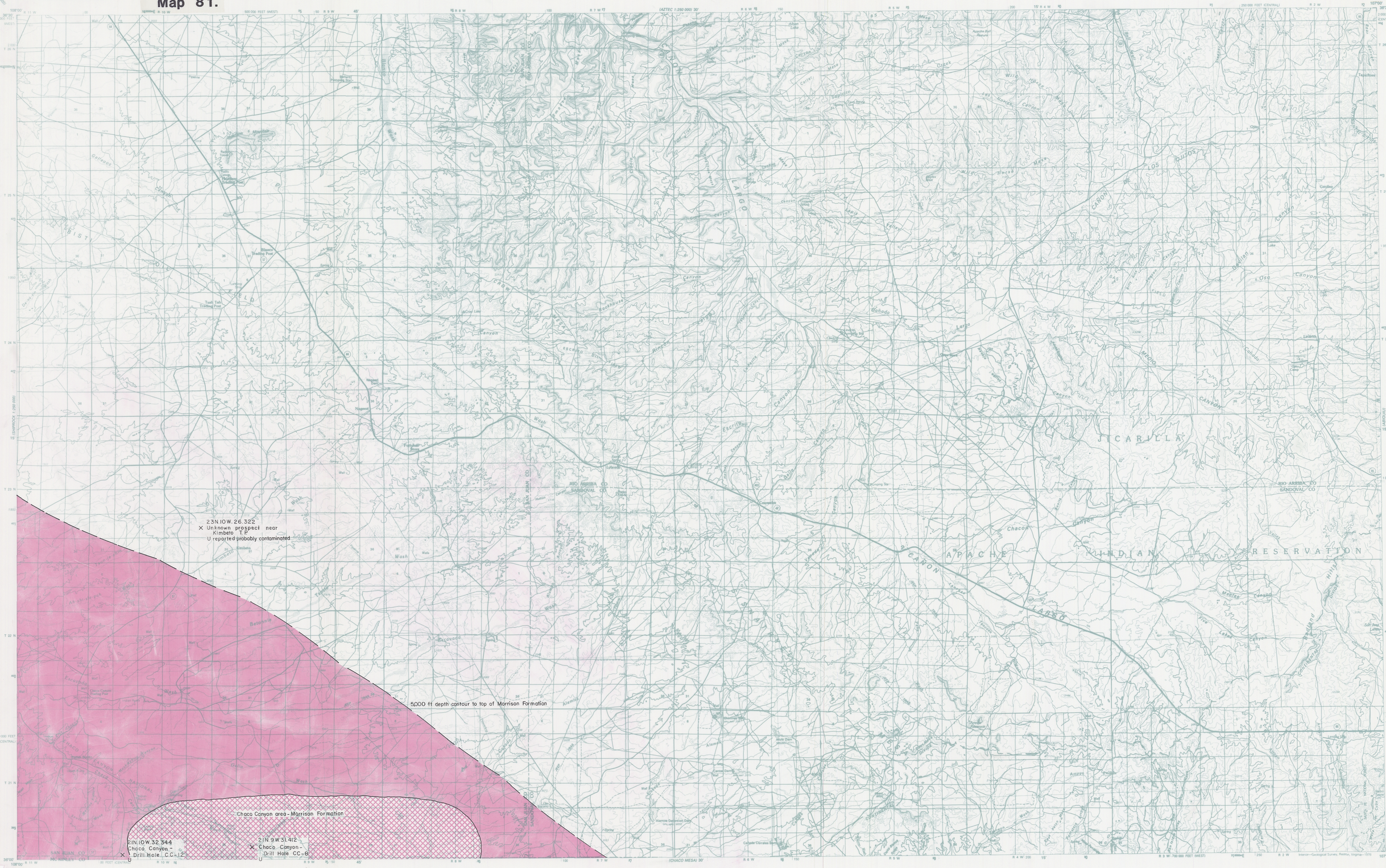
CHACO CANYON QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES


I7877-I94
I1463-I99
I178I-225
25770-217
I985I-228
Deep Kf Coal (> 250 ft)
DH-6K
DH-3K
DH-5K
DH-8K
DH-8K
DH-IK
DH-4K
DH-7K
DH-9K
BLM-10K
Kf
USGS-8
USGS-7
B-5
I-15
B-11
B-15
B-17
B-9
B-13
B-19
D-9
D-15
D-17
F-9
F-13
F-15
I-21
F-11
F-19
USGS-6
F-17
I-11
I-13O
I-13
I-23
I-17
I-19
L-22D
L-24
L-18
L-20
N-28
N-30
N-320
N-34
N-25
P-36
P-22
P-32
P-34
SJ-50
USGS-5
R-24.5
R-26
R-28D
P-30
P-24
SJ-393
P-26D
P-28
11
Kmfu
CC-12
SAN JUAN
MC KINLEY
SANDOVAL CO.
RESERVATION
Chaco Canyon Trading Post
Mesa Portales
Mesa Prieta
Mesita Negra
Mesita Negra
Mesita Negra

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OF-232, 233
Map 81.

CHACO CANYON QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES



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Projection and 10 000-meter grid, zone 13: Universal Transverse Mercator
50 000-foot grid ticks based on New Mexico coordinate system, central and west zones. 1927 North American datum

Areas covered by dashed light-blue pattern are subject to controlled inundation

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1 Huerfano Trading Post NW–1966
2 Huerfano Trading Post–1967
3 Nageezi–1959
4 Gonzales Mesa–1963
5 Lapis Point–1963
6 Schmitz Ranch–1963
7 Qiro–1963
8 Huerfano Trading Post SW–1966
9 Blanco Trading Post–1966
10 Tatoya Canyon–1963
11 Otero Stone–1963
12 Billy Rice Canyon–1963
13 Lindrith–1963
14 Pueblo Bonito NW–1966
15 Kimbeto–1967
16 Lybrook NW–1966
17 Lybrook–1966
18 Counselor–1966
19 Tanoma Wash–1966
20 Five Lakes Canyon NW–1963
21 Five Lakes Canyon NE–1963
22 Pueblo Bonito–1966
23 Sargent Ranch–1966
24 Fire Rock Wash–1966
25 Lybrook SE–1966
26 Mule Dam–1966
27 Deer Mesa–1966
28 Taylor Ranch–1963
29 Arroyo Chijuilla–1963

UTM GRID AND 1976 MAGNETIC NORTH DECLINATION AT CENTER OF MAP

SCALE 1:100 000

KILOMETERS

MILES

FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

NEW MEXICO

QUADRANGLE LOCATION

Moderate

Low

Very low for Morrison, Todilto, and Dakota Formations, Low for other rocks to 5,000 ft

LEGEND

Perennial stream, lake
Intermittent stream, lake
Village or locality
Landmark structure
Public park or recreation area
Forest or game land area
Other public area or Military or Indian reservation

ROAD CLASSIFICATION

Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Street or unimproved road
Trail
Interstate route
U.S. route
State route

CHACO CANYON, NEW MEXICO

SW/4 AZTEC (NJ 13-10) 1:250 000-SCALE MAP

N3600–W10700/30x60

1976

MAP 81 Mineral occurrences, prospects, mines, and resource potential for Chaco Canyon 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.

OF-232, 233
Map 84.

NAVAJO RESERVOIR, NEW MEXICO

30X60 MINUTE SERIES (TOPOGRAPHIC)

Well ● 123
Well ● 56
Well ● > 50
Well ● 20-50
Well ● 52
Well ● 51
Well ● 20-50
Well ● 56
Well ● 20-50
Well ● 56
Well ● 56
Well ● 70
Well ● 20-50
Well ● 56
Well ● 20-50
Well ● 20-50
Well ● 20-50
Well ● 42
Well ● 20-50
Well ● 47
Well ● 20-50
Well ● 48
Well ● 49
Well ● 49
Well ● 20-50
Well ● 67
Well ● 61
Well ● 57
Well ● 56
Well ● 49
Well ● 41
Well ● 89

Well
Spring
33 Temperature, °C
Very low

SCALE 1:100 000
1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 50 METERS

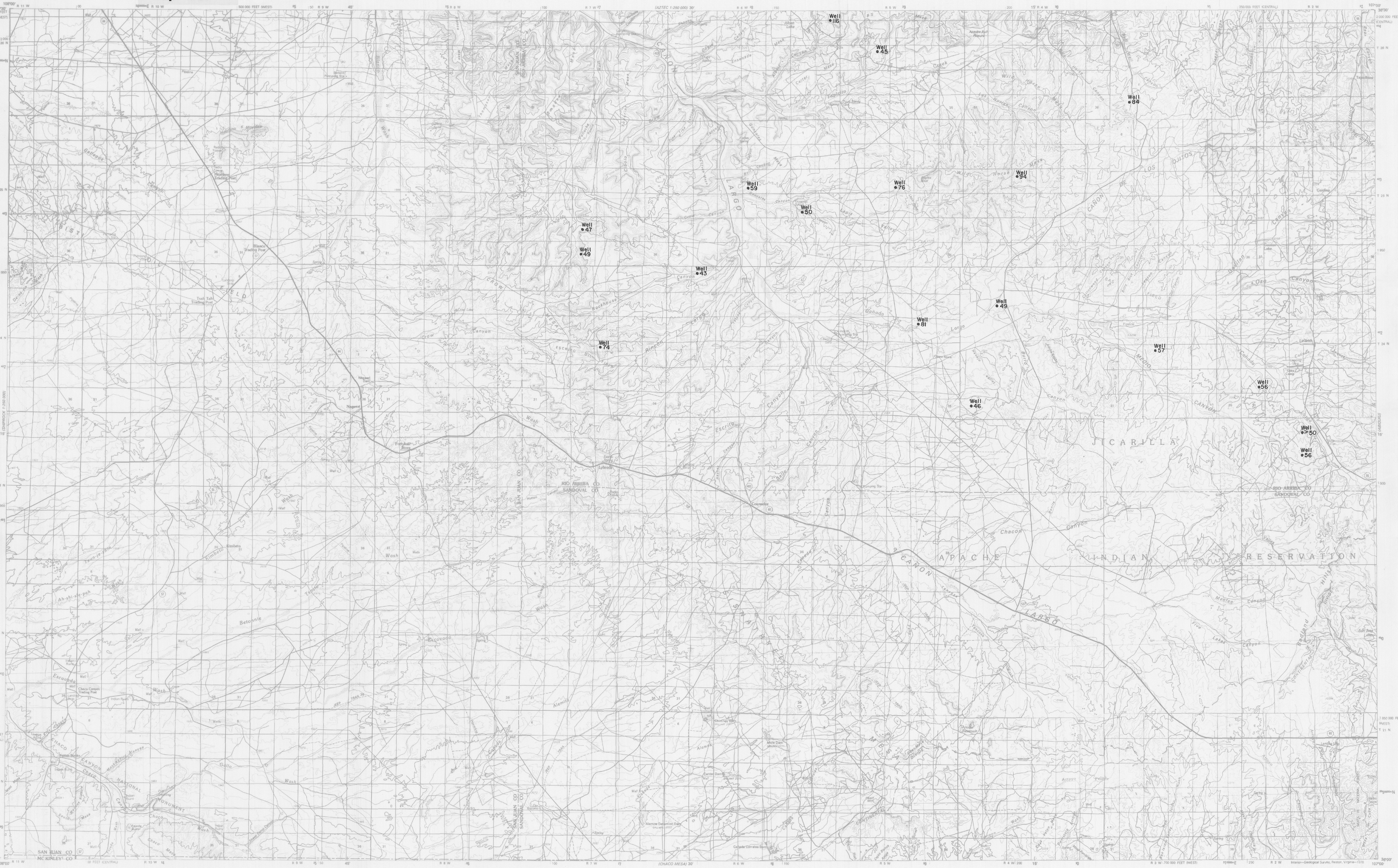
NAVAJO RESERVOIR, NEW MEXICO
N3630–W10700/30x60
1980

MAP 84 **Geothermal wells and resource potential in the Navajo Reservoir in the 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.**

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OF-232, 233
Map 85.

CHACO CANYON QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES



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INDEX TO 1:24 000 AND 1:62 500-SCALE MAPS

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22	23	24	25	26	27	28	29

1 Huerfano Trading Post NW–1966
2 Huerfano Trading Post–1967
3 Nageezi–1969
4 Gonzales Mesa–1963
5 Lapis Point–1963
6 Schmitz Ranch–1963
7 Ojito–1963
8 Huerfano Trading Post SW–1966
9 Blanco Trading Post–1966
10 Tahoe Canyon–1963
11 Otero Stone–1963
12 Billy Rock Canyon–1963
13 Lindrith–1963
14 Pueblo Bonito NW–1966
15 Kimberly–1967
16 Lybrook NW–1966
17 Lybrook–1966
18 Cousinsen–1966
19 Tinnicha Wash–1966
20 Five Lakes Canyon NW–1963
21 Five Lakes Canyon NE–1963
22 Pueblo Bonito–1966
23 Sargent Ranch–1966
24 Fire Rock Wash–1966
25 Lybrook SE–1966
26 Mule Dam–1966
27 Deer Mesa–1966
28 Taylor Ranch–1963
29 Armen Chuskite–1963

UTM GRID AND 1976 MAGNETIC NORTH DECLINATION AT CENTER OF MAP

SCALE 1:100 000

KILOMETERS

MILES

FEET

NATIONAL GEODETIC VERTICAL DATUM OF 1929

NEW MEXICO

QUADRANGLE LOCATION

Well
Spring
56 Temperature
Very low

LEGEND

Perennial stream, lake
Intermittent stream, lake
Village or locality
Landmark structure
Public park or recreation area
Forest or game land area
Other public area or Military or Indian reservation

ROAD CLASSIFICATION

Primary highway, hard surface
Secondary highway, hard surface
Light-duty road, hard or improved surface
Street or unimproved road
Trail
Interstate route
U.S. route
State route

CHACO CANYON, NEW MEXICO
SW/4 AZTEC (NJ 13-10) 1:250 000-SCALE MAP

N3600–W10700/30x60

1976

MAP 85 Geothermal wells and resource potential in the Chaco Canyon 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.

OF-232, 233
Map 88.

NAVAJO RESERVOIR, NEW MEXICO

30X60 MINUTE SERIES (TOPOGRAPHIC)

32N.11W.21
Pit 0845
Sand & Gravel

32N.9W.10.300
Pit 0868
Gravel

32N.8W.13.300
Pit 0858
Gravel

32N.6W.26.220
Pit 0670
Gravel

32N.2W.11.240
Pit 0671
Andesite

32N.2W.26.333
Pit 58137
Sand & Gravel

Alluvium and terrace deposits

31N.10W.5.320
Pit 5942
Sand & Gravel

31N.10W.4.300
Pit 5943
Gravel

31N.10W.29.100
Sand & Gravel
31N.10W.29.200
Sand & Gravel
31N.10W.30.340
Sand & Gravel
31N.11W.35.222
Pit 59110
Sand

31N.11W.23.130
Pit 0859
Gravel

31N.9W.30.210
Pit 0867
Gravel

31N.7W.32.110
Pit 0867
Gravel

30N.11W.1
Sand & Gravel
30N.11W.3.444
Pit 5940
Sand & Gravel
30N.11W.11.420
Spencerville Pit
Sand & Gravel
30N.11W.11.310
Pit 6207
Sand
30N.11W.10.422
Pit 5909
Sand

30N.8W.5.112
Pit 6453
Sand & Gravel

30N.8W.16.300
Pit 6544
Sand & Gravel

30N.8W.19.232
Pit 6410
Sand & Gravel

30N.8W.15.134
Pit 6453
Sand & Gravel

30N.7W.6.100
Pit 6449
Sand & Gravel

30N.7W.3.100
Gravel

30N.9W.18.312
Pit 0860
Diorite

30N.10W.22.311
Pit 6208
Materials pit

30N.9W.22.341
Pit 6209
Sand

30N.9W.25.120
Sand & Gravel

30N.8W.23.222
Pit 5870
Sand & Gravel

30N.8W.14.400
Sand & Gravel
30N.8W.15.420
Sand & Gravel
30N.8W.15.330
Sand & Gravel

30N.3W.12.400
Pit 7013

30N.2W.20.140
Pit 0672
Sand

30N.2W.22.140
Pit 5932
Sand

30N.3W.25.130
Pit 5860
Sand

30N.2W.30.412
Pit 5931
Monzonite

30N.3W.27.310
Pit 5859
Sand

29N.11W.26.330
Sand & Gravel

29N.11W.5.130
Sand & Gravel
29N.11W.11.100
Sand & Gravel

29N.10W.19.420
Sand & Gravel
29N.10W.20.310
Sand & Gravel
29N.10W.22.111
Pit 0862
Sand & Gravel

29N.9W.9.330
Sand & Gravel
29N.9W.17.220
Sand & Gravel
29N.9W.17.111
Sand & Gravel
29N.9W.8.310
Sand & Gravel
29N.9W.8.414
Pit 0863
Sand & Gravel
29N.10W.24.144
Sand & Gravel

29N.9W.35.214
Sand & Gravel
30N.9W.34.113
Sand & Gravel

29N.9W.9.400
Pit 0865
Sand & Gravel
29N.9W.17.130
Pit 57149
Sand & Gravel
29N.9W.19.233
Sand & Gravel

29N.9W.35.100
Sand & Gravel

29N.10W.23.440
Sand & Gravel
29N.10W.26.110
Sand & Gravel
29N.10W.35.230
Sand & Gravel
29N.10W.35.140
Sand & Gravel
29N.10W.27.200
Sand & Gravel
29N.9W.17.420
Sand & Gravel
29N.9W.17.300
Sand & Gravel

29N.10W.19.400
Sand & Gravel
29N.11W.26.110
Sand & Gravel
29N.11W.26.324
Sand & Gravel
29N.11W.27.310
Pit 5970
Sand & Gravel
29N.11W.28.430
McCoy Pit
Sand & Gravel
29N.11W.33.422
Pit 77-15-S
Sand & Gravel
29N.10W.31.300-400
Sand & Gravel
28N.11W.22.200
Sand & Gravel

28N.8W.6
Sand & Gravel

Alluvium and terrace deposits

28N.8W.17.330
Sand & Gravel

28N.11W.35
Pit 0865
Sand

27N.9W.12.141
Pit 0866
Sand & Gravel

27N.11W.26.340
Sand & Gravel

Eolian sand deposits

26N.10W.1.400
Sand & Gravel

29N.5W.18.300
Sandstone

29N.3N.20.200
Pit 6712
Sand & Sandstone

28N.3W.5.330
Pit 6713
Sandstone

EXPLANATION

- Materials pit, produced
- Pit, production unknown
- High
- Very low

SCALE 1:100 000
1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 50 METERS

NAVAJO RESERVOIR, NEW MEXICO
N3630—W10700/30x60
1980

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA

MAP 88 **Aggregate pits and resource potential in the Navajo Reservoir 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.**

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OF-232, 233
Map 89.

CHACO CANYON QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES

26N.10W.7.432
Pit 0818
Sand & Gravel

26N.10W.21.322
Pit 0819
Sand & Gravel

Quaternary eolian sand

Quaternary eolian sand

Quaternary terrace deposits

26N.9W.32.212
Pit 0814
Sand & Gravel

24N.9W.4.444
Pit 820
Materials pit

24N.7W.12.321
Pit 821
Sand & Gravel

Quaternary eolian sand

24N.8W.21.222
Pit 0815
Sand & Gravel

24N.8W.21.233
Sand & Gravel

Quaternary eolian sand

24N.9W.36.440
Sand & Gravel

23N.8W.1.233
Pit 817
Sand & Gravel

23N.8W.8.410
Sand & Gravel

Quaternary terrace deposits

Quaternary terrace deposits

Quaternary eolian sand

22N.10W.12.1
Pit 0816
Materials Pit

Quaternary eolian sand

Quaternary terrace deposits

Quaternary eolian sand

Quaternary terrace deposits

26N.3W.18
Pit 6503
Sand

26N.3W.13
Pit 0874
Lamprophyre

24N.4W.8
Pit 6122
Sand

24N.4W.33
Pit 6222
Sand

23N.4W.4
Pit 6121
Sand

Quaternary eolian sand

23N.2W.11
Pit 5972
Sand

JICARILLA APACHE INDIAN RESERVATION

LARGO CANYON

Chacon Canyon

Escrito Canyon

Oso Canyon

Mesita Canyon

Rincon Canyon

Crow Canyon

Rockhouse Canyon

Tsaile Trail Spring Pond

Nahodoi Dam

Ah-shi-sle-pah Wash

Excavada Wash

Alemito Wash

Cañada Córrales Dam

Arroyo Peñasco

Arroyo Pelado

Chacon Creek

Escrito Creek

Mesita Creek

Oso Creek

Largo Creek

Rincon Creek

Crow Creek

Rockhouse Creek

Nahodoi Creek

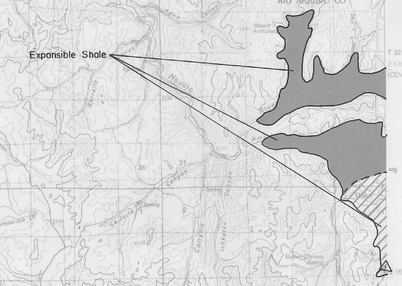
Excavada Wash

Alemito Wash

OF-232, 233
Map 92.

NAVAJO RESERVOIR, NEW MEXICO

30X60 MINUTE SERIES (TOPOGRAPHIC)



SCALE 1:100 000
1 CENTIMETER ON THE MAP REPRESENTS 1 KILOMETER ON THE GROUND
CONTOUR INTERVAL 50 METERS

High
Very low
Unknown

NAVAJO RESERVOIR, NEW MEXICO
N3630–W10700/30x60
1980

MAP 92 Resource potential for crushed and dimension stone, mica, and silica sand in the Navajo Reservoir 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

OF-232, 233
Map 93.

CHACO CANYON QUADRANGLE
NEW MEXICO
1:100 000-SCALE SERIES


Expansible Shale
CHACO CANYON NATIONAL MONUMENT
APACHE INDIAN RESERVATION
JICARILLA
RIO ARRIBA CO
SANDOVAL CO
SAN JUAN CO
RIO ARRIBA CO
SANDOVAL CO
CANON LARGO
CANYON DE LOS OJOS
Chaco Canyon Trading Post
Nageezi
Bisti Trading Post
Pueblo Bonito
Pueblo Alto
Penasco Blanco
Kin Kletso
Casa Chiquita
Una Vida
Hungo Pavi
Chetro Ketl
Wijiji
Kin Bineola
Peñasco Tieso
Kin Ya'a
Kin Nizhoni
Kin Ya'a Trading Post
Kin Ya'a Mesa
Kin Ya'a Wash
Kin Ya'a Canyon

NAVAJO RESERVOIR, NEW MEXICO **OF-232, 233** **Map 96.**

30X60 MINUTE SERIES (TOPOGRAPHIC)

Mica, very low for silica

Mica, unknown for silica

Silica

Silica

Note: There is a high resource potential for crushed stone covering the entire county. There is a moderate resource potential for dimension stone covering entire county unless otherwise indicated.

Note: There is a high resource potential for crushed stone covering entire study area of county. There is a moderate resource potential for dimension stone covering entire study area of the county.

Low

Unknown

SCALE 1:100 000

CONTOUR INTERVAL 50 METERS

NAVAJO RESERVOIR, NEW MEXICO
N3630–W10700/30x60
1980

MAP 96 **Resource potential for lightweight aggregate and limestone in the Navajo Reservoir 30- by 60-minute topographic quadrangle, San Juan and Rio Arriba Counties, New Mexico.**