A Preliminary Mineral-Resource Potential of Northwestern New Mexico; Introduction

McLemore and others

New Mexico Bureau of Mines and Mineral Resources
Open-file Report 228

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PREFACE

During the spring of 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 pepare 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 first of six reports describing the geology and mineral-resource potential of northwestern New Mexico. This first report is divided into two parts. Part I describes the methodology and classification involved in evaluating the mineral-resource potential. Part II is an executive summary of the mineral resource potential of each county. The preceding five reports, Open-file Reports 229-233 are detailed reports of the mineral-resource potential of each 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These reports are based upon time-consuming analyses of all available data, published and unpublished, by a group of geologists and technical support staff.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 as detailed in the acknowledgments of each report.

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Methodology of Assessing Mineral-Resource Potential

(by Virginia T. McLemore)

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, conveyance of land, or 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 geological, geochemical,geophysical, and economic data and brief field reconnaissance. A more rigorous and complete analysis of all available information and additional field work could expand

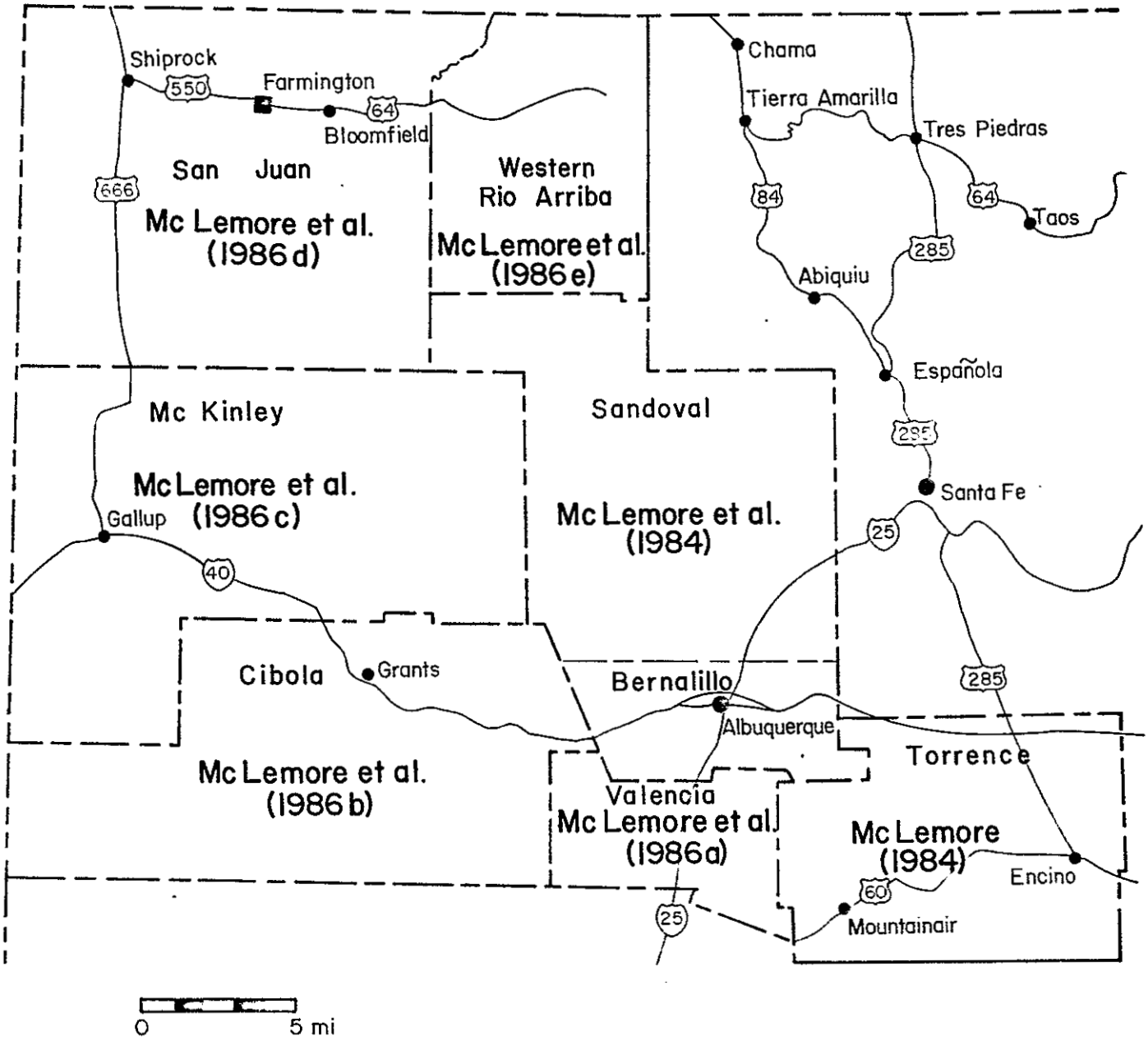

Figure 1 – Areas assessed by New Mexico Bureau of Mines and Mineral Resources

the preliminary conclusions of this paper.

Organization of Present Study

The present study involves a mineral-resource assessment of Valencia, Cibola, McKinley, San Juan, and western Rio Arriba Counties and is divided into six reports; an introduction (this report) and five detailed assessments for each county (Fig. 1; McLemore et al., 1986a, b, c, d, e). However, only one set of maps at a scale of 1:100,000 is included even though 1:100,000-scale maps may cover more than one county (Fig. 2). Table 1 lists the oversized maps.

This introductory report is divided into two parts. Part I describes the methodology and classification of mineral-resource potential. Part II is an executive summary of the mineral-resource potential of each county.

Each detailed county assessment (McLemore et al., 1986a, b, c, d, e) includes a text, appendices, and supporting figures and tables. The text includes a discussion of geology, production, known mineral occurrences and deposit types, and the mineral-resource and development potential for each commodity. Mineral occurrences and the mineral-resource potential are plotted on 1:100,000-scale maps (Table 1) and summarized on page-size figures. Mineral occurrences, prospects, mines, and deposits are individually described in an appendix. Petroleum tests are plotted and tabulated.

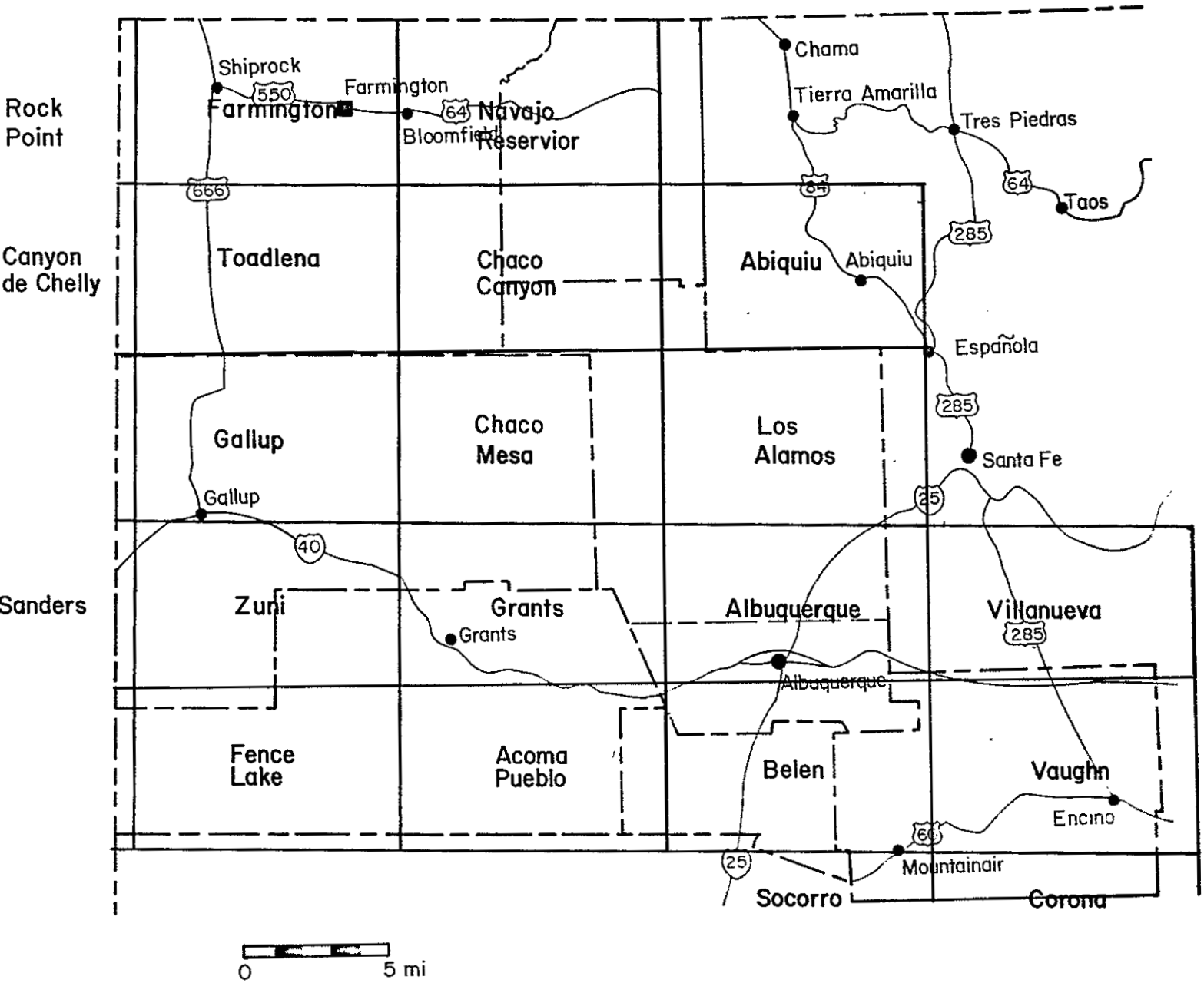

FIGURE 2 - Index to 1:100,000 scale topographic maps covering northwestern New Mexico.

Table 1 - 1:100,000-scale maps included in mineral resource potential of northwestern New Mexico.

Map No.	Map Title	Corresponding Open-file Reports
1	Mineral occurrence and resource potential for metals and uranium in the Socorro 30- by 60-minute topographic quadrangle, Valencia County, New Mexico.	229
2	Mineral occurrence and resource potential for metals and uranium in the Belen 30- by 60-minute topographic quadrangle, Valencia County, New Mexico.	229
3	Mineral occurrences, prospects, mines, and resource potential for metals and uranium in the Acoma Pueblo 30- by 60-minute topographic quadrangle, Valencia and Cibola Counties, New Mexico.	229, 230
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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 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 explored 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 currently producing, a useful mineral or material.

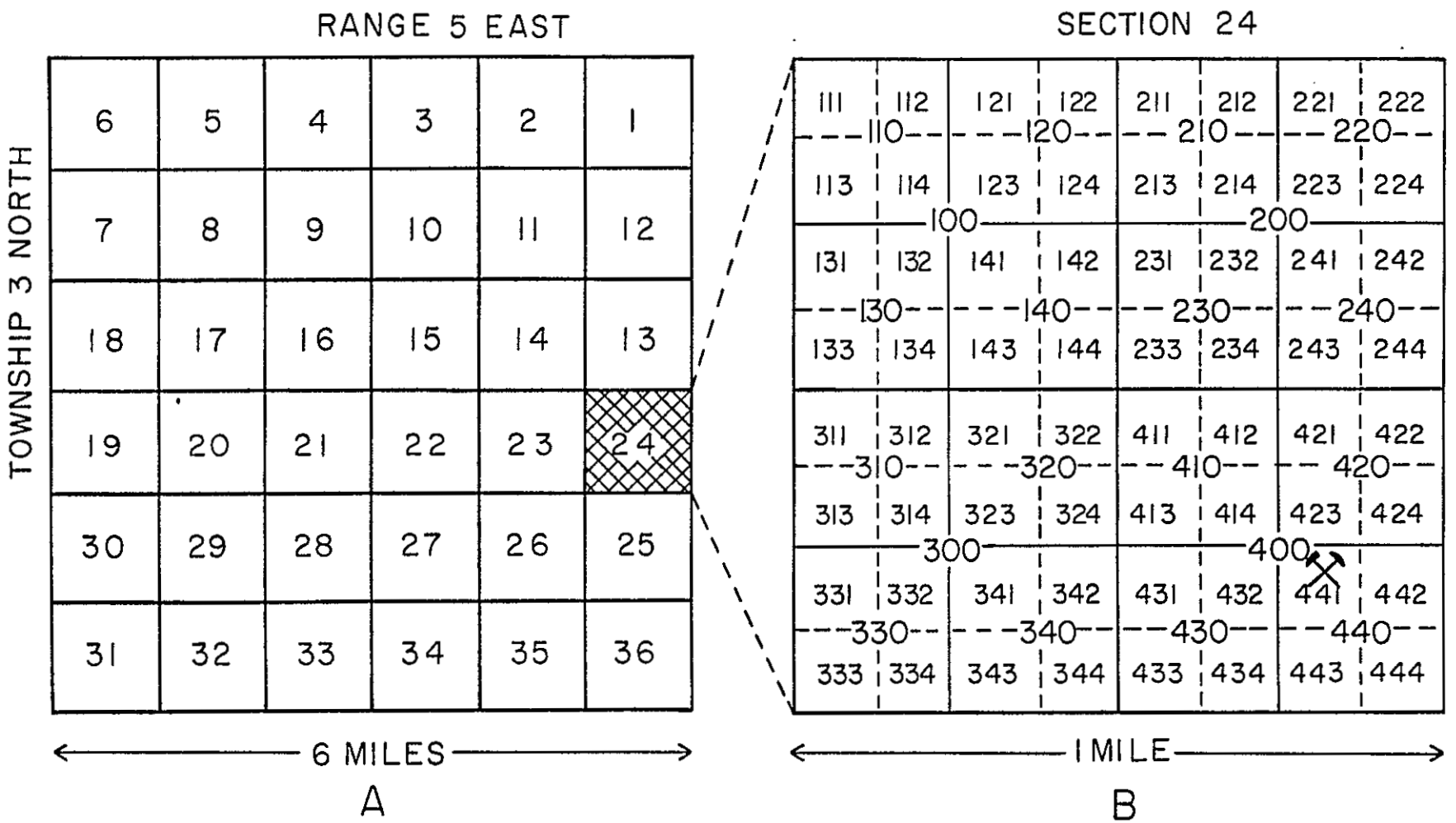
The mineral-resource potential of an area is the likelihood or probability that a mineral will occur in sufficient quantities so that it can be extracted economically under current or future conditions (Taylor and Steven, 1983). Mineral-resource potential is preferred in describing an area whereas mineral-resource 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.

Numbering System

The numbering system used in this report is based upon the township, range, and section land-grid system (Fig. 3) and is used by the New Mexico State Engineer for numbering water wells and springs. In this system, each occurrence or sample location has a unique location number consisting of four parts separated by periods (i.e. 3N.5E.24.441). The first part refers to the township, the second part to the range, and the third part to the section. The fourth part locates the occurrence to the nearest quarter-quarter-quarter section block, if posible, as indicated in Figure 3. An occurrence or sample number designated 3N.5E.24.441 is located in the NW1/4 SE1/4 SE1/4 of section 24, T3N, R5E. Some occurrences are located only to the nearest section, quarter-section, or quarter-quarter section because the occurrence can not be more accurately located or the occurrence extends over the entire given area. In unsurveyed areas, the locations are approximated by projecting section lines.

Figure 3— 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.



EVALUATION PROCESS AND SOURCES OF INFORMATION

Introduction

The evaluation of mineral-resource potential involves a complex process of geologic analogy of prominsing or favorable geologic environments with geologic settings (i.e. models) that contain known economic deposits. Such subjective assessments or evaluations depend on the available information concerning the area to be evaluated and on the current knowledge and understanding of known economic deposits. Assessments of resource potential depend upon the knowledge and experience of the researchers, therefore these evauations are assessed by a team of NMBMMR geologists who specialize in specific commodities and are subsequently reviewed by additional commodity specialists. Evaluations of resource potential are time-dependent because the data base, technology, and economic conditions change with time. The date of resource potential studies must be given and these studies must be periodically updated.

Assessment Procedures

The process of evaluating the mineral-resource potential used currently by the NMBMMR is similar to that used by the U.S. Geological Survey (Shawe, 1981; Goudarzi, 1984) and Oak Ridge National Laboratory (Voelker et al., 1979). However, only minimal field investigation is incorporated into these studies because of time constraints imposed upon the NMBMMR by the BLM.

1. The most important stage in any geologic investigation and especially in these evaluations is the compilation of all

available published and unpublished data. A complete bibliographic search of published geologic references is essential. Bibliographies used are listed in Table 2. A geologic index to mapping is helpful and included in each report. Evaluation of the resource potential involves complex integration and interpretation of several data sets maintained by various state and federal agencies, including a) MRDS (Mineral Resources Data Systems, formerly CRIB, Computerized Resource Information Bank, and MILS (Mineral Industry Location System); b) DMEA (Defense Minerals Exploration Administration); c) NURE (National Uranium Resource Evaluation), HSSR (Hydrogeochemical and Stream-sediment Reconnaissance) and ARMS (Aerial Radiometric and Magnetic Survey); d) NCRDS (National Coal Resource Data System); e) AML (Abandoned Mine Lands); and f) various unpublished file data from state and federal agencies (NMBMMR, State Inspector of Mines, State Highway Department, BLM, U.S. Bureau of Mines, U.S. Department of Energy). From published and unpublished data sets known mineral occurrences, prospects, mines, and deposits and oil and gas tests are identified and plotted on maps. Geochemical and geophysical anomalies are described and identified.

2. Known deposit types are identified and favorable geologic environments that may contain potential economic resources are defined. Geologic models are developed. All types of metallic, nonmetallic, and energy fuel deposits are examined. Field examinations, when time permits, are valuable.

3. A preliminary evaluation of the mineral-resource potential from available data is determined. A number of factors must be evaluated, including a) host rock favorability, b)

Table 2 - Bibliographies and geologic map indices.

Bibliography	Comments
Burks and Schilling (1955)	general bibliography covering through 1950
Schilling and Schilling (1956)	general bibliography covering 1951-1955
Schilling and Schilling (1961)	general bibliography covering 1956-1960
Ray (1966)	general bibliography covering 1961-1965
Koehn and Koehn (1973)	general bibliography covering 1966-1970
Wright and Russell (1977)	general bibliography covering 1971-1975
Heljeson and Holts (1981)	general bibliography covering through 1975
Adkins-Heljeson and Holts (1984)	general bibliography covering 1976-1980
Robertson (1976)	bibliography of Precambrian geology
Schilling (1975)	bibliography of Grants uranium region
McLemore (1982, 1983)	bibliography of uranium in New Mexico
Kirk et al. (1983)	bibliography of M.S. thesis and Ph.D. dissertations
Boardman and Brown (1958)	geologic map index
McIntosh and Morgan (1970)	geologic map index
McIntosh and Eister (1979)	geologic map index
New Mexico Bureau of Mines and Mineral Resources Price Lists	publications and open-file reports
Various listings of M.S. thesis and Ph.D. dissertations from Universities	

structural controls, c) evidence of mineralization, d) previous mining and production, e) geochemical and/or geophysical anomalies, f) regional geologic setting, g) time of mineralization, h) alteration, i) mineralogy, j) processes affecting mineralization since formation, and k) geologic

history. Reports are written describing known deposit types, assessing the resouce potential, and explaining how conclusions were reached.

4. Recommendations for additional studies and types of data required for better assessments are made.

The evaluation of the preliminary mineral-resource potential should be followed by field investigations and more detailed mapping, geochemical sampling, and geophysical studies. A final assessment should be made based on detailed field investigations. However, these detailed studies are not included under the cooperative agreement between the BLM and NMBMMR.

Repeated evaluation of the mineral-resource potential is required. New data on the study area should be incorporated into the data base. New geologic concepts and models and more sophisticated exploration techniques could drastically alter the assessments. New technologies that require different commodities and changes in mining, milling, and processing could allow exploration and development of lower-grade or new types of deposits. Political and economic conditions change rapidly and can transform today's mineral curiosity into tomorrow's mineral deposit. Therefore, mineral-resource potential assessments must be revised periodically and updated on a timely basis.

CLASSIFICATION OF MINERAL-RESOURCE POTENTIAL

Classification of mineral-resource potential differ from classification of the mineral resources. Quantities of mineral resources are classified according to availability of geologic data (geologic assurance), economic feasibility (identified or undiscovered), and as economic or subeconomic (Fig. 4). Mineral-resource potential is a qualitative judgment of the probability of the existence of a commodity.

Classification of mineral-resource potential varies from simple subjective schemes, like that used currently by NMBMMR, to complex quantitative and statistical methods (Harris and Euresty, 1969; Harris, 1969; Harris and Agterberg, 1981). However, it is rare that an adequate data base for all commodities is available for complex statistical treatment, especially for preliminary assessments. Furthermore, a simple classification scheme is more versatile for uses such as land-use planning and exploration for new deposits. The potential is classified for the purposes of this report according to availability of geologic data and relative probability of occurrence as high, moderate, low, very low, or unknow (Fig. 5).

High mineral-resource potential is assigned to areas where there are known mines or deposits or where the geological, geochemical, or geophysical data indicate an excellent probability that mineral deposits occur. All acitve and producing properties fall into this class as well as identified deposits in known mining districts or in known areas of mineralization. Speculative deposits, such as reasonable

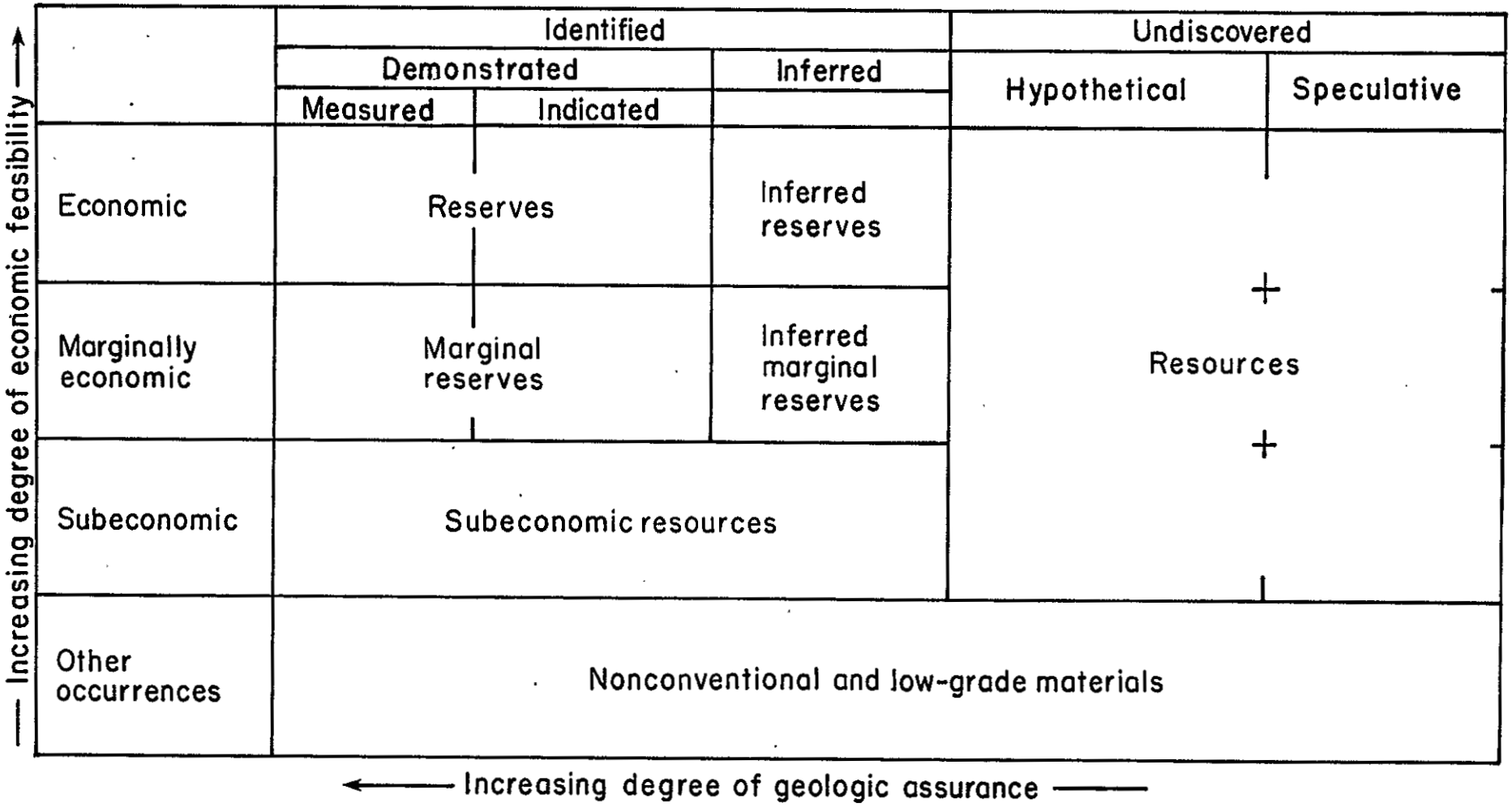


Figure 4. Classification of mineral resources

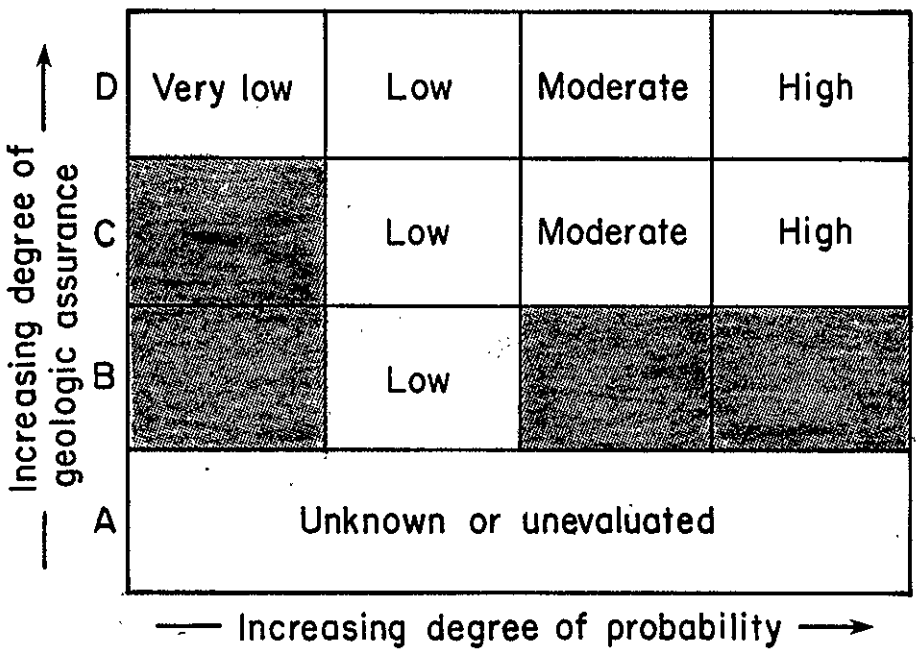


Figure 5. Classification of mineral-resource potential

extensions of known mining districts and identified deposits or partially known deposits within geologic trends or areas of mineralization, are classified as high mineral-resource potential where sufficient data indicates a high probability of occurrence. Information, such as quantity, quality, grade, past and present production, depth to deposit, and reserves, is important although not always essential, in determining that an area has a high potential. Exploration may be in progress or expected to occur within 10 years.

Moderate mineral-resource potential exists in areas where geologic, geochemical, or geophysical data suggest a reasonable possibility that undiscovered deposits occur in formations or geologic settings elsewhere. Speculative deposits in known mining districts or mineralized areas are assigned a moderate potential if evidence for a high potential of economic deposits is inconclusive. This assessment, like other classifications, can be revised when new information, new genetic models, or changes in economic conditions develop.

Low mineral-resource potential exists in areas where available data imply the occurrence of mineralization, but indicate a low probability for the occurrence of a deposit. This includes speculative deposits in areas of geologic environments or settings not known to contain economic deposits, but which are similar to environments or settings of known economic deposits. Additional geologic data may be needed to classify better such areas.

A classification of very low mineral-resource potential is reserved for areas where sufficient information indicates that an

area is unfavorable for economic deposits. This evaluation may include areas with dispersed but uneconomic mineral occurrences as well as areas that have been depleted of their mineral resources. Use of the very low potential classification requires a high level of geologic assurance to support such an evaluation. Very low mineral-resource potential is assumed for potential deposits that are too deep to be extracted economically, even though there may not be a high level of geologic assurance. These "economic" depths vary according to the commodity and current and future economic conditions.

A classification of unknown mineral-resource potential is reserved for areas where necessary geological, geochemical, and geophysical data are inadequate to otherwise classify an area. This assessment is low and any other classification (high, moderate, low, or very low) would be misleading. These areas should receive high proximity 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 possibility of the occurrence of resources.

This classification scheme is similar to that used by Brobst and Goudarzi (1984) where a high mineral-resource potential

corresponds to substantiated resource potential and a moderate potential corresponds to a probable resource potential. Goudarzi (1984) of the U.S. Geological Survey proposes a similar classification scheme to the one used in this report.

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.

Part II

Summary of the mineral-resource potential

by Virginia T. McLemore

An Executive Summary of

A Preliminary Mineral-Resource Potential of Valencia County, Northwestern New Mexico

by

Virginia T. McLemore,
Ronald F. Broadhead,
James M. Barker,
George S. Austin,
Kris Klein,
Karen B. Brown,
Diane Murray,
Mark R. Bowie,
and John S. Hingtgen

New Mexico Bureau of Mines and Mineral Resources
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Prepared in cooperation with
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Bureau of Land Management

ABSTRACT

A preliminary mineral-resource potential assessment of Valencia County involves analyses of available published and unpublished geologic, geochemical, geophysical, and economic data and a brief field 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, and unknown is used. 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.

Travertine deposits along the Lucero uplift in western Valencia County are currently being mined for dimension stone and have a high resource potential. Products include 2-inch sheets and 8-inch slabs. Additional travertine deposits may occur along

the Hubbell bench where the resource potential is low. The potential for travertine as crushed stone is also high.

High potential also exists for sand and gravel deposits in Quaternary-Tertiary deposits. Resources in the Rio Puerco drainage system, central Rio Grande valley, and terraces in eastern Valencia County are extensive. Material for adobe also has a high-resource potential in these areas.

Crushed and dimension stone resources occur in Precambrian rocks and Paleozoic sandstones and limestones in the Manzano Mountains, where the resource potential is high. Limestone for cement occurs in the Pennsylvanian Madera Formation in the southern Manzano Mountains where the resource potential is high. Travertine from the Lucero uplift also could be used in cement.

Moderate potential exists for (1) Cu-Au-Ag ($\pm$ U, Pb) in Precambrian rocks in the Manzano Mountains, (2) gypsum in the Permian Yeso and San Andres Formations in the Lucero uplift, (3) scoria and cinders in the Cat Hills area in northern Valencia County, (4) silica sand in Precambrian quartzites in the Manzano Mountains, and (5) petroleum accumulations in Paleozoic and Mesozoic reservoirs in the Albuquerque Basin.

Additional geologic mapping and geochemical studies are suggested in areas with active claims, in the Lucero uplift and Manzano Mountains, and in areas with unknown resource potential. Aggregate resources should be mapped and sampled in greater detail prior to extraction. Isopach facies and structure contour maps of several formations in the Rio Grande valley in central Valencia County should be completed to delineate favorable areas for oil and gas accumulations.

SUMMARY

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

The mineral-resource potentials for various commodities in Valencia County are summarized in Table 15 and Figures 11, 15, 16, 17, 18, 19, 21, and 24. The most important commodity in Valencia County is travertine used for dimension stone in the Lucero uplift. High potential also exists for sand and gravel, limestone, adobe material, and crushed and dimension stone. Moderate potential exists for Cu-Au-Ag (±U, Pb) in Precambrian rocks, gypsum, scoria and cinders, silica sand, zeolites, and petroleum. Additional work is necessary to calculate reserves and resources in these areas.

TABLE 3 - Summary of mineral-resource potential in Valencia County (after McLemore et al., 1986a).

Commodity or type of deposit	Formation	Geographic location	Mineral-resource potential
Cu-Au-Ag (± U, Pb)	Precambrian greenstones or metasedimentary rocks	Hell Canyon district Manzano Mountains	moderate unknown
Placer Au	Quaternary or Tertiary gravels	Manzano Mountains, Albuquerque Basin	unknown
Stratabound sedimentary Cu-U deposits (± Ag)	Permian and Pennsylvanian sedimentary rocks	Scholle district	moderate to low
	Permian and Triassic sedimentary rocks	Rio Puerco district	low
Barite and fluorite	—	Valencia County	low
Adobe	Quaternary deposits	Valencia County	high
Crushed and dimension stone	Precambrian rocks Permian Abo Formation, Pennsylvanian Wild Cow and Bursum Formations	Various localities in in Manzano Mountains and Lucero uplift	high to moderate
Gypsum	Permian Yeso and San Andres Formations	Lucero uplift	moderate
Kyanite	Precambrian White Ridge quartzite and Sevilleta Formation	Manzano Mountains	low
Lightweight aggregate	Tertiary scoria and cinders	Cat Hills	moderate
		Manzano Mountains	moderate
	Paleozoic and Cretaceous shales (expansible)	Lucero uplift and Manzano Mountains	unknown
Limestone and travertine	Paleozoic limestones and Quaternary travertines	Lucero uplift and southern Manzano Mountains	high
Mica	Precambrian rocks	Manzano Mountains	low
Sand and gravel	Quaternary and Tertiary deposits	Valencia County	high
Silica sand	Permian Glorieta Sandstone Member	Lucero uplift	unknown
	Precambrian Sais Quartzite	Manzano Mountains	moderate
Zeolites	Tertiary-Quaternary Santa Fe Group	Albuquerque Basin	low
Petroleum	Paleozoic and Mesozoic sedimentary rocks	Albuquerque Basin, Rio Puerco Fault zone	moderate
Geothermal	—	Lucero uplift	moderate to low
Coal	Cretaceous rocks	Rio Puerco field	low

RECOMMENDATIONS

1) Detailed geologic mapping and geochemical studies in Precambrian terranes in the Manzano Mountains are needed to determine the mineral-resource potential for base- and precious-metals and uranium.
2) Isopach facies and structure-contour maps of several formations in the Rio Grande valley in central Valencia County should be completed in order to delineate favorable areas for oil and gas accumulations.
3) Aggregate resources should be mapped and sampled in greater detail prior to extraction of such materials.
4) Any areas with active claims should be examined (Fig. 10).
5) Geologic mapping and geochemical studies are required on the Luerco uplift to evaluate the resource potential.
6) Area near the Manzano Mountains should be examined for geothermal resource potential.
7) Drilling is required in the Rio Puerco coal field in northwestern Valencia County to aid in evaluating the coal resource potential.
8) The rating of unknown for vermiculite and expansible shale does not imply that the potential is low. Rather, the appropriate rock types are present but need to be examined in more detail specifically for these resources.

An Executive Summary of

A Preliminary Mineral-Resource Potential of Cibola County, Northwestern New Mexico

by

Virginia T. McLemore,
Ronald F. Broadhead,
Gretchen Roybal,
William L. Chenoweth,
James M. Barker,
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Uranium is currently being mined from the Morrison Formation at Mt. Taylor mine, although economic conditions are unsettled for U.S. uranium producers. The uranium resource-potential is high in the Morrison and Todilto Formations in the Grants

district and could be mined if economic conditions improve. Coal resource potential is high in the Salt Lake field. The Salt River Project of Arizona plans to mine coal just south of Cibola County in the near future. Petroleum resource potential is moderate in the Puerco fault zone and Acoma and Zuni Basins.

The resource potential for base- and precious-metals, fluorite, and barite is moderate in Precambrian rocks in the Zuni Mountains. Various units throughout the county have a high resource potential locally for clays, crushed and dimension stone, gemstones (small quantities), limestone, and travertine. Pumice, scoria, and perlite have a high resource potential in the Mt. Taylor area.

Additional geologic mapping and geochemical studies are suggested in areas with active claims, in the Lucero uplift and Zuni Mountains. Exploration drilling and sampling of fluorspar veins in the Zuni Mountains is required to properly assess their potential. Aggregate resources should be mapped and sampled prior to extraction. The rhyolites near Mt. Taylor should be examined for tin potential.

SUMMARY

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

The mineral-resource potential for various commodities in Cibola County are summarized in Table 30 and Figures 18, 20, 22, 26, 28, 29, 30, 31, and 32. The most important commodities in the county are coal and uranium. Additional work is necessary to calculate reserves and resources of these commodities in areas of high potential.

TABLE 4 - Summary of mineral-resource potential in Cibola County (after McLemore et al., 1986b).

Commodity	Geologic Formation	Geographic Area	Mineral-resource potential
Uranium (± vanadium, molybdenum)	Morrison Formation Todilto Limestone	Grants district	high to moderate
Coal	Cretaceous units	East Mt. Taylor field South Mt. Taylor field Datil Mts. field Salt Lake field Zuni field	moderate to low moderate to low low high to moderate low
Petroleum	Pennsylvanian rocks Pennsylvanian-Cretaceous rocks Pennsylvanian-Cretaceous rocks Permian rocks Permian-Cretaceous rocks	Lucero uplift Puerco fault zone Acoma Basin Zuni uplift Baca Basin	low moderate moderate low to very low moderate to low
Geothermal	various host rocks	Lucero uplift western Cibola Co., Zuni Mts. Mt. Taylor	moderate to low low unknown
Base- and precious-metals, fluorite, barite Cu, Au, Ag, U, V Cu, Au, Ag, U, V Tin Clays	Precambrian rocks Permian sandstones Permian and Triassic sandstones Tertiary volcanics fluvial units sandy loam deposits (adobe)	Zuni Mts. Zuni Mts. Rio Puerco district Mt. Taylor — —	moderate low low unknown high locally high locally
Crushed and dimension stone	Precambrian to Quaternary units	throughout the county	moderate
Gemstones	various units	throughout the county	locally high for small quantities
Gypsum	Todilto Formation Yeso Formation	Laguna-Suwanee Lucero uplift Zuni Mts.	moderate moderate low
Pumice, scoria, and perlite	Tertiary volcanics and flows	Mt. Taylor area	high to moderate
Scoria	Tertiary volcanic flows	Zuni Mts. area	high to moderate
Limestone	Madera Group Todilto Formation San Andres Formation	Sierra Lucero Arroyo Colorado, Grants/Wingate Zuni Mts., Ojo Caliente	high moderate high
Sand and gravel	various	—	low to moderate
Travertine	Quaternary deposits	Ojo Caliente, Salado Spring, Mesa del Oro, Malpais Steptoe, Chicken Mt.	high moderate

RECOMMENDATIONS

1) Any areas with active claims should be examined (Fig. 15).
2) Isopach facies and structure-contour maps of several formations in Cibola County should be completed to delineate favorable areas for oil and gas accumulations.
3) Aggregate resources should be mapped and sampled in greater detail prior to extraction of such materials.
4) Geologic mapping and geochemical studies are required in the Lucero uplift and in the northern and central Zuni Mountains to evaluate the mineral resource potential.
5) Sample fluorspar veins for silver and gold content.
6) Examine rhyolites near Mt. Taylor for tin potential.
7) Chemical sampling of the Glorieta Sandstone Member and other high-silica sandstones is required to determine the potential for high-silica sand resources.
8) Detailed studies of the mineralogy and chemistry of clay deposits are required to assess their potential.
9) Geochemical and geophysical studies of the Mt. Taylor area are required to assess the geothermal-resource potential.
10) Exploration drilling and sampling of fluorspar veins in Zuni Mountains are required to determine depth and extent of the deposits.
11) Examine outcrops of the Yeso Formation for manganese resources.
12) Exploration and testing of expansible shale and vermiculite regions rated unknown are needed to delineate any ores.

An Executive Summary of

A Preliminary Mineral-Resource Potential of McKinley County, Northwestern New Mexico

by

Virginia T. McLemore,
Gretchen Roybal,
Kim Birdsall,
Ronald F. Broadhead,
William L. Chenoweth,
Robert M. North,
James M. Barker,
Peter Copeland,
Mark R. Bowie,
John S. Hingtgen,
Karen B. Brown,
and Kris Klein

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United States Department of Interior
Bureau of Land Management

ABSTRACT

A preliminary mineral-resource potential assessment of McKinley 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.

Energy resources are the most important commodities in McKinley County, although other commodities have been produced. Coal is currently being produced and has a high potential in the Star Lake, San Mateo, Crownpoint, and Gallup fields. Oil and gas

production is substantial from the San Juan Basin in McKinley County and the resource potential is high in several formations in the San Juan and Acoma Basins. Uranium is currently being mined from the Morrison Formation at the Section 23 mine (Homestake), although economic conditions are unsettled for U.S. uranium producers. The uranium resource-potential is high in the Morrison and Todilto Formations in the Grants district and could be mined if economic conditions improve.

Various units throughout the county have a high resource potential locally for clays, crushed and dimension stone, silica sand, gemstones (small quantities), limestone, and humate. Many of these commodities are needed to support production of the energy resources. The resource-potential for CO_2 and helium in the Acoma and San Juan Basins, Gallup sag, and Defiance uplift is moderate. The resource potential for base- and precious-metals, fluorite, and barite is unknown in Precambrian rocks in the northern Zuni Mountains.

Additional geologic mapping and geochemical studies are required in areas with active claims and in the northern Zuni Mountains. Isopach facies and structure-contour maps of several formations in Cibola County should be completed to delineate favorable areas for oil and gas accumulations. Aggregate resources should be mapped and sampled prior to extraction. The rhyolites near Mt. Taylor should be examined for tin potential. Detailed studies of the mineralogy and chemistry of clays and silica sand resources are needed to fully evaluate these resources.

SUMMARY

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

The mineral-resource potential for various commodities in McKinley County are summarized in Table 30 and Figures 17, 20, 22, 24, 26, 30, 31, 32, 33, 35, and 36. The most important commodities are petroleum, coal, and uranium. Aggregate resources, limestone, clays, 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 5 - Summary of mineral-resource potential in McKinley County (after McLemore et al., 1986c).

COMMODITY	GEOLOGIC FORMATION	GEOLOGIC AREA	MINERAL-RESOURCE POTENTIAL
Coal	Fruitland Formation	Star Lake field	high
	Menefee Formation	Chaco Canyon field	low to moderate
		Chacra Mesa field	low
		San Mateo field	high
		Standing Rock field	moderate
	Crevasse Canyon Formation	Crownpoint field	high to moderate
		Gallup field	high
		Zuni field	low to high
Petroleum	Upper Cretaceous sandstones, Entrada Sandstone	San Juan and Acoma Basins	moderate to high moderate to low
	Cretaceous, Jurassic, Permian, Pennsylvanian	Gallup sag	moderate to low
	none	Zuni uplift	low to very low
	Permian and Pennsylvanian	Defiance uplift	low
Uranium (+vanadium, ±molybdenum)	Morrison, Dakota, and Todilto	Grants district	high to moderate
Base and precious metals, barite, fluorite	Precambrian veins	Zuni Mountains	unknown
Iron	Paleozoic limestone	Zuni Mountains	low
Tin, beryl	Tertiary volcanics	Mt. Taylor	unknown
CO_2, He	Paleozoic and Mesozoic units	San Juan and Acoma Basins	moderate
	Paleozoic and Mesozoic units	Gallup sag	moderate
	Paleozoic and Mesozoic units	Defiance uplift	moderate
Clays	Mesozoic units	entire county	moderate to high
	Cretaceous units	northern and western McKinley County	high
	recent stream beds	---	moderate
Crushed and Dimension stone	various units	---	moderate to high
Gemstones	Kimberlite tuffs	Navajo Reservation	moderate to high
Gypsum	Permian rocks	Zuni Mountains	low
Humate	Cretaceous coal-bearing units	coal fields	moderate to high
Pumice	Tertiary tuffs	Zilditloi Mountain T20N, R21W	moderate
Scoria and cinders	Tertiary volcanics	Malpais	moderate
		Zilditloi Mountains	moderate
Expansible shale	various units	---	unknown
Limestone	San Andres Formation	Zuni Mountains	high
	Todilto Limestone	Todilto Park, Wingate-Grants	moderate
Sand and gravel	various Quaternary units	scattered throughout county	high
Silica sand	various units	---	low to high
Zeolites	Bidahochi Formation	bootheel area	unknown
	Brushy Basin Member	Chuska Mountains	unknown

RECOMMENDATIONS

1) Geologic mapping is required in the Zuni Mountains area to determine the mineral resource potential.
2) Any areas with active claims should be examined (Fig. 12).
3) Isopach facies and structure-contour maps of several formations in McKinley County should be completed to delineate favorable areas for oil and gas accumulations.
4) Aggregate resources should be mapped and sampled in greater detail prior to extraction of such materials.
5) Examine rhyolites near Mt. Taylor for tin potential.
6) Chemical sampling of high silica sandstones is required to determine the potential for high-silica sand resources.
7) Detailed studies of the mineralogy and chemistry of clay deposits are required to assess their potential.

An executive Summary of

A Preliminary Mineral-Resource Potential of San Juan County, Northwestern New Mexico

by

Virginia T. McLemore,
Ronald F. Broadhead,
Kevin Cook,
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Gretchen Roybal,
Robert M. North,
Peter Copeland,
Mark R. Bowie,
John S. Hingtgen,
Kris Klein,
and Karen B. Brown

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United States Department of Interior
Bureau of Land Management

ABSTRACT

A preliminary mineral-resource potential assessment of San Juan County involves analyses of available published and unpublished geologic, geochemical, geophysical, and economic data and a brief field 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 usable data.

Energy resources are the most important commodities in San Juan County, although other commodities have been produced. Coal, oil, and gas are currently being produced and have high potentials in various parts of San Juan County. A high resource

potential exists locally for carbon dioxide, clay, helium, sand and gravel, and limestone. Much of the county has a high resource potential for crushed and dimension stone.

A moderate resource potential exists for uranium in the Shiprock district and at the Boyd prospect. A moderate potential exists locally for humate.

Additional geologic mapping and geochemical studies are suggested in areas with active claims, at the Boyd prospect, in areas of aggregate resources, and in areas with potential for silica sand, clay, and zeolites. More drilling and quality analyses are needed to better evaluate the coal resource potential. The significance of barium anomalies along the Kirtland-Fruitland contact and in the Nacimiento Formation needs to be examined.

SUMMARY

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

The mineral-resource potential for various commodities in San Juan County is summarized in Table 37 and Figures 24, 25, 27, 30, 31, 32, 36, 37, 39, and 40. The most important commodities are petroleum and coal. Aggregate resources, CO_2, helium, limestone, clays, 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 calcualate reserves and resources of these commodities in areas of high potential.

County (after McLemore et al., 1986d).

Commodity	Geologic Formation	Geologic Area	Mineral Resource Potential
Petroleum	Tertiary, Cretaceous, Jurassic, Pennsylvanian, Mississippian units	San Juan Basin	high
	Devonian, Mississippian, Pennsylvanian, Permian, Triassic, and Jurassic units	Defiance uplift	low (southwest)
Coal	Fruitland Formation	Fruitland Field	high
		Navajo Field	high
		Bisti Field	high
		Star Lake Field	high to moderate
	Menefee Formation	Barker Field	low
		Hogback Field	moderate
		Toadlena Field	unknown
		Newcomb Field	low
		Chaco Canyon Field	very low to low
Uranium (Vanadium)	Jurassic rocks	Shiprock District	moderate
	Cretaceous rocks	Boyd Prospect	moderate
	Westwater Canyon Member	Tocito Dome	unknown
	Upper Cretaceous rocks	Beach-placer deposits	moderate
Geothermal		(mostly) western San Juan County	very low
Metals (other than vanadium)	various formations	Entire County	low
Barite and Fluorite	Cretaceous rocks	Northern San Juan Basin	unknown
CO_2	various units	San Juan Basin	moderate to high
	various units	Defiance uplift	moderate to high
Clay	various units	entire county	low to high
Crushed and dimension stone	various units	entire county	high
Helium	various units	San Juan Basin	moderate to high
	various units	Defiance uplift	moderate to high
Humate	same as coal	same as coal	low to moderate
Pumice	Tertiary and Quaternary units	entire county	very low to low
Scoria and cinders		entire county	very low to low
Expansible shale			unknown or low
Limestone	Todilto limestone	Sanostee-Beautiful Mountain southward	moderate to high
Mica	many sedimentary units	entire county	low
Saline minerals	Pennsylvanian	Hermosa Formation	low
Sand and gravel	Quaternary, Tertiary, and Cretaceous units	entire county	high
Silica sand	various units	entire county	unknown
Sulfur	various units	Barker dome	low
Zeolite	Brushy Basin	Chuska Mountains	low
	Chuska Sandstone	Chuska Mountains	unknown

RECOMMENDATIONS

1) Any areas with active claims should be examined (Fig. 14).
2) Isopach facies and structure-contour maps of several formations in San Juan County should be completed to delineate favorable areas for oil, gas, CO_2, and helium accumulations.
3) Aggregate resources should be mapped and sampled in greater detail prior to extraction of such materials.
4) Chemical sampling of high-silica sandstones is required to determine the potential for high-silica sand resources.
5) Detailed studies of the mineralogy and chemistry of clay deposits are required to assess their potential.
6) More drilling and quality analyses are needed to better evaluate the coal resource potential for several fields, especially the Barker field.
7) Gather drill hole and outcrop data to estimate total coal resources and reserves in various coal fields.
8) Stratigraphic studies are needed at the Boyd prospect to determine correlation with lower Fruitland Formation to aid in uranium resource potential.
9) More drill hole data is needed to better delineate the uranium deposits in the Westwater Canyon Member on Tocito dome.
10) Investigate the significance of barium anomalies along the Kirtland-Fruitland contact and in the Nacimiento Formation in northern San Juan and southern Rio Arriba Counties.

11) More testing of crushed stone resources is required to determine their commercial capabilities.

12) More analytical and field work is needed to determine the resource potential for zeolites.

An Executive Summary of

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

by

Virginia T. McLemore,
Ronald F. Broadhead,
Gretchen Roybal,
William L. Chenoweth,
James M. Barker,
Peter Copeland,
Mark R. Bowie,
Kevin Cook,
John S. Hingtgen,
Kris Klein
and Karen B. Brown

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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 Alta area has a high 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.

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 7 - Summary of mineral-resource potential in western Rio Arriba County (after McLemore et al., 1986e).

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
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 ores.

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