GEOEXPLORERS INTERNATIONAL, INC.
5701 EAST EVANS AVENUE, DENVER, COLORADO 80222, USA, TEL. 303-759-2746

DR. JAN KRASON
PRESIDENT

GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT OF THE MANZANO AREA, NEW MEXICO

BY
JAN KRASON, A. WODZICKI AND SUSAN K. CRUVER

GEOEXPLORERS INTERNATIONAL, INC.
5701 East Evans Avenue
Denver, Colorado 80222
Telephone 303-759-2746

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GEOLOGY, ENERGY AND MINERAL RESOURCES ASSESSMENT OF THE MANZANO AREA, NEW MEXICO

by

Jan Krason, Antoni Wodzicki and Susan K. Cruver

SUMMARY

The Manzano Geological Resource Area (GRA) is located at the foothills and along the western slope of the central part of the Manzano Mountains, in central New Mexico. Included in the GRA is one Wilderness Study Area (WSA) known as the Manzano WSA (010-092), which comprises 845 acres (3.4 sq. km).

Geology of the Manzano GRA is complex and includes rocks ranging from Precambrian (1.2 to 1.65 m.y. old) through recent age. However, within the WSA occur only Precambrian granite (1.5 m.y. old) which is in fault contact with Pennsylvanian and Permian strata. There is a relatively thin, but widespread veneer of (recent) alluvial fans formed of granitic blocks and poorly sorted rock debris.

The alluvial fans and the pediment gravel which occurs further west within the Rio Grande valley mask the subsurface geological structures. Alluvium also masks the above-mentioned Manzano fault and other faults which steeply dip in the Rio Grande graben.

The geological environments, although locally favorable in the GRA for various mineral deposits and hydrocarbons, appear to have very low or no favorability within and, in close proximity to, the WSA. Therefore, there are no GEM resources classification maps enclosed with this report and no further geological work is recommended for the Manzano Wilderness Study Area.

INTRODUCTION

Purpose and Methodology

The need and desirability of the "Geological, Energy and Minerals (GEM) Resources Assessment" in the "Wilderness Study Areas" (WSA) has been recognized for some time by the Bureau of Land Management (BLM). The assessment is now being performed by various contractors for the BLM.

Wilderness Study Areas, widely scattered within the Sonoran Desert and Mexican Highlands and grouped into Region 5 by the BLM, are being studied and assessed by Geoexplorers International, Inc. The present report pertains to one WSA in central New Mexico which is located within the Manzano Geological, Energy and Mineral Resources Area (GRA).

The purpose of the present study is to assess the potential for locatable, leasable and salable resources within the GRA, and specifically within each of the WSAs. This assessment has been carried out through literature study of the geology, structure and economic geology of the GRA, and a consideration of the regional paleogeographic, plate tectonic and metallogenic setting of the GRA within the southern Cordillera. Thus, the assessment is not only based on data from the GRA itself, but also on metallogenic concepts within the regional paleogeographic and plate tectonic framework.

Geological, Energy and Mineral (GEM) Resources Area (GRA)

In this report "resources" are defined as mineral and/or fossil fuel concentrations amenable to economic development under current or reasonably anticipated conditions. Resources include reserves and other mineral or fossil fuel concentrations that may eventually become reserves but are currently either economically or technically not recoverable. Resources are also defined as deposits inferred to exist, but not yet discovered. Such resources cannot be considered as available until actually discovered.

Considering the BLM´s requirements, the GRA boundaries have been determined in accordance with the following criteria:

1. The size of the GRA is approximately 690,000 acres (2,790 km^2), which if shown on the map to the scale of 1:250,000 (also required by BLM) does not exceed a sheet of paper 8.5 by 11 inches,
2. The GRA boundary does not cut across a Wilderness Study Area, and
3. The geologic environment and mineral occurrences are also taken into primary consideration.

The name of the "Manzano GRA" has been suggested and used by the authors of this report. The criteria for establishment of the Wilderness Study Area are not the subject of this report. Also, its boundary, code number and name has been established by the Bureau of Land Management prior to this study.

Location and Access

The Manzano GRA lies in central New Mexico, within the east-central part of the Socorro 1:250,000 scale quadrangle map (see fig. 1). The GRA´s geographic coordinates are as follows:

latitude 34°28´45"W - 35°00´00"N and

longitude 106°10´50"W - 106°42´25"W.

The same area can be described by the townships T3N to T9N and ranges R3E to R7E.

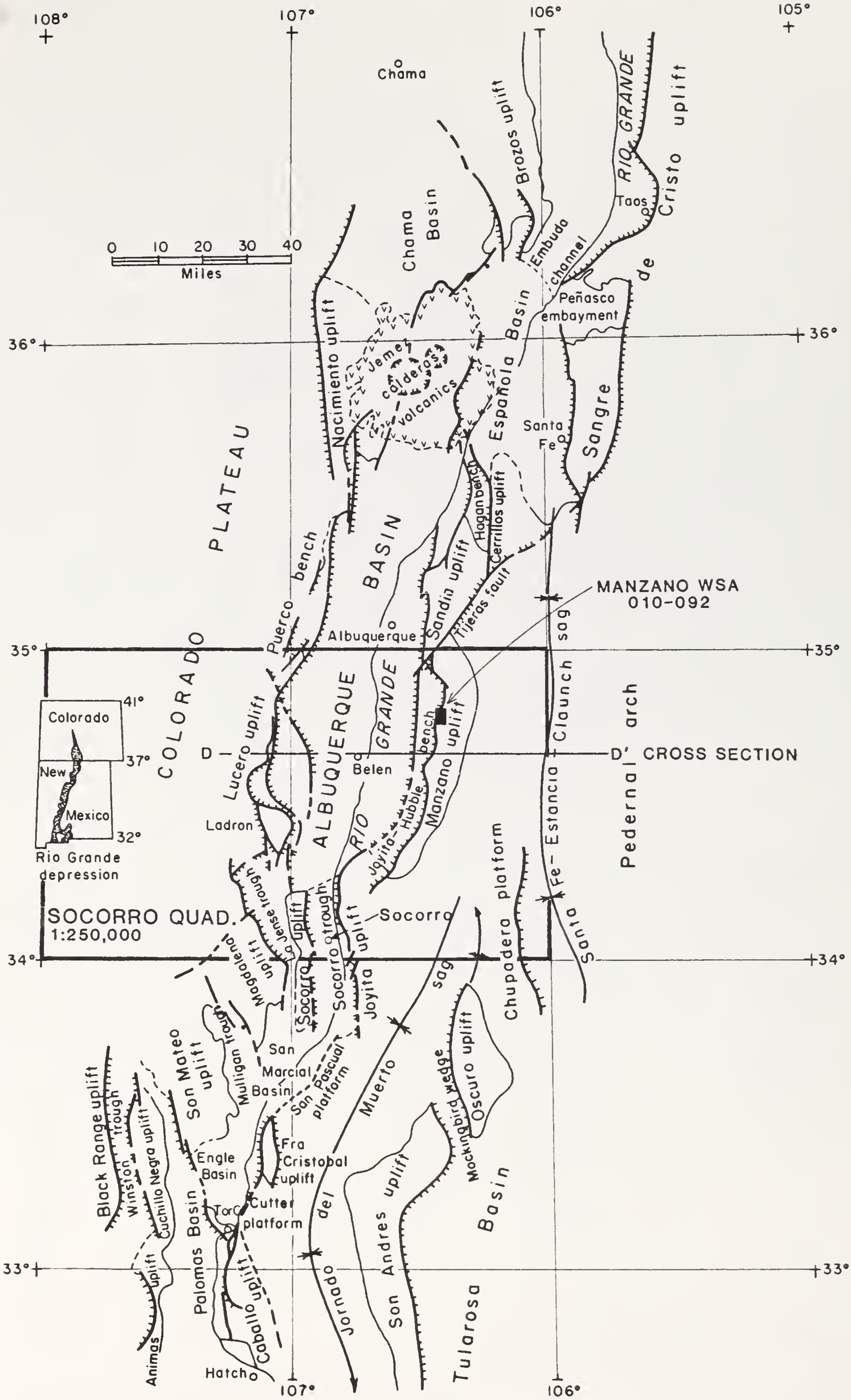


FIGURE 1. TECTONIC MAP OF THE RIO GRANDE RIFT SYSTEM IN NEW MEXICO AND LOCATION OF THE MANZANO GRA; after V.C. Kelley

In this GRA is only one Wilderness Study Area also named "Manzano", with code number 010-092. The WSA includes 845 acres (3.4 sq. km) which occupies the W1/2 sec. 31 of T6N, R4E, and the W1/2 sec. 6 and W1/2 sec. 7, T7N and R4E. The WSA has a rectangular shape which is extended in the north-south direction. On the east, the WSA borders the Cibola National Forest.

The WSA is located in Torrance County along its western border with Valencia County. The Manzano WSA is about 16 miles east of Los Lunas in the Rio Grande valley, and is approximately 17 miles south of Albuquerque.

Access to the WSA is possible from Los Lunas by four wheel drive vehicle and then walking about one mile from an unpaved road. Within and in close proximity to the WSA there are no roads or hiking trails.

PHYSIOGRAPHY

The Manzano GRA lies within and adjacent to the Rio Grande rift, a pronounced north-trending tectonic and physiographic depression. The area is in the Mexican Highland section of the Basin and Range Province as defined by Fenneman (1928).

The GRA can be divided into three distinct physiographic terrains (fig. 1): the mountainous terrain running north-south in the center of the GRA, the high plateau of the eastern part of the GRA, and the floodplain and lowlands of the western half of the GRA.

The Manzano Mountains comprise the mountainous terrain and the Chupadera Platform is the high, eastward sloping plateau in the eastern part of the GRA. The floodplain and lowlands are located within the Rio Grande graben. The Rio Grande has downcut into floodplain sediments, creating terraces. One occurs approximately 110 feet above the level of the river, between Isoleta and Los Lunas (fig. 3).

Total relief of the GRA is approximately 5100 feet, with the Manzano Peak the highest point at 10,098 feet.

The Manzano WSA lies along the margin between the mountainous and lowland terrains in the center of the GRA. The WSA partly overlies the steep western slope of the Manzano Mountains and partly overlies more gently sloping, but still quite steep, alluvial fans formed along the faulted western edge of the Manzano Mountains. Relief in the WSA is about 1200 feet.

GEOLOGY

The regional geological setting and main structural units of central New Mexico are shown in figures 1 and 2. Geologic environments and energy and mineral resources within the Manzano GRA are shown in figure 3 with the legend and explanation in figure 4.

In all these illustrations (figs. 1 through 3) it is shown that the Manzano GRA covers portions of the Albuquerque Basin including the Rio Grande graben, Joyita-Hubble bench, Manzano uplift and Chupadera platform (Kelley, 1977). The area is in the eastern edge of the Rio Grande graben and is intensely faulted.

Lithostratigraphy - Rock Units

The Manzano GRA includes rocks ranging in age from Precambrian to Holocene. However, as not all stratigraphic units are equally important for the GEM resources assessment within the WSA, the following stratigraphic descriptions focus attention on those rock units which crop out in and around the WSA. The lithostratigraphic units cropping out within the GRA are shown in figure 3. Brief descriptions of the units are shown in the lithostratigraphic legend (fig. 4).

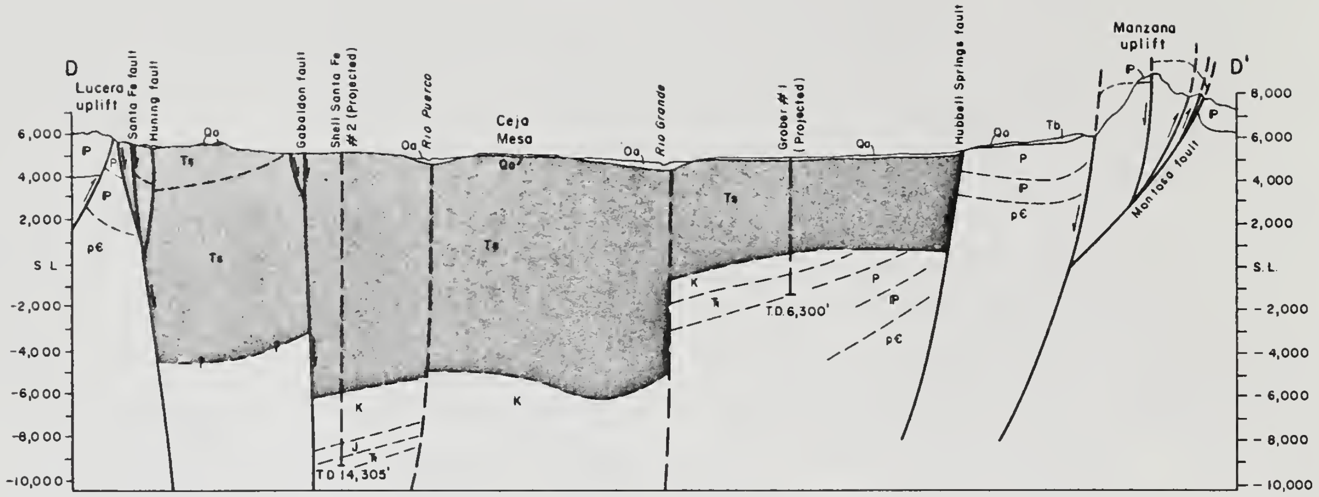


FIGURE 2. WEST-EAST STRUCTURE SECTION ACROSS ALBUQUERQUE BASIN, DATUM IS MEAN SEA LEVEL; after V.C. Kelley, 1977.

FIG. 3. GEOLOGIC, ENERGY AND MINERAL RESOURCES MAP OF THE MANZANO AREA, NEW MEXICO

Scale
1 : 250,000
LEGEND: see enclosed

Figure 4. LEGEND

FOR

GEOLOGIC, ENERGY AND MINERAL RESOURCES MAPS

Scale of all maps is 1:250,000 or as otherwise indicated.

LITHOSTRATIGRAPHY

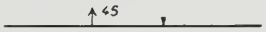
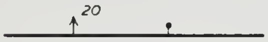
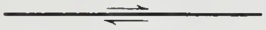
After Vincent C. Kelley, 1977 and C. H. Dane and G. O. Bachman, 1965

QUATERNARY	HOLOCENE	Qa Qfa	ALLUVIUM – Qa: Arroyos: Qfa: Fans
		Qe	EOLIAN SAND – Blankets
	PLEISTOCENE	Qt	GRAVEL TERRACES
		Qo	ORTIZ PEDIMENT GRAVEL AND SURFACE – Fanglomerate ranging from large boulders to pebbles
TERTIARY	PLIOCENE	Tb	Basaltic flows and cinders of San Felipe, Cerros del Rio, Wind Mesa, Lucero Mesa, Cat Mesa, Isleta and lesser centers
	MIOCENE	Ts	SANTA FE FORMATION– Undivided: pinkish, light olive drab and white sandstone; gray and brown mudstone; arkose, conglomerate, and fanglomerate
		Td	DATIL VOLCANICS – Volcanic fanglomerate and tuff
TRIASSIC		T̄R	SANTA ROSA AND CHINLE FORMATIONS – Reddish-brown mudstone, sandstone, and conglomerate
PERMIAN	LEONARD	Py	YESO FORMATION – Sandstone, mudstone, gypsum
	WOLFCAMP	Pa	ABO FORMATION – Reddish to white sandstone, mudstone and gypsum
PENNSYLVANIAN		ℙ	MADERA LIMESTONE AND SANDIA FORMATION – Undivided
PRECAMBRIAN		p€g	GRANITIC PLUTONS
		p€m	METAMORPHIC ROCKS– Gneiss, schist, quartzite, and greenstone

SPECIAL SYMBOLS

OF STRUCTURAL FEATURES

After U.S. Geological Survey

	Contact – Dashed where approximately located; short dashed where inferred; dotted where concealed
	Contact – Showing dip; well exposed at triangle
	Fault – Dashed where approximately located; short dashed where inferred; dotted where concealed
	Fault, showing dip – Ball and bar on downthrown side
	Normal fault – Hachured on downthrown side
	Fault – Showing relative horizontal movement
	Thrust fault – Sawteeth on upper plate
	Anticline – Showing direction of plunge; dashed where approximately located; dotted where concealed
	Asymmetric anticline – Short arrow indicates steeper limb
	Overturned anticline – Showing direction of dip of limbs
	Syncline – Showing direction of plunge; dashed where approximately located; dotted where concealed
	Asymmetric syncline – Short arrow indicates steeper limb
	Overturned syncline – Showing direction of dip of limbs
	Monocline – Showing direction of plunge of axis
	Minor anticline – Showing plunge of axis
	Minor syncline – Showing plunge of axis

Strike and dip of beds – Ball indicates top of beds known from sedimentary structures

	Inclined		Horizontal
	Vertical		Overturned

Strike and dip of foliation

	Inclined		Vertical		Horizontal

Strike and dip of cleavage

	Inclined		Vertical		Horizontal

Bearing and plunge of lineation

	Inclined		Vertical		Horizontal

Strike and dip of joints

	Inclined		Vertical		Horizontal

Note: planar symbols (strike and dip of beds, foliation or schistosity, and cleavage) may be combined with linear symbols to record data observed at same locality by superimposed symbols at point of observation. Coexisting planar symbols are shown intersecting at point of observation.

SPECIAL SYMBOLS

FOR ENERGY AND MINERAL RESOURCES

KNOWN DEPOSITS AND OCCURRENCES

◯ - O Oil field
◯ - G Gas field
◯ - Os Oil shale

⬭ - C Coal deposit
⬡ - C Coal occurrence

■ - Mineral orebody - as specified with symbol
◧ - Mineral deposit - as specified with symbol
☐ - Mineral occurrence - as specified with symbol
▭ - Mineral district (Fig.= inserted map)

EXPLORATION AND/OR MINING ACTIVITY

MINERALS AND COAL

✕ Mineral deposit, mine or prospect with recorded prod.
✕ Prospect or mine with no recorded production
≻— Accessible adit, or tunnel
≻+ Inaccessible adit, or tunnel

◩ Vertical shaft
◩ Inclined shaft
⚒ Active open pit, or quarry
⚒ Inactive open pit, or quarry

✕ Active gravel or clay (cl) pit
✕ Inactive gravel or clay (cl) pit
⊕ Exploration hole with data available
⊗ Exploration hole without data
▭ Mining district (Fig.= inserted map)

PETROLEUM

● Oil well
● Oil and gas well
☼ Gas well

○ Show of gas
◐ Show of oil
◐ Show of oil and gas
○ Shut-in well

⊙ CO_2- or He-helium- rich well
⌖ Dry well - abandoned

GROUND WATER

○ Water well of special importance
○ Water well of high yield
○ Flowing water well

◒ Brine
◐ Mineral water

◓ Thermal water
⊗ Radioactive water
▲ Thermal point

ENERGY RESOURCES

O	Oil
G	Gas
Os	Oil shale
Ot	Tar sands
C	Coal
Cb	Lignite (brown coal)
Cp	Peat
U	Uranium
Th	Thorium
Gt	Geothermal

MINERAL RESOURCES

METALS

Al	Aluminum
Sb	Antimony
As	Arsenic
Be	Beryllium
Bi	Bismuth
Cd	Cadmium
Cr	Chromium
Cs	Cesium
Co	Cobalt
Cu	Copper
Ga	Gallium
Ge	Germanium
Au	Gold
Fe	Iron
Pb	Lead
Li	Lithium
Mn	Manganese
Hg	Mercury
Mo	Molybdenum
Ni	Nickel
Nb	Niobium or Columbium
Pt	Platinum group
RE	Rare earth
Re	Rhenium
Sc	Scandium
Ag	Silver
Te	Tellurium
Tl	Thallium
Sn	Tin
Ti	Titanium
W	Tungsten
V	Vanadium
Zn	Zinc
Zr	Zirconium and
Hf	Hafnium

NONMETALS - INDUSTRIAL MINERALS

ab	Abrasives
al	Alum
as	Asbestos
Ba	Barite
be	Bentonite
ca	Calcite
cl	Clay
	Construction materials :
cs	Crushed stone
la	Lightweight aggregates, includ.:
pm	Pumice and volcanic cinders
pe	Perlite
ec	Expanded clay, shale, slate
vm	Vermiculite
sg	Sand and gravel
cr	Cement raw materials
bs	Building stones
ll	Lime
dl	Diatomite
	Nonmarine and marine evaporites and brines
pt	Potash
na	Salt - mainly halite
gy	Gypsum and anhydrite
nc	Sodium carbonate or sulfate
bn	Boron minerals
nl	Nitrates
Sr	Strontium
Br	Bromine
cc	Calcium chloride
mg	Magnesium compounds
fs	Feldspar
F	Fluorite (fluorspar)
gs	Gem stones
ge	Graphite
He	Helium
kl	Kaolin
ky	Kyanite and related minerals
ls	Limestone
lm	Lithium minerals
mg	Magnesian refractories
ml	Mica
ph	Phosphate
pl	Pigment and fillers
qz	Quartz crystals
sl	Silica sand
S	Sulfur
tc	Talc
ze	Zeolites
hm	Humate

SPECIAL GEOLOGICAL FEATURES

POINT OF SPECIAL GEOLOGIC INTEREST

m	Mineral occurrence
f	Fossil locality
v	Volcanic phenomenon
t	Stratigraphic sequence
s	Structural, bedding, foliation, etc.,
b	Brecciation, shear zone, etc.,
y	High yield spring
p	Spring with mineral water
u	Radioactive spring
g	Thermal spring
a	Extensive rock alteration
r	Lithologic type locality

FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE FOR MINERAL RESOURCES

FAVORABILITY:

1A - Undefined

1 - Not favorable - combine with either B, C, or D

2 - Low
3 - Moderate
4 - High

} combine with either A, B, C, or D

LEVEL OF CONFIDENCE:

A - Insufficient data

B - Indirect evidence

C - Direct evidence

D - Abundant direct and indirect evidence

Precambrian

Precambrian rocks are exposed in the Manzano Mountains, occur at shallow depth along mountain flanks and form the crystalline basement of the entire GRA. In accordance with the geologic map of the Albuquerque basin by Kelley (1977; fig. 3), there are two major groups of Precambrian rocks. In the southern and northern parts of the Manzano Mountains, and probably under most of the GRA, occur metamorphic rocks composed mainly of gneiss, schist, quartzite, and greenstone. The central part of the Manzano Mountains including the area adjacent to the WSA is composed of a granitic pluton.

The basal unit of the metamorphic rocks consists of approximately 1900 feet of metasediments, mostly phyllite with subordinate metaquartzite. The metasediments are overlain by 4500 feet of mafic metavolcanics (Tijeras-Hell Canyon greenstone) with minor cherty iron formation and silicic metavolcanics. Overlying the greenstone are more metasediments (maximum thickness of 9500 feet) that are mostly phyllites and metaquartzites. Locally, a rhyodacite crystal-rich tuff, 2000 feet in thickness and containing abundant lithic fragments, unconformably overlies the greenstone. The uppermost unit is metarhyolite with subordinate metabasaltic sills with maximum thickness of about 5000 feet in the Manzano Mountains (Fulp and Woodward, 1981).

In the southern Manzano Mountains only the upper sequence of metasediments and overlying metarhyolite are exposed. The rocks are isoclinally folded and metamorpohosed to the lower amphibolite facies (Fulp and Woodward, 1981).

Granitic rocks intrude the metasediments and metavolcanics. The Sandia Mountain granite is reported to be approximately 1500 m.y. old by

Brookins (1974). The Ojito quartz monzonite, which occurs within and to the east of the WSA, and Priest Granite (in T5N, R4E) in the Manzano Mountains, intrude the supracrustal rocks (Fulp and Woodward, 1981). According to Condie and Budding (1979), the granitic plutons were emplaced during late stages of tectonic activity or they are post-tectonic. The granitic rocks are composed mainly of highly saussauritized sodic plagioclase. The contact effects of the pluton on surrounding metamorphic rocks, with exception of silicification, are insignificant (Reiche, 1949). Within the WSA the Ojito quartz monzonite is mostly covered by alluvial fans (Qfa).

Pennsylvanian

In the Manzano GRA, the Pennsylvanian Sandia and Madera Formations rest directly on the Precambrian crystalline basement. Both of these formations, included as one lithosratigraphic unit on the enclosed geologic map (fig. 3), occupy much of the entire eastern half of the GRA. The Pennsylvanian rocks crop out along the eastern slopes of the Manzano Mountains and in the numerous canyons of the Chapadera Platform. Pennsylvanian strata also occur within the Rio Grande graben, mainly in the subsurface.

The Sandia Formation consists of interbedded black shale, dark gray limestone, and gray to light olive-gray and brownish sandstone. Locally, the sandstone is conglomeratic, especially near the base; carbonaceous streaks are also found locally. Total thickness of the Sandia Formation ranges from 10 to 230 feet (Kelly, 1963; Reiche, 1949). The Sandia Formation and associated rocks were deposited on the erosional surface of the Precambrian (Titus, 1980).

The Madera Limestone is divided into a lower gray limestone member and an upper arkosic limestone member. The lower member consists of massive, cliff-forming beds of gray cherty limestone with minor interbedded gray limestone, gray and black shale, and calcareous siltstone. In contrast, the upper member is more than half siltstone, sandstone, and shale. It consists of alternating light gray cherty limestone, arkosic calcarenite, red or brown arkosic sandstone, and gray shale. In the Manzano Mountains, thickness of approximately 1300 feet of Madera have been measured in outcrops. The Madera Limestone is the best aquifer with highest water yield in the area (Titus, 1980).

Permian

Permian sediments crop out in the southeastern part of the Manzano GRA and in a few localities within the Rio Grande graben (fig. 3). In the graben, Permian strata are overlain disconformably by Triassic, Tertiary and Quaternary sediments.

Two Permian formations, the Abo (Pa) and Yeso (Py), are present in the Manzano GRA (figures 3 and 4).

Abo Formation (Pa)

The Abo Formation consists of dark red to reddish brown shale and siltstone, and dark red to pink, locally light gray, sandstone with discontinuous beds of arkosic sandstone, conglomerate, and pellet limestone. The sandstone beds are fine- to very coarse-grained, partly conglomeratic, and are moderately to well cemented. The total thickness reported by Kelley (1963) is 700 to 900 feet.

The Abo Formation crops out in various locations of the southeastern part of the Manzano GRA, where it appears as an erosional remnant resting on the Madera Limestone. In the Rio Grande graben, the Abo is also present, but is not separated from Yeso Formation on the geologic map (fig. 3).

Yeso Formation (Py)

The Yeso Formation, also of early Permian age, consists of two members. The lower unit, the Mesita Blanca Sandstone Member, is an evenly bedded, tan, brown and buff sandstone that is 90 to 150 feet thick. The upper San Ysidro Member is orange-red and pink sandstone with interbedded shale and some gray, caverneous limestone. Locally, discontinuous beds of gypsum or gypsiferous siltstone occur near the top of the unit. Thickness of the San Ysidro Member ranges from 250 to 400 feet.

The Yeso crops out within the Rio Grande graben, locally along the hanging side of the Hubbell Springs fault (fig. 2 and 3). It is very likely that the Yeso, and probably the Abo Formation occur also in subsurface in the Manzano WSA, directly beneath Quaternary sediments.

Apparently younger Permian age strata are not present within the Manzano GRA.

Triassic

In the GRA, Triassic rocks crop out only in one location, about five miles southwest of the Manzano WSA (see fig. 3). However, according to Kelley (1977), the Triassic is also widely present in the subsurface, within the Rio Grande graben (fig. 2). The younger Triassic Chinle Formation and Santa Rosa Sandstone crop out in the GRA.

The Santa Rosa Sandstone consists mainly of light gray to reddish brown lenticular sandstone and reddish brown shale. The sandstone is coarse grained and conglomeratic near the base, with pebbles of limestone and quartz occurring. The formation is 70 to 400 feet thick and is the lower part of a thick red-bed sequence that includes the overlying Chinle Formation (Titus, 1980).

The Chinle Formation consists of a thick section of reddish brown and tan-brown mudstone and thin beds of sandstone.

Jurassic and Cretaceous

Although Jurassic and Cretaceous strata also occur in the Rio Grande graben (Kelley, 1977, Titus, 1980), they do not crop out anywhere within the Manzano GRA. In the subsurface, the Jurassic is undifferentiated, and according to Kelley (1977), consists of Morrison, Entrada and Todilto Formations, which are composed of sandstone, mudstone, gypsum and limestone.

The Cretaceous strata are also undivided (see fig. 2), but consist of the Dakota, Mancos and Mesaverde Formations, including sandstone, shale and numerous coal lenses (Kelley, 1977, Titus, 1980).

Neither Jurassic nor Cretaceous strata are present within or in close proximity of the Manzano WSA.

Tertiary

Tertiary rocks are widespread in the Rio Grande graben. They are particularly well exposed along the escarpments of the Rio Grande Valley and in the western part of the graben. Within the Manzano GRA the Tertiary Santa Fe Formation crops out along the eastern banks of the Rio Grande Valley and underlies the pediment gravels and eolian sands of Quaternary age (fig. 2 and 3).

Santa Fe Formation (Ts - undivided and Tsc - Ceja Member)

The Santa Fe Formation or Group (Titus, 1980) is Miocene to Pliocene in age. The Santa Fe Formation consists of loose or poorly cemented alluvial silt, sand, and gravel that was deposited in the Rio Grande graben as valley-fill. Caliche that developed under old buried land surfaces occurs at various depths. The lithology of the Santa Fe varies locally, but consists mainly of pinkish, light olive and white sandstone, gray and brown mudstone, arkosic sandstone, conglomerate and fanglomerate. The Ceja Member (Tsc) consists of grayish sand and pebbly conglomerate. The Santa Fe Formation is about 4000 to 5000 feet thick in the area to the west of the Manzano WSA between the Hubbel Springs fault and the Belen fault (Kelley; 1977, see fig. 2).

According to Kelley (1977), the Santa Fe Formation does not occur in the area east of the Hubbel Springs fault. This also means that the Santa Fe is not present near the Manzano WSA.

Basaltic Flows

Within the Manzano GRA, about five miles south of the WSA, occur small areas of basaltic flows and cinders composed principally of olivine basalt (Tb) and including volcanic fanglomerate (Ta) and tuff (fig. 3). However, their distribution within the Rio Grande graben is limited to a few occurrences. In the vicinicy of Los Lunas, about 15 miles west of the WSA, andesitic flows (Ta) also occur.

Quaternary

The oldest of the post-Santa Fe Formation units is thin alluvial pediment gravel and sand of the Pleistocene Ortiz (Qo) pediment. It consists of fanglomerate ranging from large boulders to pebbles (Kelley, 1977) which forms a relatively thin (up to 150 feet thick), but widespread blanket (fig. 2 and 3). The Ortiz covers a large portion of the central part of the Manzano GRA. The eastern extension of the Ortiz is only about a mile west of the Manzano WSA. However, Kelley (1977) points out that determination of the extent of the Ortiz pediment is difficult because soil, caliche, and eolian deposits cover much of the area. Furthermore, the sands and gravels are generally thin and easily confused with the gravel of the Ceja Member of the Santa Fe Formation (Tsc).

Within the Ortiz pediment, directly west and south of the Manzano WSA, occur gravel terraces (Qt; fig. 3). They are composed of subrounded to rounded pebbles of locally derived material.

Eolian sands and sand dunes (Qe) cover much of the western part of the Manzano GRA (fig. 3). According to Kelley (1977) transverse form sand dunes are most common, but in blanket-like deposits, longitudinal streaks or low dunes prevail. Eolian sand blankets and dunes lie on the well developed caliche cap of the Ortiz pediment surface and in places are piled in low hills behind the edge of the Ceja Mesa, reaching heights of 15 to 40 feet. Uncovered pediment to the east is lower than the hills in places. The dune field is fairly well stabilized, but low longitudinal ribs or streaks are still clearly visible (Kelley, 1977).

The Manzano WSA is almost entirely underlain by very well developed alluvial fans (Qfa). The zone of alluvial fans occupies the foothills and lower western slopes of the Manzano Mountains (see fig. 3). According to Kelley (1977), many if not most alluvial fans have little or no abrupt change of slope, and may extend 10 to 15 miles or more with a nearly uniform slope. The fans along the Manzano base appear to represent a rather recent uplift of the Manzano Mountains and/or subsidence of the basin surface. The alluvial fans probably rest directly on the Precambrian crystalline basement of the Manzano Mountains and Permian age strata.

Most recent valleys of the Rio Grande and numerous arroyos in the Chupadera platform are filled with alluvial sediments. In the Rio Grande this includes floodplain sediments. Thickness of the recent fill is difficult to determine, although usually the lithology is clearly different than the underlying rocks. Alluvial sediment consists of unconsolidated silt, sand and gravels.

Structural Geology

The regional structural features of the Manzano WSA and GRA are shown on figure 1. The WSA is located at the western edge of the Manzano uplift and the eastern edge of the Rio Grande graben. The boundary between these two major structural units is the Manzano fault, a normal fault which runs through the WSA (Kelley, 1977; Cape et al., 1983).

Characteristic of the Rio Grande rift are series of marginal faults with a thick sequence of sediments accumulated in the graben or basin (Cape and others, 1983). Internal structures of the rift and the bordering uplifts are complex. The structures on the east side of the graben are different in magnitude and style from those of the west side (Kelley, 1977). The structural features clearly influence geomorphology (fig. 2 and 3). Kelley (1977) emphasizes that "The Rio Grande depression or rift does have within its basins horsts, buried ridges, troughs, embayments, short branches, constructed channels, benches, and protruding wedges as well as its marginal uplifts."

The most important and directly relevant structure to this study is the above-mentioned Manzano fault. Its length is about 47 miles. Parallel to this fault and about five miles westward is the Hubbell Springs fault (fig. 2 and 3). On the uplifted eastern side of the Hubbell Springs fault there are flat-lying Permian Yeso and Abo rocks and Triassic strata and a thin veneer of pediment sediments, terraces and fan gravels (fig. 3). Displacement on the Hubbell Springs fault is about 4500 feet (fig. 2). Similar offset also occurs along the Rio Grande fault which borders the deepest part of the Rio Grande rift valley (fig. 2).

Considerably different tectonic features can be observed in the eastern part of the Manzano GRA. Paleozoic rocks, which rest directly on the Precambrian crystalline basement, dip gently eastward. However, along the eastern flanks of the Manzano Mountains a series of major faults occur marking the border between the Manzano uplift and the Chupadera platform.

Paleontology

Paleontological documentation is important for three major reasons:

a. guide fossils which in the sedimentary sequence are most useful for stratigraphic correlation,

b. outstanding fossil specimens or fossils which are extraordinarily well preserved can be beneficial to science and/or tourism, and

c. fossils can be excellent indicators of the paleogeographic and paleoecological environments; as a result, even moderately to poorly preserved "uninteresting" fossils can be geologically important.

Plant fossils must also be considered important as organic material which can trigger the precipitation of uranium and/or other metals.

To the authors´ knowledge, there are no fossil localities with any of the above-mentioned characteristics within the Manzano WSA. However, it is known that the Madera Limestone in particular and some carbonates of Permian age are biogenic and contain abundant marine fossils. Various species of pelecypods, brachiopods, corals, bryozoans, and foraminiferas are known to occur in the upper Paleozoic rocks.

Geologic History and Paleogeographic Development

The geologic history of the area is long and complex; only a brief synopsis is presented here. Excellent summaries of the main events that affected the Cordillera of New Mexico are given by Dickinson (1981) and Burchfiel (1979). More detailed accounts are given by Kelley (1977), for the Precambrian, Condie and Budding (1979), and for the Paleozoic, Kottlowski (1963).

The area lies within a 1.2 to 1.65 b.y.B.P. ENE-trending belt within the North American craton, which is distinct from a 1.65 to 1.9 b.y.B.P. belt to the northwest. Rocks of the 1.2 to 1.65 b.y.B.P. belt which occurs in the GRA include metasedimentary and both mafic and felsic meta-igneous rocks that have been folded twice, metamorphosed and intruded by granites.

The post-Precambrian geologic history can be summarized as follows:

1. Some time prior to the mid-Paleozoic, central New Mexico was uplifted and eroded to a peneplain. At that time older Paleozoic strata, presumably deposited during early Paleozoic transgessions, were removed.
2. A major transgression took place during the Mississippian and Pennsylvanian. At this time, the shallow marine clastic and carbonate sediments of the Sandia and Madera Formations were deposited.

3. During the late Pennsylvanian and early Permian, the Ouachita orogeny to the south caused the Pedernal and Burro-Zuni uplifts and a gradual regression took place in central New Mexico. The uplifts were the main sediment sources during the late Pennsylvanian and Permian. This regression began in Madera time and the Abo Formation, a continental red bed sequence, was deposited during the culmination of this event.
4. A marine transgression followed with deposition of shallow marine-lagoonal Yeso Formation which contains evaporites and redbeds, and the mainly carbonate San Andres Formation, which occurs to the south of the Manzano GRA.
5. During the Triassic, the area was uplifted, bevelled and deposition of the continental, Santa Rosa and Chinle Formations took place.
6. The area remained uplifted during the Jurassic and much of the Cretaceous and no sedimentation took place. During the Upper Cretaceous, shallow marine sedimentation was followed by deposition of terrestrial beds of the Mesaverde Formation.
7. The Laramide orogeny caused only minor thrusting and folding in central New Mexico. This was followed by a period of erosion and bevelling of the surface.
8. From latest Eocene and continuing to the present day a period of volcanism and tectonism has affected central New Mexico and can be divided into three phases:
    a. The first phase lasted from 40 to 30 m.y. During this time, the dip of the Benioff zone beneath the American plate decreased to less than 15° and calc-alkaline,

mainly andesitic and quartz latitic, volcanism took place. Voluminous quartz latitic ash flow deposits were erupted from cauldrons and small epizonal monzonite plutons were intruded.

b. The second phase lasted from 30 to 20 m.y. At this time, the Pacific plate collided with North America, the San Andreas fault was initiated and a modified back arc stage of volcanism took place as a result of the still-active Farallon plate beneath the southern Cordillera. Volcanism took on a bimodal character with calc-alkaline to high potassium calc-alkaline basaltic andesite and high-silica rhyolite being the dominant phases erupted. Extensive ash flow deposits of high silica rhyolite were erupted from cauldrons and epizonal plutons of quartz monzonite and granite were intruded.

c. From 20 m.y. to the present, interplate normal faulting and bimodal volcanism has taken place and is probably associated with cessation of subduction and the growth of the San Andreas transform. During this time, the Rio Grande rift developed and was filled with valley-fill sediment.

9. Igneous activity and deformation have continued to the present day as evidenced by the presence of magma chambers beneath the Rio Grande Valley southwest and west of the Monzano GRA.

ENERGY AND MINERAL RESOURCES

Locations of known mineral occurrences and mining exploration sites in the Manzano GRA are plotted on figure 3. The information presented on the map and summarized in the following descriptions was derived was derived from the

U.S. Geological Survey (1981a, 1981b), Haigler and Southerland (1965) Fulp and Woodward (1981), LaPoint (1979), Woodward et al. (1978) and Kelley and Northrop (1965).

It should be noted that in the Manzano GRA there is a relatively small number of mineral occurrences and none are located within or near the WSA. Base and precious metal mineralization is confined to the north-central part of the GRA and mainly to the shear system in the metamorphic rocks of Precambrian age. Uranium-bearing occurrences are located in the south-central part of the Manzano GRA and, with one exception, occur in the Pennsylvanian and Permian (Abo Formation) strata. In this GRA, eighteen oil wells have been drilled. All were dry, but one (located about 15 miles to the east of the Manzano WSA) hit a large pocket of CO_2 and this well is still in operation.

Known Mineral Deposits, Mines, Oil Wells, or Prospects with Recorded Production

12. Mary M Mines
Location: Sec. 16, T8N, R5E
Commodities: Ag, Cu, Au
Deposit Description: Consists of small pits and adits in sheared greenstone with abundant quartz veinlets. Mineralization consists of malachite, chalcopyrite, pyrite, magnetite and gold.
Production: Small shipments of ore have been reported.
References: Haigler and Southerland, 1965; Kelley and Northrop, 1975.

13. Milagros Mine and Star Shaft
Location: Sec. 21, T8N, R5E
Commodities: Ag, Cu, Au
Deposit Description: Consists of copper carbonates, iron oxides, minor native copper, gold and silver.
Production: Over $300,000 of gold and silver.
References: Haigler and Southerland, 1965; Woodward and others, 1978.

17. Carbon Dioxide Well
Location: Sec. 32, T7N, R7E
Commodity: CO_2
Production: Yes.
References: U.S. Geological Survey, 1981.

42. York Mine

Location: Sec. 9, 16, T8N, R5E (location very approximate)

Commodities: Cu, Pb, Zn

Deposit Description: Small, stratiform copper-lead-zinc body occurring in a cherty iron-marble lens. Host rocks are tuffaceous metasediments within a terrane dominated by greenstone and mafic metasediments.

Production: Yes.

Reference: Fulp and Woodward, 1981.

45. Copper Girl Mine

Location: Sec. 28, T4N, R5E

Commodity: Cu

Deposit Description: An organic-rich, chalcocite-bearing gray shale lies on a curved, shallow depression formed on top of a brown medium-grained sandstone. The sandstone is light brown below the gray shale, but laterally it grades abruptly into red sandstone, and here it is overlain by red mudstones that probably represent oxidized overbank muds. Chalcocite occurs in nodules and as a replacement of partially compressed organic debris. The mine consists of a small adit, 6´ high, 6´ wide, now partially blocked by caving. Adit is driven eastward in a light gray sandy mudstone of the Abo Formation; it is at least 12-15´ long, untimbered, and shows evidence of some roof falls about 10´ back. A thin bed of coarse grained conglomeratic arkosic channel sandstone crops out just below the adit entrance. This sand unit contains an appreciable amount of copper locally, with malachite and azurite present at this site, and also produces the highest scintillometer response of any rock type on the dump or at the outcrop; readings of up to 225 cps were recorded. Readings of just over 150 cps were recorded at the portal. No uranium mineralization is visible.

Another small adit was started 50´ south of the main adit, but no underground workings exist at present. Several rounds were apparently set off and the stub adit was completely caved. Scintillometer response here was weak, less than 2x background.

The small dump from the main adit is about 40´ wide (N-S) and extends westward down slope for approximately 50´ at the angle of repose. It is visible because of its light gray color contrasting with the generally reddish brown outcrops.

The mine is in a red bed copper deposit; the uranium mineralization is below ore grade. However, Lovering, 1956, stated that high grade uranium deposits occur in the Scholle district in T2N, R5E about 3 miles north of Scholle in Torrance County.

The Meader Corporation had the Copper Girl registered with the state Mine Inspector´s Office in 1956. Uranium ore production, if any, is unknown (direct quote from LaPoint, 1979).

Production: Yes.
Reference: LaPoint, 1979.

49. Long Shale Cut
Location: Sec. 10, T3N, R5E
Commodity: Cu
Deposit Description: A brown, poorly exposed sandstone is overlain by green and purple shales containing abundant limestone nodules. Lenses of reddish limestone pebble conglomerates and sandstones with trough cross-stratification surround and overlie this sequence. Chalcocite, as small nodules and as replacement of woody material, is found in calcareous, organic siltstone, which forms a small lens about 50 feet long and three feet thick, within the shales. The presence of fine-grained calcareous, non-red sediments with limestone nodules is suggestive of sediments deposited in a small lake between fluvial channels (direct quote from LaPoint, 1979).
Production: Yes.
Reference: LaPoint, 1979.

50. Cole Mine
Location: Sec. 15, T3N, R5E
Commodity: Cu
Deposit Description: Workings occur on the bench that separates the lower and upper Abo Formation. A cut has exposed two fluvial channels; the bedding in the lower channel dips to the north. Both channels consist of dense gray sandstone with limestone pebbles that increase in abundance toward the base. The upper part of the upper channel contains woody debris that commonly is replaced by chalcocite. The sandstone are overlain by a gray, thinly bedded, calcareous siltstone. Red mudstones overlie this sequence. The conglomerate of the upper channel contains numerous small areas of slightly anomalous radioactivity readings of two to three times background, but no uranium minerals were noted. Copper minerlaization is also spotty (direct quote from LaPoint, 1979).
Production: Yes.
Reference: LaPoint, 1979.

Known Mineral Prospects, Occurrences, Oil and Gas Wells with No Recorded Production

1. Unnamed Mineral Pigments Occurrence
Location: Sec. 24, T9N, R4E
Commodity: Mineral pigments
Production: Unknown.
Reference: Haigler and Southerland, 1965.

2. Unnamed Mineral Occurrence
Location: Sec. 31, T9N, R5E
Commodity: Unknown
Production: Unknown.
Reference: Haigler and Southerland, 1965.

3. Unnamed Fluorite Occurrence
Location: Sec. 20, T9N, R5E
Commodity: F
Production: Unknown.
Reference: Haigler and Southerland, 1965.

4. Unnamed Mineral Occurrence
Location: Sec. 4, T8N, R5E
Commodity: Unknown
Production: Unknown.
Reference: Haigler and Southerland, 1965.

5. Unnamed Mineral Occurrence
Location: Sec. 5, T8N, R5E
Commodity: Unknown
Production: Unknown.
Reference: Haigler and Southerland, 1965.

6. Unnamed Mineral Occurrence
Location: Sec. 6, T8N, R5E
Commodity: Unknown
Production: Unknown.
Reference: Haigler and Southerland, 1965.

7. Unnamed Mineral Occurrence
Location: Sec. 6, 7, T8N, R5E
Commodity: Unknown
Production: Unknown.
Reference: Haigler and Southerland, 1965.

8. Unnamed Mineral Occurrence
Location: Sec. 16, T8N, R5E
Commodity: Unknown
Production: Unknown.
Reference: Haigler and Southerland, 1965.

9. Unnamed Fluorite Occurrence
Location: Sec. 8, T8N, R5E
Commodity: F
Production: Unknown.
Reference: Haigler and Southerland, 1965.

10. Unnamed Lead Occurrence
Location: Sec. 9, T8N, R5E
Commodity: Pb
Production: Unknown.
Reference: Haigler and Southerland, 1965.

11. Unnamed Barite Occurrence
Location: Sec. 9, T8N, R5E
Commodity: Ba
Production: Unknown.
Reference: Haigler and Southerland, 1965.

14. Unnamed Uranium Occurrence
Location: Sec. 28, T4N, R5E
Commodity: U
Production: Unknown.
Reference: Haigler and Southerland, 1965.

15. Unnamed Copper Occurrence
Location: Sec. 28, T4N, R5E
Commodity: Cu
Production: Unknown.
Reference: Haigler and Southerland, 1965.

16. Unnamed Uranium and Vanadium Occurrence
Location: Sec. 15, T3N, R5E
Commodity: U, V
Production: Unknown.
Reference: Haigler and Southerland, 1965.

18. Dry Oil and Gas Test Well
Location: Sec. 8, T8N, R3E
Depth: 10,378 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

19. Dry Oil and Gas Test Well
Location: Sec. 25, T7N, R2E
Depth: 1,956 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

20. Dry Oil and Gas Test Well
Location: Sec. 9, T6N, R3E
Depth: 446 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

21. Dry Oil and Gas Test Well
Location: Sec. 29, T6N, R3E
Depth: 1,150 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

22. Dry Oil and Gas Test Well
Location: Sec. 29, T6N, R3E
Depth: 507 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

23. Dry Oil and Gas Test Well
Location: Sec. 35, T6N, R3E
Depth: 1,115 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

24. Dry Oil and Gas Test Well
Location: Sec. 18, T5N, R3E
Depth: 6,800 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

25. Dry Oil and Gas Test Well
Location: Sec. 32, T6N, R4E
Depth: 500 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

26. Dry Oil and Gas Test Well
Location: Sec. 2, T5N, R4E
Depth: 890 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

27. Dry Oil and Gas Test Well
Location: Sec. 3, T5N, R4E
Depth: 641 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

28. Dry Oil and Gas Test Well
Location: Sec. 3, T5N, R4E
Depth: 823 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

29. Dry Oil and Gas Test Well
Location: Sec. 23, T6N, R5E
Depth: 1,955 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

30. Dry Oil and Gas Test Well
Location: Sec. 32, T7N, R7E
Depth: 2,200 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

31. Dry Oil and Gas Test Well
Location: Sec. 12, T6N, R6E
Depth: 1,343 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

32. Dry Oil and Gas Test Well
Location: Sec. 36, T5N, R6E
Depth: 2,147 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

33. Dry Oil and Gas Test Well
Location: Sec. 18, T4N, R7E
Depth: 2,008 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

34. Dry Oil and Gas Test Well
Location: Sec. 32, T4N, R7E
Depth: 3,104 feet
Commodity: Oil and gas
Production: None.
Reference: U.S. Geological Survey, 1981.

35. Unnamed Uranium Occurrence
Location: Sec. 10, 11, T3N, R5E
Commodity: U
Production: Unknown.
Reference: U.S. Geological Survey, 1981.

36. Unnamed Uranium Occurrence
Location: Sec. 23, 25, T5N, R4E
Commodity: U
Production: Unknown.
Reference: U.S. Geological Survey, 1981.

37. Unnamed Uranium Occurrence
Location: Sec. 13, 14, T3N, R5E
Commodity: U
Production: Unknown.
Reference: U.S. Geological Survey, 1981.

38. Unnamed Uranium Occurrence
Location: Sec. 23, T3N, R5E
Commodity: U
Production: Unknown.
Reference: U.S. Geological Survey, 1981.

39. Unnamed Uranium Occurrence
Location: Sec. 14, 15, T4N, R5E
Commodity: U
Production: Unknown.
Reference: U.S. Geological Survey, 1981.

40. Unnamed Uranium Occurrence
Location: Sec. 29, T4N, R4E
Commodity: U
Production: Unknown.
Reference: U.S. Geological Survey, 1981.

41. Unnamed Uranium Occurrence
Location: Sec. 27, 34, T4N, R5E
Commodity: U
Production: Unknown.
Reference: U.S. Geological Survey, 1981.

43. Unnamed Copper Occurrence
Location: Sec. 21, T4N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

44. Unnamed Copper Occurrence
Location: Sec. 20, 29, T4N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

46. Unnamed Copper Occurrence
Location: Sec. 10, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

47. Unnamed Copper Occurrence
Location: Sec. 10, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

48. Unnamed Copper Occurrence
Location: Sec. 10, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

51. Unnamed Copper Occurrence
Location: Sec. 10, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

52. Unnamed Copper Occurrence
Location: Sec. 16, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

53. Unnamed Copper Occurrence
Location: Sec. 15, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

54. Unnamed Copper Occurrence
Location: Sec. 22, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

55. Unnamed Copper Occurrence
Location: Sec. 21, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

56. Unnamed Copper Occurrence
Location: Sec. 21, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

57. Unnamed Copper Occurrence
Location: Sec. 21, T3N, R5E
Commodities: Cu, U
Production: Unknown.
Reference: LaPoint, 1979.

Mining Claims, Leases and Material Sites

Mining claims recorded by the BLM and reported as of April, 1982, were thoroughly checked. However, neither patented nor unpatented claims have been found within or in close vicinity of the Manzano WSA.

Mineral Deposit Types

Geological environments to be considered as potentially favorable for the occurence of mineral or energy resources in the Manzano GRA include (see fig. 5):

- Precambrian metamorphic rocks,
- Paleozoic sedimentary rocks, specifically Permian red beds,
- Cretaceous coal measures,
- Late Tertiary valley-fill sediments.

Precambrian Metamorphic Rocks

Ore deposit types that may have been formed in direct association with volcanic activity during the Precambrian include:

a. Volcanogenic polymetallic massive sulfide deposits,

b. Greenstone exhalative gold deposits, commonly with copper mineralization

c. Iron-bearing deposits, and

d. Hydrothermal deposits associated with Precambrian intrusives or metamorphism.

Numerous occurrences of massive sulfide deposits are found in older Precambrian rocks in Arizona. In New Mexico, volcanogenic zinc-lead-copper deposits that often contain economic values of precious metals,

Figure 5. GEOLOGICAL ENVIROMENTS OF THE MANZANO AREA AND ASSOCIATED POTENTIAL MINERAL DEPOSIT TYPES

MINERAL DEPOSIT TYPE GEOLOGICAL ENVIROMENT - HOST ROCKS	Volcanogenic Massive Sulfide Deposits	Hydrothermal Deposits (including replacement deposits)	Barite-Fluorite and/or base metal Deposits	"Red-Bed" Type Deposits	Uranium Deposits (all types)	Coal Deposits	Hydrocarbon Deposits
Mid- and Late Tertiary Basin-Fill Sediments					X		
Cretaceous Sediments		X				X	
Paleozoic Sediments			X	X			X
Precambrian Igneous and Metamorphic Rocks	X	X					

are of great exploration interest (Fulp and Woodward, 1981). They are associated with banded iron formations which are zoned, with sulfide facies near the rhyolitic center and carbonate and oxide facies further away. Metavolcanic rocks occur in the northern part of the Manzano GRA in the Tijeras-Hell Canyon, approximately seven miles from the northern end of the WSA (fig. 3). There are three abandoned mines (York #42; Mary M, #12; and Milagros mine and shaft #13) in that area, of which the York mine is associated with volcanogenic rock and contains polymetallic sulfide mineralization. According to Fulp and Woodward (1981) the York deposit is a small stratiform copper-lead-zinc body occurring in cherty-iron-marble lens. Host rocks are tuffaceous metasediments, with greenstone and mafic metasediments occurring nearby. Numerous copper occurrences are reported in the greenstone between Tijeras Canyon and Hell Canyon (Reiche, 1949).

The Mary M and Milagros mines are deposits of exhalative gold, with copper greenstone (Fulp and Woodward, 1981). The Mary M deposit consists of a few small pits and adits in sheared greenstone with abundant quartz veinlets. Mineralization consists of malachite, chalcopyrite, pyrite, mgnetite, and gold. In the Milagros mine and adjacent Star shaft, mineralization that occurs in sintery quartz veins and metachert in sheared greenstone and metasediments. The deposit occurs within the zone of oxidation and consists of copper carbonates, iron oxides, minor native copper, gold and silver.

Paleozoic and Mesozoic Sediments

Paleozoic and Mesozoic sediments are potential host rocks for accumulation of hydrocarbons and possible "red-bed" type copper and silver deposits.

Particularly in eastern New Mexico, oil and gas have long been produced from the Paleozoic rocks, with most of the oil production coming from Pennsylvanian and Permian strata. In the Manzano GRA, similar rocks occur on both sides of the Manzano Mountains. Oil and gas potential in these areas has been recognized and numerous exploratory wells have been drilled. However, no commercial oil or gas has been found. Also, it is very unlikely that any oil or gas can be found within or in close proximity to the Manzano WSA due to intense faulting in the area.

Red bed copper and silver mineralization occurs within the southern part of the GRA in the Scholle district (LaPoint, 1979). The host rocks are sediments of the Abo Formation. In the Scholle district there are numerous copper-bearing occurrences and mine prospects. They have been studied and described by Phillips (1960) and LaPoint (1976, 1979).

The locations of the prospects are shown in figure 3 and their geological characteristics are summarized (after LaPoint, 1979) in the section on "known mineral deposits, prospects and/or occurrences".

According to LaPoint, copper mineralization with anomalous amounts of uranium (two to three times above the background) occurs throughout the district. Mineralization is confined mainly to the lower part of the Abo Formation, and numerous small deposits may be found within a stratigraphic range from 40 to 100 feet. Mineralization occurs in the areas where reducing conditions have prevailed and the host sediments are fluvial channels in the lower, more arkosic, portion of the Abo. This apparent stratigraphic control of the copper mineralization suggests that during their formation, sandstone channels provided a pathway for carrying copper-bearing ground water from sediments that were oxidizing into sediments that were organic-rich and reducing. Mineralization occurs mainly in finer grained sediments that were deposited in ponds rich in organic matter. In coarser grained sediments, such as channels, mineralization is more spotty and is present only where there is an adequate reductant.

In the Scholle district, numerous uranium-bearing prospects and highly radioactive spots (2 to 3 times above the background) also occur. However, according to Pierson and others (1982), the results of the ground water sampling show the presence of strong anomalies along the outcrops, but only a few anomalies downdip where the Abo Formation is covered by younger sedimentary rocks.

Cretaceous Coal Measures

Although Cretaceous strata do not crop out within the Manzano GRA or in the Rio Grande graben, they are present in the subsurface and do contain coal-bearing seams. Coal occurs in the Mesaverde Formation (Kelley, 1977), which within the GRA, occurs only in the deepest part of the Rio Grande graben (fig. 2).

Late Tertiary Valley-Fill Sediments

Valley-fill sediments mainly of the Santa Fe Formation underlie the Rio Grande Valley but do not crop out in the Manzano WSA. Late Tertiary valley-fill sediments represent a potentially favorable environment for the occurrence of stratabound uranium deposits.

In order to form a uranium deposit by the agency of circulating groundwater it is necessary to have adequate source rocks, permeable sediments and a suitable reductant. The Santa Fe Formation contains clasts of rhyolitic Datil Volcanics and coeval rhyolitic ash. Both are probably suitable sources of uranium; Miesch (1956) reports that Datil rhyolites contain between 10 to 50 ppm eU. The Santa Fe Formation contains abundant sandstone and gravel and is doubtlessly sufficiently permeable. It is not certain, however, if adequate reductants are present to cause precipitation of uranium. Suitable reductants include organic matter in the sediments or reducing geothermal fluids.

Reducing geothermal fluids are possible reductants in light of present-day and past geothermal activity in the Rio Grande rift (Chapin et al., 1978).

Mineral Economics

The assessment of the geological, energy and mineral resources favorability should rely upon not only geology. Exploration, recovery, cost of the production of the resource from sources with varying qualities and/or concentrations are included in those considerations. Special consideration must be given to the strategic and critical minerals and metals. However, in the Manzano GRA the only known mineral occurrences or exploration areas for oil and gas deposits are located in considerable distance from the WSA. Moreover, the geological conditions favorable for mineral and/or energy deposits in various parts of the GRA do not appear to be present in the Manzano WSA.

THE GEOLOGY, ENERGY AND MINERAL RESOURCES OF THE MANZANO WILDERNESS STUDY AREA

In this section the Manzano WSA is discussed with respect to its physiography, geology, mineral occurrences, resource potential and recommendations for further work. Much of this information has been presented in other sections of this report and is summarized in this section. The classification of resource potential and level of confidence is in accordance to the schemes provided by the Bureau of Land Management (attachment 9, dated March 24, 1982) as detailed below.

Classification Scheme

1. The geologic environment and the inferred geologic processes do not indicate favorability for accumulation of mineral resources.

2. The geologic environment and the inferred geologic processes indicate low favorability for accumulation of mineral resources.
3. The geologic environment, the inferred geologic processes, and the reported mineral occurrences indicate moderate favorability for accumulation of mineral resources.
4. The geologic environment, the inferred geologic processes, the reported mineral occurrences, and the known mines or deposits indicate high favorability for accumulation of mineral resources.

Level of Confidence Scheme

A. The available data are either insufficient and/or cannot be considered as direct evidence to support or refute the possible existence of mineral resources within the respective area.

B. The available data provide indirect evidence to support or refute the possible existence of mineral resources.

C. The available data provide direct evidence, but are quantitatively minimal to support to refute the possible existence of mineral resources.

D. The available data provide abundant direct and indirect evidence to support or refute the possible existence of mineral resources.

Manzano Wilderness Study Area (010-092)

Physiography

The Manzano WSA lies at the foothills and on the western slopes of the central part of the Manzano Mountains. Slopes in the WSA are steep and a relief is approximately 1200 feet within the WSA´s width of one-half mile.

Geology

Precambrian granites of the Ojita pluton (Condie and Budding, 1979) and Quaternary fan deposits crop out in the Manzano WSA. The granitic rocks of the pluton vary in color from gray to tan and generally are medium grained. According to Condie and Budding (1979) the northern and southern contacts of the Ojita pluton are well exposed and range from concordant to discordant to the surrounding metamorphic rocks. With the exception of silicification, contact effects of the pluton on the surrounding rocks are minimal.

The Manzano fault runs through the WSA. The eastern side of the seemingly normal fault is uplifted. As a result, Pennsylvanian and Permian strata are in fault contact with Precambrian granite. There is no evidence of any mineralization associated with the fault or fault zone.

Directly atop Permian rocks rest alluvial fans, which are widely spread along the western slope and foothills of the Manzano Mountains (Kelley, 1977). The alluvial fans are generally thin, locally up to 50 feet thick. The alluvial fans are composed mainly of granitic blocks and poorly sorted clastic material.

Mineral Deposits

There are no mineral or energy deposits or occurrences within the Manzano WSA. The nearest deposits and occurrences are more than six miles from the WSA boundaries. The geology of the area is well known; the area has been prospected but no mineral occurrences have been reported. Precambrian granites of central New Mexico contain few mineral deposits and those that are known to the authors are post-Precambrian in age. No mineralization is known to occur in alluvial fans of central New Mexico.

Land Classification for GEM Resources Potential

The entire WSA is considered to have extremely low potential for mineral and energy resources at a confidence level of C. The greatest potential is for use of Precambrian granite as building stone or crushable rock, however, similar rocks crop out in numerous areas with easier access and more gentle slopes.

Conclusions and Recommendations

It is very unlikely that mineral and/or energy resources occur in the Manzano WSA. No further geologic work is recommended for the WSA.

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