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 CARRIZOZO AREA, NEW MEXICO

BY

JAN KRASON, SUSAN K. CRUVER AND ANTONI WODZICKI

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 CARRIZOZO AREA, NEW MEXICO

by

Jan Krason, Susan K. Cruver and Antoni Wodzicki

SUMMARY

The Carrizozo "Geological, Energy and Mineral (GEM) Resources Area" (GRA) is located in Lincoln and Socorro Counties, central New Mexico. Precambrian igneous and metamorphic rocks underlie the area and present a geologic record of two periods of deformation and intrusion. The area was tectonically quiet until the Pennsylvanian-Permian when the Ouachita orogeny to the south caused warping. Material derived from the erosion of uplifted areas was deposited in terrestrial and shallow-water marine environments as the Bursum, Abo, Yeso, San Andres and Artesia Formations. Following another uplift in the Triassic, the Dockum Group continental redbeds were deposited. Uplift occurred again during the Jurassic. The Cretaceous Dakota sandstone records a change from continental shallow-water marine conditions, with the overlying Mancos Shale being entirely marine. During deposition of the Mesaverde Group, marine regression occurred. The Laramide orogeny caused gentle folding. Fluvial sediments of the Eocene Cub Mountain Formation were deposited following a period of erosion. Andesites and latites of the Late Eocene to Oligocene Sierra Blanca volcanics overlie the Cub Mountain rocks. Subsequent intrusion of alkalic igneous rocks resulted in doming, folding, faulting and gravity sliding of the older rocks. Igneous activity has continued to the present as evidenced by the alkali olivine basalt flows which cover the center of the GRA and upon which the two Wilderness Study Areas are located.

Iron, gold tungsten (a byproduct of gold production), silver, lead, copper and coal have been produced from mines within the area. Deposits of uranium, molybdenum, barite, zinc, vermiculite and fluorite are also present but have not produced. Paleozoic sedimentary rocks are host to iron deposits (pyrometasomatic replacements) at some intrusive contact with Tertiary plutonic rocks, with one iron deposit also containing uranium. Permian redbeds are potentially favorable for the occurrence of stratabound and "sabkha"-type copper-silver deposits and also contain gypsum salt. Oil and gas may be present in Paleozoic rocks. Thin bituminous coal beds occur in the Cretaceous Mesaverde Group. Tertiary to Quaternary structurally-controlled vein deposits of gold, silver, copper, tungsten, lead, zinc, barite and flourite are associated with fossil hydrothermal systems of the Sierra Blanca Mountains and Lone Mountain. Ferromagnesian minerals in lamprophyre dikes have altered to form vermiculite. Disseminated molybdenum-copper deposits are associated with Tertiary intrusives in the Nogal Peak area. Late Tertiary and Quaternary sediments are host to placer gold and may be favorable for the deposition of stratabound uranium.

The Carrizozo GRA is classified as very favorable for the occurrence of iron as a pyrometasomatic replacement of limestone and gypsum, hydrothermal and placer gold, porphyry molybdenum-copper and bituminous coal, and is considered moderately favorable for the occurrence of hydrothermal silver, copper and lead, stratabound copper and stratabound uranium. The Carrizozo Lava Flow WSA is moderately favorable for the occurrence of stratabound copper, but both WSAs must be considered as potentially favorable for pyrometasomatic iron deposits, hydrothermal gold, silver and base metal deposits, uranium and porphyry molybdenum-copper deposits due to the presence of Tertiary instrusives. The following are recommended in order to better evaluate the resources of the WSAs: field checking of Permian rocks for the presence of locally reducing facies and "sabkha"-type environments in addition to sampling and analysis of groundwater, all to provide data about stratabound copper deposits; field checking and petrographic and chemical sampling and analysis to determine favorability for hydrothermal gold, silver and base metal deposits and porphyry molybdenum-copper deposits associated with Tertiary intrusives.

INTRODUCTION

Purpose and Methodology

The need for "Geological, Energy and Minerals (GEM) Resources Assessment" of "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. The present report pertains to two WSAs in central New Mexico which have been grouped together into the Carrizozo Geological Energy and Minerals Resources Area (GRA).

The purpose of the present study is to assess the potential for locateable, leaseable and saleable 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.

Location and Access

The Carrizozo Geological Resources Area lies in the northwestern part of the Roswell 1:250,000 quadrangle and the northeastern part of the Tularosa 1:250,000 quadrangle, central New Mexico (fig. 1). The Southern Pacific railway line runs north-south through the central part of the GRA and highways U.S.-380 and U.S.-54 run from the northwest to southeast and north to south parts of the area, respectively. New Mexico Highway 349 transverses the

the mountains in the northeastern part of the GRA. Unimproved, dry-weather roads provide reasonable access to the remaining parts of the GRA, with the exception of the higher parts of the Sierra Blanca Mountains, Lone Mountain and Carrizozo Mountain. Two Wilderness Study Areas are located in the central part of the GRA.

Both WSAs are administered by the Roswell BLM District and have been designated in the BLM's Wilderness Study Areas Decisions (BLM, Nov. 1980 and June 1981) as follows:

NM-060-109	Little Black Peak	15,570 acres	(63 km^2)
NM-060-110A	Carrizozo Lava Flow	11,000 acres	(44.5 km^2)
	Total	26,570 acres	(107.5 km^2)

The WSAs and surroundings are shown in figure 1.

PHYSIOGRAPHY

The Carrizozo GRA lies within the Sacramento section of the Basin and Range Province and, in the very easternmost part, the Pecos Valley section of the Great Plains province (Kelley and Thompson, 1964).

The GRA can be divided into three distinct physiographic terrains (fig. 1): The mountainous areas in the northeastern and southeastern parts, a broad basin occupying most of the rest of the GRA, and a plateau in the northwest.

The mountainous areas consist of the Sierra Blanca Mountains, a volcanic and intrusive pile filling part of the Sierra Blanca basin in the south-center, Carrizozo Mountain in the east-center, and Lone Mountain in the north-center. All the mountains were uplifted as a result of Tertiary intrusion.

The broad lowland is composed of the Claunch sag in the north-center, and the Tularosa basin, a bajada, in the southwest and the Sierra Blanca

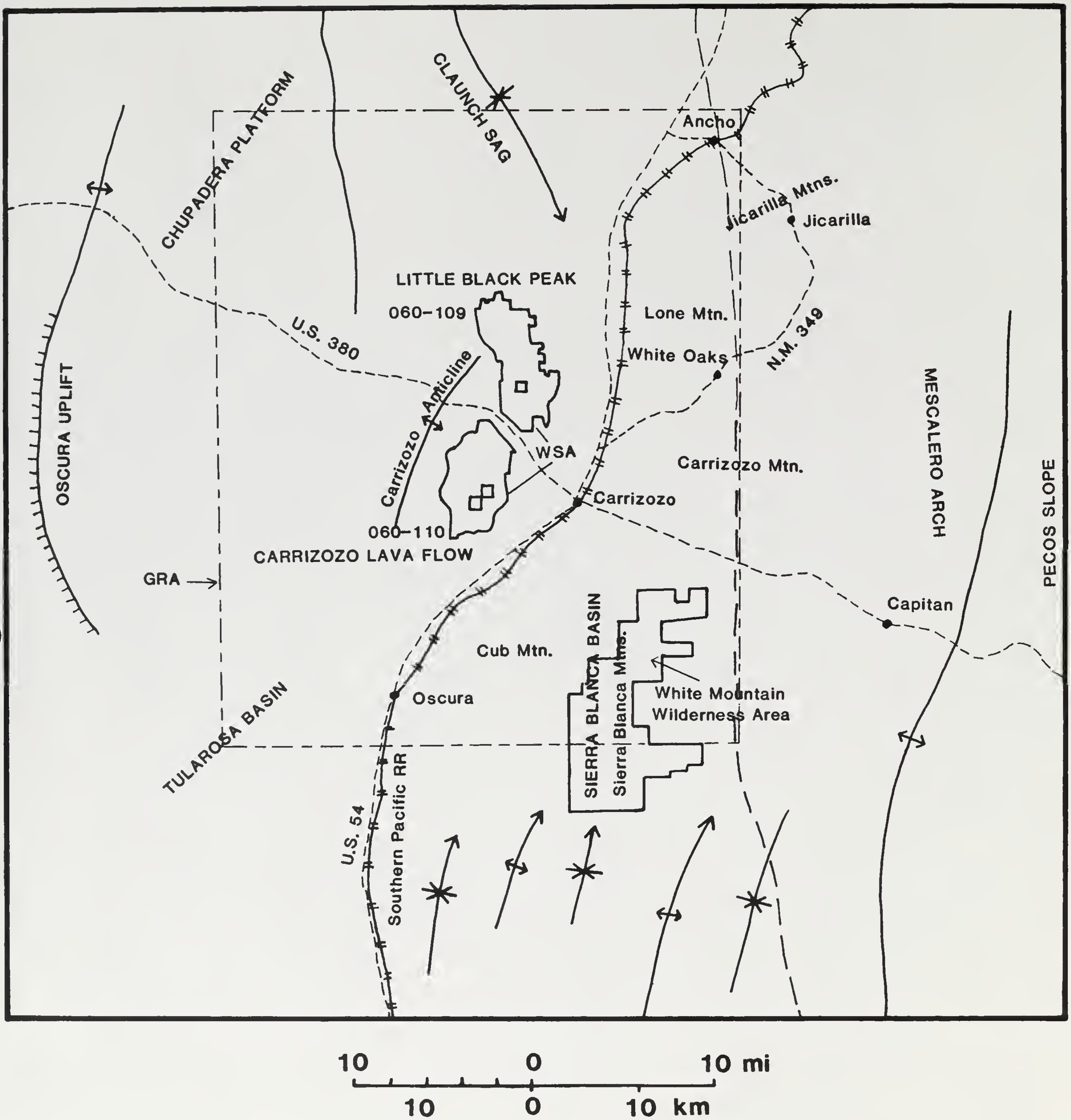


FIGURE 1. PHYSIOGRAPHIC MAP SHOWING THE LOCATION OF THE CARRIZOZO GRA AND THE TWO WSAs

basin in the center. All are tectonic depressions partly filled by Quaternary alluvium. The basins were formed as a result of folding associated with Tertiary basin and range block faulting. The two WSAs are located on Quaternary basalt flows of the Carrizozo malpais which forms a low plateau in the center of the Tularosa basin.

The plateau areas are composed of the Chupadera platform in the northwest and the Mescalero arch in the east; the latter grades into the Pecos Valley to the east of the GRA.

GEOLOGY

The lithology and stratigraphy, structural geology and tectonics, paleontology and geological history of the Carrizozo GRA and surrounding central New Mexico are described in this section in order to facilitate the assessment of mineral potential within the area. The regional geologic setting is summarized in figure 2 and the detailed geology of the Carrizozo GRA is shown in figure 3.

Lithostratigraphy - Rock Units

In central New Mexico, Precambrian crystalline basement is unconformably overlain by late Paleozoic to Mesozoic shallow marine and continental sediments, mid-Tertiary arc volcanics, late Tertiary sediments, late Tertiary to Quaternary bimodal volcanics and associated sediments, and is intruded by Tertiary stocks, laccoliths, sills and dikes. The area lies close to the eastern limit of the effect of the Laramide orogeny.

Precambrian Rocks

Precambrian rocks do not crop out within the GRA but have been encountered by oil exploration drilling. The Precambrian rocks underlying the

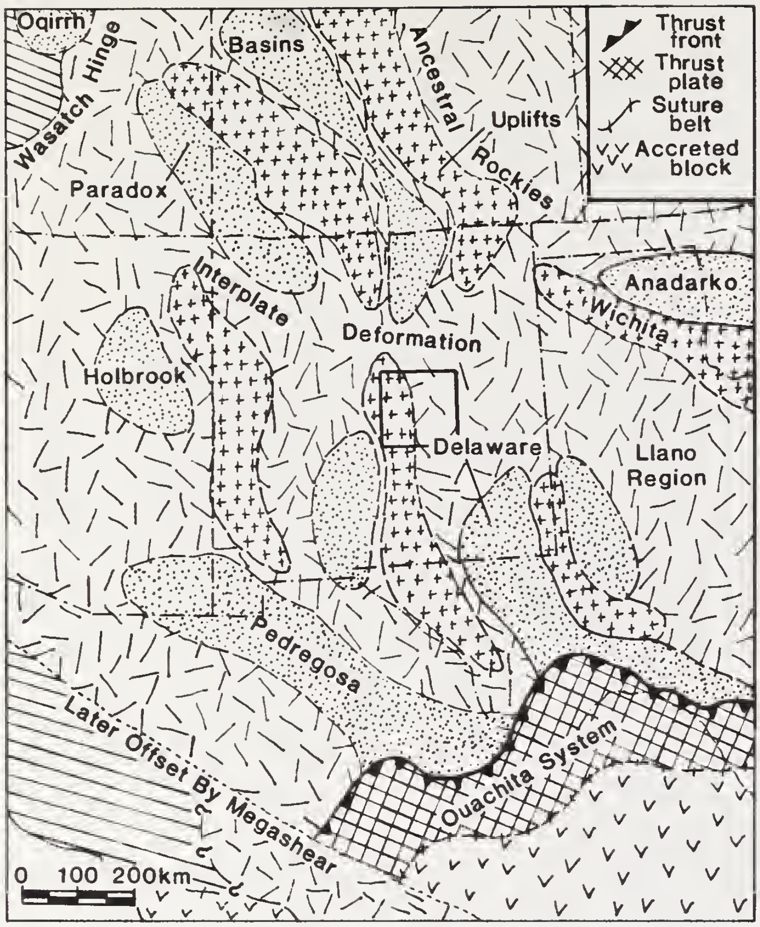
FIGURE 2: Paleotectonic maps of the southern Cordillera, New Mexico and adjoining areas, and map of mineral-deposit assemblage zones of the same area. Boldface square is approximate location of figure 1.

A. Paleotectonic map, mid-Carboniferous to mid-Triassic (325-225 m.y.B.P.), featuring basins and uplifts of the Pennsylvanian and Early Permian. Dotted areas = basins; plusses (+) = uplifts.

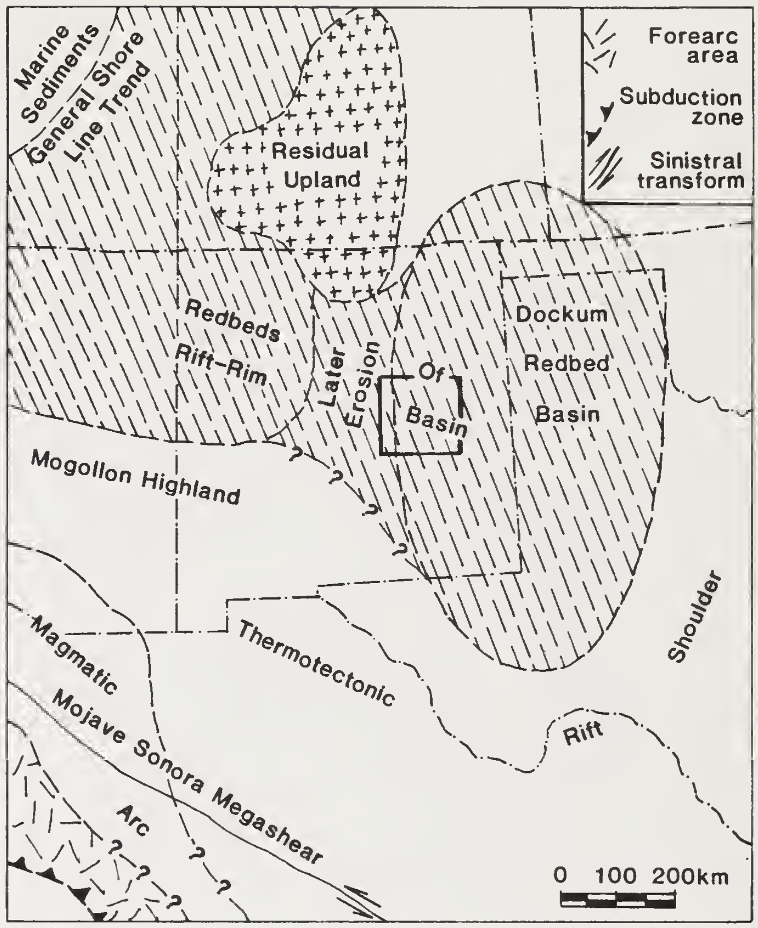
B. Paleotectonic map, mid-Triassic to mid-Late Jurassic (225-150 m.y.B.P.), showing redbed basins (dashed pattern) and thermo-tectonic rift shoulder. Rifted continental margin is immediately southeast of the area.

C. Paleotectonic map, latest Cretaceous to Recent time (75-0 m.y.B.P.), showing extent of Tertiary Laramide deformation and later Tertiary to present Rio Grande rift.

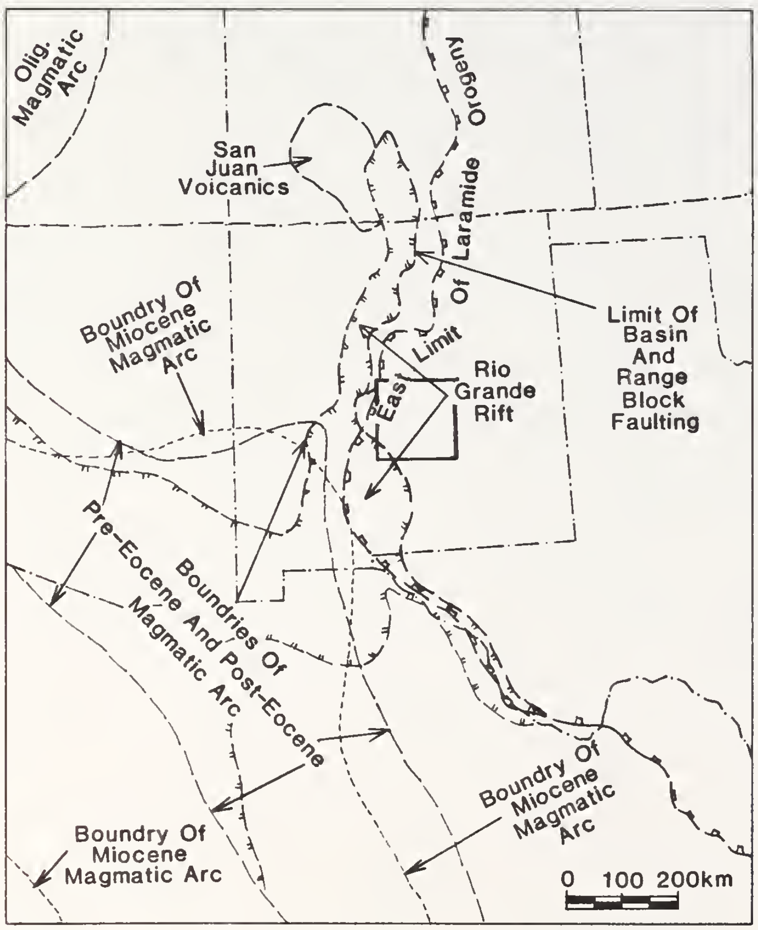
D. Mineral deposit assemblage zones. Light face dotted pattern = fluorite zone; bold face dotted pattern = molybdenum zone; v = copper-molybdenum zone. A, B, and C after Dickinson, 1981; D after Clark et al., 1982.


Oqirrh
Wasatch Hinge
Basins
Ancestral
Rockies
Uplifts
Thrust front
Thrust plate
Suture belt
Accreted block
Paradox
Interplate
Deformation
Anadarko
Wichita
Holbrook
Delaware
Llano Region
Pedregosa
Later Offset By Megashear
Ouachita System
0 100 200km

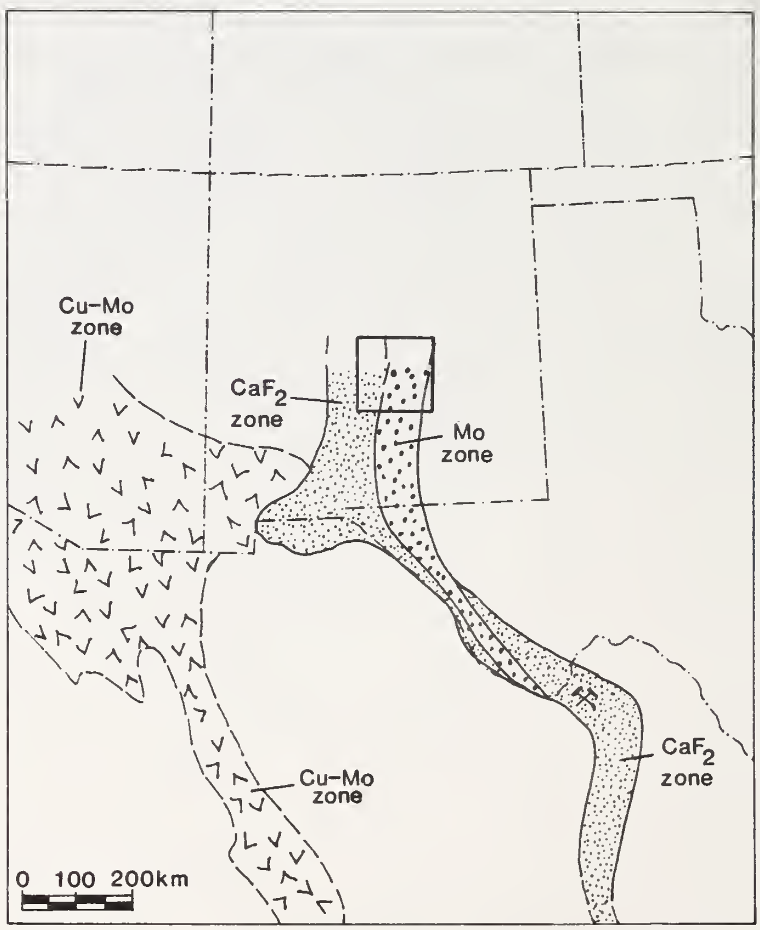
2a.


Marine Sediments
General Shore Line Trend
Residual Upland
Forearc area
Subduction zone
Sinistral transform
Redbeds
Rift-Rim
Later Erosion
Of
Basin
Dockum
Redbed
Basin
Mogollon Highland
Magmatic
Arc
Mojave Sonora Megashear
Thermotectonic
Rift
Shoulder
0 100 200km

2b.


Olig. Magmatic Arc
San Juan Volcanics
Laramide Orogeny
East Limit Of
Limit Of Basin And Range Block Faulting
Boundry Of Miocene Magmatic Arc
Rio Grande Rift
Pre-Eocene And Post-Eocene Magmatic Arc
Boundries Of
Boundry Of Miocene Magmatic Arc
Boundry Of Miocene Magmatic Arc
0 100 200km

2c.


Cu-Mo zone
CaF2 zone
Mo zone
CaF2 zone
Cu-Mo zone
0 100 200km

2d.

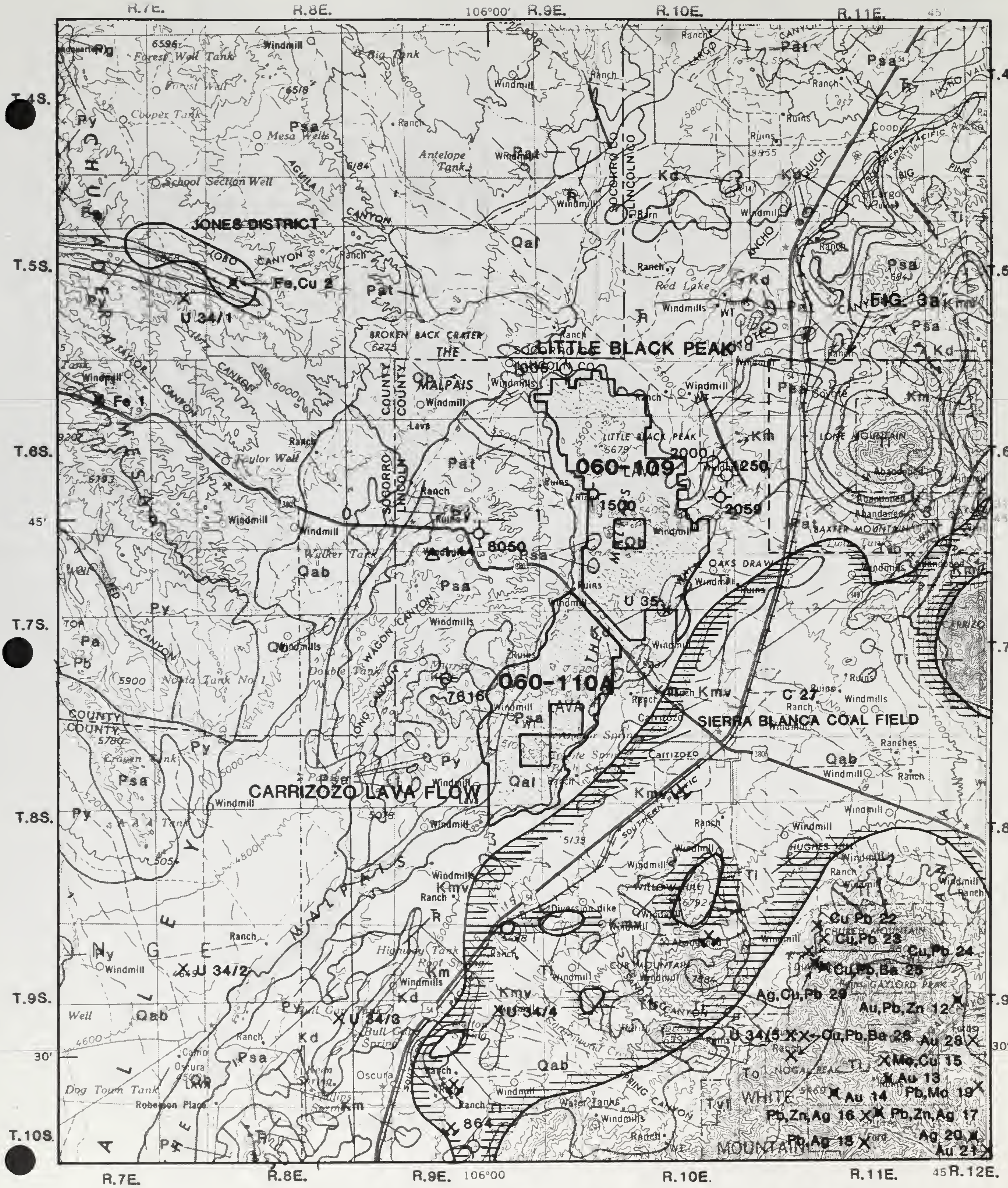


FIG. 3. GEOLOGIC, ENERGY AND MINERAL RESOURCES MAP OF THE CARRIZOZO AREA, NEW MEXICO

Scale
1 : 250,000
LEGEND: see enclosed

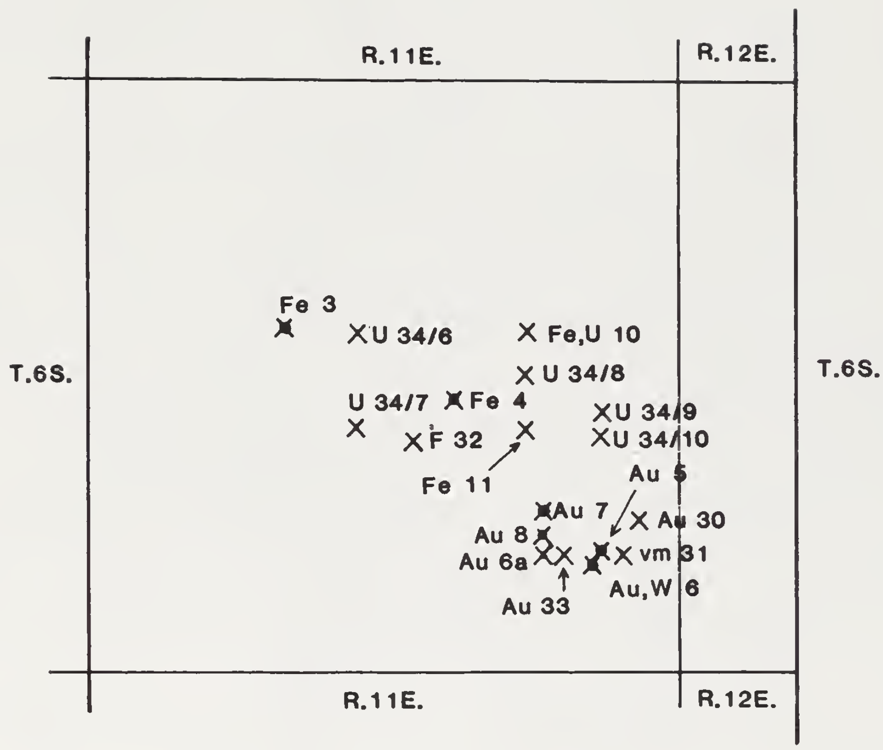


FIG. 3a **DETAILED MAP FROM FIG. 3**

Scale 1 : 125,000

Figure 4. **LEGEND**

FOR

GEOLOGIC, ENERGY AND MINERAL RESOURCES MAPS

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

LITHOSTRATIGRAPHY

After C.H. Dane and G.O. Bachman, 1965,
and Segerstrom et al., 1979

QUATERNARY	HOLOCENE	Qal	ALLUVIUM
	PLEISTOCENE	Qab	ALLUVIUM, bolson deposits and other surficial deposits
		Qb	ALKALI OLIVINE BASALTS of the Carrizozo malpais (recent) and Broken Back crater flow (Pleistocene?) asterisk ( ) indicates eruptive center
TERTIARY	PLIOCENE TO MIOCENE	To	OGALLALA FORMATION – slightly lithified fan gravels, gray, yellow and white sands and silts
		Tvb	VOLCANIC BRECCIAS, tuffs, volcanic sediments with interbedded mudstone, sandstone and shale. Possibly correlative with the Sierra Blanca volcanics
	OLIGOCENE	Tvl	SIERRA BLANCA VOLCANICS – andesite flows, breccias and tuffs with latite and trachyte flows
	EOCENE	Ti	INTRUSIVES – augite diorite, diorite, quartz diorite, monzonite, granodiorite, granite, alkali syenite, trachyte and lamprophyres. Stocks, laccoliths, sills and dikes
		Tbc	CUB MOUNTAIN FORMATION – continental arkose, claystone, mudstone, and siltstone, graywacke with veinlets of gypsum
CRETACEOUS	UPPER	Kmv	MESAVERDE GROUP – yellow to brown calcareous sandstone, siltstone, clay, shale and coal
		Km	MANCOS SHALE – gray to black shale, with interbedded limestone and sandstone
		Kd	DAKOTA SANDSTONE – sandstone with interbedded siltstone, and shale. Locally glauconitic
TRIASSIC		T̄R	DOCKUM GROUP: CHINLE FORMATION – purple to brown siltstone, mudstone and claystone with thin quartz sandstone and conglomerate SANTA ROSA SANDSTONE – red to brown calcareous sandstone with interbedded siltstone and shale

PERMIAN	GUADALUPE	Pat	ARTESIA FORMATION - buff to red calcareous sandstone and siltstone
		Psa	SAN ANDRES LIMESTONE - gray limestone with sandstone and gypsum interbeds
	LEONARD	Pg	GLORIETA SANDSTONE - white to pink quartz sandstone
		Py	YESO FORMATION - orange to light red sandstone, gypsum, limestone, siltstone and shale
	WOLFCAMP	Pa	ABO SANDSTONE - dark red limestone, gypsum, siltstone, shale and limestone pebble conglomerate
		Pb	BURSUM FORMATION - red to brown conglomerate, arkose and shale with interbedded limestone

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

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
li Lime

di 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
- ni Nitrates
- Sr Strontium
- Br Bromine
- cc Calcium chloride
- mg Magnesium compounds

fs Feldspar
F Fluorite (fluorspar)
gs Gem stones
ge Graphite
He Helium
ki Kaolin
ky Kyanite and related minerals
ls Limestone
lm Lithium minerals

mg Magnesian refractories
mi Mica
ph Phosphate
pi Pigment and fillers
qz Quartz crystals
si Silica sand
S Sulfur
tc Talc
ze Zeolites
hm Humate

SPECIAL GEOLOGICAL FEATURES

POINT OF SPECIAL GEOLOGIC INTEREST

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

Carrizozo GRA are dated as 1.57 to 1.35 b.y.B.P. and are included in the central granite belt of Muehlburger and Denison (1964). The rocks are part of the ENE-trending 1.65 to 1.2 b.y. belt of rocks that extends from southwest New Mexico to Illinois (Condie and Budding, 1979). In central New Mexico this belt consists mainly of granitic plutons (70%) which intrude metamorphic rocks (30%). The metamorphic grade ranges from lower greenschist to amphibolite facies. In decreasing order of abundance, the metamorphic rocks consist of phyllite and quartz-mica schist, quartzite and arkosite, mafic meta-igneous rock, siliceous meta-igneous rock and gneiss (Condie and Budding, 1979). According to Condie and Budding (1979), this sequence of rocks is similar to the association found in modern continental rift systems, but according to Dickinson (1981), the voluminous granites, calc-alkaline metavolcanics and widespread metamorphic belts suggest a convergent environment.

Drill cores from a well within the Carrizozo GRA have included Precambrian troctolite (olivine-plagioclase rock interpreted as a differentiate of gabbro). Near the GRA, Precambrian feldspathic quartzites, albite diabase, granodiorite, and granite gneiss cut by diorite dikes have been drilled (Muehlberger and Denison, 1964).

Permian

Permian sediments crop out over much of the western, and northeastern parts of the Carrizozo GRA (fig. 3). The Permian rocks of the GRA and adjacent areas have been studied by Kottlowski et al. (1956), Kottlowski (1963), Weber (1964), Smith (1964) Budding (1964) and Segerstrom and Ryberg (1974), and have been divided into the Bursum, Abo, Yeso, Glorieta, San Andres and Artesia Formations, all of which crop out in the Carrizozo GRA.

The Bursum Formation consists of dark red to reddish brown conglomerate, arkose, shale with interbedded brownish green algal limestone and colonial limestone. The formation is 450 feet thick in the Mockingbird Gap quadrangle (Bachman, 1968) several miles to the west of the GRA, but only a small part of the section crops out at the western edge of the Carrizozo GRA (fig. 3) (Weber, 1964).

The Abo Formation, which crops out in the western part of the GRA (fig. 3), consists of interbedded dark reddish-brown mudstone, claystone and arkosic conglomerate, with much of the arkosic conglomerate found at the base. Thickness of the mainly terrestrial Abo Formation in the western part of the GRA is 1560 feet (Weber, 1964). The Abo apparently conformably overlies the Bursum Formation.

The Yeso Formation, which crops out in the west half of the GRA (fig. 3), is mainly shallow marine-lagoonal and consists of orange to light red interbedded limestone, salt beds, gypsum, sandstone and mudstone. The Yeso Formation is up to 4265 feet thick (Weber, 1964) in the GRA, but true thickness is difficult to determine due to thickening resultant from folding and mobilization of salt beds. The Yeso is only 750 feet thick in the type area north of Socorro, but is reported to be 1500 feet thick in the San Andres Mountains (Bachman and Harbour, 1970) to the west of the Carrizozo GRA.

The Glorieta Sandstone is not persistent in the GRA, present only as lenses and discontinuous beds in the basal section of the San Andres Limestone (Budding, 1964; Smith, 1964) in the west-central and western parts of the GRA and as a continuous bed in the northwestern part. The Glorieta Sandstone is white to light gray to pink medium-grained, well-sorted quartz sandstone (Budding, 1964; Segerstrom and Ryberg, 1974). The Glorieta Sandstone conformably overlies the Yeso Formation.

The San Andres Limestone crops out in the central, west, northwest and northeast parts of the Carrizozo GRA (fig. 3). In the northeast part of the GRA it consists of chert-bearing, dark gray porous limestone with sandstone interbeds near the base and discontinuous gypsum layers near the top (Budding, 1964; Segerstrom and Ryberg, 1974). A thickness of 510 to 615 feet is reported by Budding (1964), whereas Segerstrom and Ryberg (1974) measured 841 feet of San Andres in the same area. Weber (1964) reports 600 to 685 feet thickness northwest of Carrizozo and Smith (1964) measured 765 feet of San Andres Limestone at Lone Mountain in the eastern part of the GRA. The contact between the San Andres Limestone and the underlying Yeso Formation is gradational.

The Artesia Formation, which crops out in the northeastern and north-central parts of the Carrizozo GRA, consists of buff to light brown and orange-red to red fine- to coarse-grained friable calcereous sandstone and siltstone with a few thin beds of gypsum (Segerstrom and Ryberg, 1974). Segerstrom and Ryberg report 376 feet of Artesia Formation in an area whereas Budding (1964) found 270 to 320 feet of what he termed "Bernal(?) Formation". There was much confusion among early workers as to what to call these rocks, but at the suggestion of the U.S. Geological Survey, the term Artesia Group was adopted in areas where more than one distinct formation occurs and Artesia Formation for areas where the shelf sediments between San Andres Limestone and Ochoan Series are more homogenous (Tait et al., 1962).

The Permian sediments were deposited in a basin into which sediments were fed from the Pedernal uplift adjacent to the GRA in the east and south and from the Burro-Zuni uplift to the northwest (fig. 2) (Dickinson, 1981).

Triassic

Triassic rocks cover much of the north-central and northeast parts of the Carrizozo GRA, with a small band cropping out in the southern section (fig. 3). Two Triassic units, the Santa Rosa sandstone and the Chinle Formation, which together make up the Dockum Group, are present in the area.

The late Triassic Santa Rosa sandstone consists of reddish brown to brown, and in a few localities, white to tan coarse- to medium-grained calcareous friable sandstone interbedded with red to brown calcareous siltstone and shale (Budding, 1964; Smith, 1964; Weber, 1964; Segerstrom and Ryberg, 1974). Coarser-grained layers are cross-bedded and grade into thin quartz and chert pebble conglomerate lenses (Budding, 1964). The Santa Rosa sandstone is 170 to 200 feet thick in the GRA (Weber, 1964; Segerstrom and Ryberg, 1974) and disconformably overlies the Artesia Formation in the northeast and San Andres Limestone in the southwest.

The Chinle Formation consists of purple to red to chocolate brown, poorly resistant siltstones, mudstones and claystones with thin quartz sandstones and limestone pebble conglomerates. Silicified wood is locally abundant in the Chinle, which varies in thickness from 200 to over 400 feet (Budding, 1964; Smith, 1964; Weber, 1964; Segerstrom and Ryberg, 1974) in the Carrizozo GRA. The contact between the underlying Santa Rosa sandstone and the Chinle is gradational. Both Triassic units are terrestrial and were derived from the Mogollon highlands to the south (fig. 2) (Dickinson, 1981). In northwestern New Mexico the Chinle is host to important stratabound uranium deposits (Hilper, 1969).

Cretaceous

Upper Cretaceous sediments of the Dakota, Mancos and Mesaverde Formations crop out in the south-central, north-central and eastern parts of the Carrizozo GRA (fig. 3).

The Dakota sandstone is composed of white to light brown medium- to coarse-grained, locally glauconitic, quartz sandstones with interbedded siltstone and carbonaceous shale (Budding, 1964; Smith, 1964; Weber, 1964; Segerstrom and Ryberg, 1974). Crossbedding is present in some of the sandstones and a few conglomeritic fluvial channel deposits are reported (Kottlowski et al., 1956, Kottlowski, 1963; Smith, 1964). The Dakota sandstone ranges in thickness from 120 to 200 feet (Budding, 1964; Smith, 1964; Segerstrom and Ryberg, 1974). The presence of glauconite suggests that the upper part of the Dakota is marine. A slight angular unconformity is present between the Chinle and the Dakota (Segerstrom and Ryberg, 1974).

Conformably overlying the Dakota sandstone is the marine Mancos Shale. The Mancos Shale is composed of gray to black, fossiliferous, calcareous, pyritic shale with sparse, thin-bedded limestone and sandstone. The Mancos shale contains abundant plant fossils, pelecypods, cephalopods ostrea and brachiopods. A thickness of 600 to 700 feet is reported for the area (Smith, 1964).

The Mesaverde Group consists of yellowish gray to buff and brown, thin-bedded, fine- to medium-grained, lenticular, calcareous sandstone, with interbeds of gray to yellowish brown siltstone and shale, gray to olive green clay and shale, carbonaceous shale and thin coal beds. Crossbedding is prevalent in the terrestrial sandstones and ripple marks are found in several localities. Several of the marine sandstones contain gastropods, cephalopods and ammonites. The Mesaverde Group is in gradational contact with the Mancos and is at least 415 feet thick (Budding, 1964; Smith, 1964).

Early Tertiary

The Cub Mountain Formation of probable Eocene age crops out in the south-central part of the GRA (fig. 3). According to Weber (1964), it consists of white to gray and yellow to brown massive to thin-bedded, fine- to coarse-grained poorly sorted arkose, some with crossbedding and channeling at the base. Interbedded with the arkose is purple, red, gray and green smectitic claystone, mudstone, siltstone and fine-grained sandstone. Thin lenses of conglomerate are present in some horizons. Coarser-grained beds at the top of the section are andesite-bearing graywackes. Seams and veinlets of gypsum are associated with fine-grained sediments. The 2400 feet of continental sediments are correlative with the Baca Formation (Weber, 1964), and according to Kelley and Thompson (1964), are also correlative with the McRae Formation. Cub Mountain rocks rest unconformably on Cretaceous Mesaverde sediments.

Mid-Tertiary

Andesitic volcanics of the Sierra Blanca volcanic pile, possibly correlative with the Late Eocene to Early Miocene Datil Formation which crops out to the west of the GRA, crop out in the Sierra Blanca Mountains in the southeast part of the GRA (fig. 3). Datil volcanism occurred between 40 and about 20 m.y. ago (Burchfiel, 1979) and peaked about 30 m.y. ago (Lipman, 1981). According to Elston and Bornhorst (1979), between 40 and 32 m.y. ago the volcanism was related to subduction of the Farallon plate and consisted of calc-alkaline andesite, quartz latite and rhyolite; activity became more felsic with time. In the Sierra Blancas, the volcanics consist of 3400 to 4000 feet of andesite breccias, tuffs, flows and porphyrys with local latites (Thompson, 1964).

Between 32 and 20 m.y. ago, the Pacific plate collided with the American plate, the San Andres fault was initiated, subduction slowed and back-arc, bimodal, calc-alkaline, basaltic andesite and high-silica rhyolite volcanism developed (Elston and Bornhorst, 1979). In the Carrizozo GRA, numerous Tertiary intrusives (the largest concentration of Tertiary intrusives in New Mexico) are likely representative of this change in magmatic style. The rocks consist of augite diorite, diorite, quartz diorite, monzonite, granodiorite, granite, alkali syenite, trachyte and lamprophyres. Intrusive forms include stocks, laccoliths, sills and dikes (Budding, 1964; Smith, 1964; Weber, 1964; Segerstrom and Ryberg, 1974).

Volcanic sediments, agglomerate, tuff and breccia interbedded with mudstone, sandstone and shale and containing fragments of the Lone Mountain stock cover part of the Lone Mountain intrusive and domed Paleozoic and Mesozoic sediments in the eastern part of the GRA (fig. 3). The 400 feet of volcanics and sediments were previously mapped as Cub Mountain Formation, but Smith (1964) tentatively correlates them with the Sierra Blanca volcanics.

Late Tertiary

Sedimentary rocks of the Pliocene Ogallala Formation, which crop out in the south-central part of the GRA, indicate a higher plateau surface than is now present in the area. The Ogallala Formation, studied by Budding (1964), Segerstrom and Ryberg (1974) and Segerstrom et al. (1979), is composed of slightly lithified fan gravel (including boulders of limestone, chert, jasper, igneous rocks, sandstone, mudstone, quartzite and magnetite), and sand and silt, which are gray to yellow-brown and white. The sediments are largely unsorted and unstratified and are host to placer gold deposits in the Jicarilla Mountains east of the Carrizozo GRA.

Quaternary

Quaternary deposits include alkali or subalkaline olivine basalt (Faris, 1980) and unconsolidated sediment. The basalt is present as flows in the center to southwest and northwest parts of the GRA (fig. 3) and likely represents a continuation of Rio Grande rift-related volcanism, which was initiated 21 m.y. ago and coincided with the growth of the San Andres transform and intra-plate block faulting of the Basin and Range Province (Elston and Bornhorst, (1979).

Three different basalt flows are recognized in the area (Faris, 1980; Smith, 1964). The oldest basalt flowed out of the Broken Back crater in the northwest part of the area. The flows show some weathering and a thin soil mantles the basalt. The two more recent Little Black Peak flows show no weathering and may have extruded in historic times. The basalts are greenish gray to black and vesicular, particularly in the upper two feet. The rock is fine-grained to aphanitic with laths of labradorite and olivine as phenocrysts. A crude trachytic texture is present. The Little Black Peak flows of the Carrizozo malpais have the ropy surface characteristic of pahoehoe. The flows are 44 miles long, from 1/2 to 5 miles in width and 162 feet thick. The two WSAs lie largely within the younger of the two flows.

Quaternary sediments include landslide deposits, glacial deposits and valley-fill. Stream sediments in the Jicarilla Mountains east of the GRA are host to second-cycle placer gold deposits (Segerstrom and Ryberg, 1974). Pleistocene glacial deposits in the Sierra Blanca Mountains show evidence of two episodes of glaciation (Richmond, 1964).

Structural Geology and Tectonics

The area lies within the North American craton which, during the Proterozoic, underwent two periods of deformation and granite intrusion (Condie and Budding, 1979). The area remained tectonically quiet until the Pennsylvanian-Permian, at which time, possibly due to the Ouachita orogeny in the south, the region underwent warping (fig. 2A) (Dickinson, 1981).

During the Laramide, minor folding took place but this was not associated with any igneous activity in central New Mexico. During the Oligocene, the dip of the Farallon plate beneath North America decreased to about 15° (Coney and Reynolds, 1977) and voluminous calc-alkaline volcanics were erupted in central New Mexico (Elston, 1978; Elston and Bornhorst, 1979).

From early Miocene to the present has been a time of intense tectonic activity along and close to the Rio Grande rift (fig 2C). The activity has been dominated by normal faulting and bimodal magmatism within and along the flanks of the Rio Grande rift. Brown et al. (1979) have found evidence of faults with displacements of up to four kilometers within the rift. The crustal thickness beneath the Rio Grande rift has been found to be 35 km, compared to 45 and 55 km beneath the Colorado Plateau and Great Plains, respectively (Keller et al., 1979). The thinning of the crust, the bimodal magmatism and the normal faulting are probably related to cessation of subduction and growth of the San Andres fault since the Miocene.

In the Carrizozo GRA, NW- to NE-trending normal faults are present along with one WNW-trending normal fault. The area was gently warped, producing the Mescalero arch, the Claunch sag-Tularosa basin and the Chupadera arch, broad north-trending structures listed in order from east to west. Intrusions in the Tertiary resulted in doming, gravity sliding, and folding of sediments between the intrusive bodies (Kelley and Thompson, 1964; Budding, 1964; Smith, 1964; Weber, 1964; Segerstrom and Ryberg, 1974).

Paleontology

Paleontological documentation is important for three major reasons, as follows:

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

b. outstanding fossil specimens or fossils which are extra ordinarily 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 can trigger the precipitation of uranium and/or other metals.

The following is a brief summary of the sedimentary formations of the WSAs and their surroundings listing types of fossils present. To the authors' knowledge, there are no fossil localities of outstanding importance, neither scientifically nor as curiosities.

The two WSAs are mostly underlain by Quaternary basalt, with lesser Permian San Andres and Yeso Formations, Triassic Dockum Group sediments, Cretaceous Dakota Sandstone and Mancos Shale, and Quaternary alluvium also cropping out.

No fossils are reported from the Yeso Formation in this part of New Mexico. As the Yeso Formation was deposited in hypersaline seas, it is unlikely to be highly fossiliferous. The San Andres Formation contains cephalopods and brachiopods. The Dockum Group contains silicified wood in other localities. Plant fossils and fecal pellets are reported from the Dakota Sandstone. The Mancos Shale contains abundant plant fossils, pelecypods, cephalopods, ostrea and brachiopods.

Geologic History

The geological history of the area is long and complex. Only a brief synopsis is presented here. Excellent summaries of the main geological events that affected the Cordillera of New Mexico are given by Hilpert (1969), Burchfiel (1979) and Dickinson (1981). A more detailed account of the geologic history of the Carrizozo-Ruidoso area of central New Mexico is presented by Kelley and Thompson (1964).

The area lies within a 1.2 to 1.65 b.y. ENE-trending belt within the North American craton. It contains metasedimentary and both mafic and felsic meta-igneous rocks that have been folded twice, metamorphosed and intruded by granites (Condie and Budding, 1979).

The post-Precambrian geologic history is summarized as follows:

1. Periodic southward tilting took place from Cambrian to Mississippian time.
2. Late Mississippian uplift and erosion. Transgression took place to the west and may have or may not have affected the Carrizozo area.
3. During the late Pennsylvanian to early Permian, the Ouachita orogeny to the south caused uplift and folding of the north-trending Pedernal Mountains (fig. 2A). The uplift was the main source of sediment during the late Pennsylvanian and Permian. During the regression, the Bursum Formation was deposited. The culmination of this regressive sequence is the Abo Formation which is a continental redbed sequence.
4. A marine transgression followed, allowing deposition of the shallow marine-lagoonal Yeso Formation which contains evaporites and redbeds, the mainly carbonate San Andres Formation and shallow marine Artesia Formation.
5. During the Triassic, the area was uplifted, bevelled and the continental redbeds of the Santa Rosa sandstone and Chinle Formation (Dockum Group) were deposited (fig. 2B).

6. The area remained uplifted during the Jurassic and no sedimentation took place. During the Cretaceous shallow marine sedimentation was followed by deposition of coal-bearing terrestrial beds of the Mesaverde Group.
7. The effects of the Laramide orogeny were barely felt in central New Mexico and resulted in gentle folding (fig. 2C). This was followed by erosion.
8. During the Eocene, the continental sediments of the Cub Mountain Formation were deposited.
9. From latest Eocene to the present followed a period of volcanism and tectonism which can be divided into three phases:
   a. The first phase lasted from 40-30 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. The Sierra Blanca volcanics were probably deposited at this time.
   b. The second phase lasted from 30-20 m.y. At this time the Pacific plate collided with North America, the San Andres fault was initiated and a modified back-arc stage of magmatism took place as a result of the still-active Farallon plate beneath the southern Cordillera. The Tertiary intrusives were probably intruded about this time.
   c. From 20 m.y. to the present, intra-plate normal faulting and bimodal volcanism has taken place and is likely associated with cessation of subduction and growth

of the San Andres transform. During this time the Rio Grande rift developed (fig. 2C).

10. Igneous activity and deformation have continued to the present day as evidenced by the historical eruption of basalt from the Little Black Peak.

ENERGY AND MINERAL RESOURCES

The following are descriptions of known mineral deposits, prospects, occurrences, mineralized areas and coal and other energy resources of the Carrizozo GRA. Location of the deposits are shown in figure 3. The following information was derived from Haigler and Sutherland (1965), New Mexico Bureau of Mines and Mineral Resources (1965), U.S. Geological Survey (1981a and b), King and Harder (1982), and other references quoted in the main body of this report. It represents a summary of knowledge available to the authors regarding individual mines and occurrences.

Known Mineral Deposits, Mines or Prospects with Recorded Production

1. Iron Horse Mine

Location:	Sec. 9, T6S, R7E, New Mexico Meridian
Commodity:	Fe
Ore Materials:	Magnetite, hematite, limonite.
Geology:	Mineralization is a result of pyrometasomatic replacement of limestone and gypsum of the Permian Yeso Formation by magnetite, some now altered to hematite and limonite, adjacent to monzonite dike.
Production:	Mine produced 6125 tons of 58% Fe ore in WWII.

2. Jones-Chupadera Mesa Magnetite Mine

Synonym Names:	Jones Camp, Jones Magnetite-Hematite Deposit; includes Vulan Group Claims, Iron Crown Claims, Rusty Bell Group Claims
Location:	33°51´48"N, 106°08´57"W SW1/4, Sec. 14, SE1/4 Sec. 15, NE1/4 Sec. 23, N1/2 Sec. 24, T5S, R7E and SW1/4 Sec. 19 and NE1/4 Sec. 30, T5S, R8E, New Mexico Meridian
Commodities:	Fe, Cu; past producer of Fe
Ore Materials:	Magnetite, hematite, chalcopyrite, azurite, malachite.

Description of Deposit: 23 ore bodies; lenticular replacement of limestone ranging from 150-1500 feet in length and from 1-30 feet in thickness. Magnetite has also concentrated in placers.
Geology: Ore deposits are pyromentasomatic replacements of limestones of the Permian Yeso Formation resultant from Tertiary monzonite dikes and diabase sill intrusions. Gangue material is calcite, actinolite, tremolite, gypsum, clay and limestone.
Production: Some production, total unknown.

3. Ferro Mine
Location: Boundary between sec. 16 and 17, T6S, R11E
Commodity: Fe
Ore Materials: Magnetite and hematite.
Description of Deposit: Lense shaped deposit 1 to 6 feet wide trending N45^{o}, dipping 50^{o}.
Geology: Pyrometasomatic replacement of Permian San Andres limestone intruded by Tertiary syenite.
Production: 4000 to 8000 tons of ore were produced.

4. Yellow Jacket Mine
Location: Sec. 22, T6S, R11E
Commodity: Fe
Ore Materials: Hematite, magnetite, specularite.
Description of Deposit: Three tabular ore bodies are present: 25 feet wide, 75 feet long, 30 feet deep; 150 feet long, 12 feet wide; 35 feet by 35 feet, 125 feet deep.
Geology: Ore is pyrometasomatic replacement of Permian San Andres limestone intruded by monzonite and syenite.
Production: Produced 20,008 tons of iron ore between 1913 and 1942, which amounted to 30% of total iron produced in Lincoln County.

5. Old Abe Mine
Location: SW1/4 sec. 25, T6S, R11E
Commodity: Au
Ore Materials: Auriferous pyrite.
Description of Deposit: N10^{o}W trending vein.
Geology: Vein is brecciated zone in Tertiary monzonite dike at its contact with Cretaceous sedimentary rocks.
Production: 45,745 ounces of gold were produced.

6. South Homestake Mine
Location: SW1/4 sec. 25, T6S, R11E
Commodities: Au, W
Ore Materials: Auriferous pyrite, huebnerite.
Description of Deposit: Closely spaced veins in N-trending fractures.
Geology: Mineralization along fractures in Tertiary monzonite dike.
Production: 30,000 ounces of gold and 90,000 lbs. tungsten produced.

7. Little Mack and Henry Clay Mines
Location: NE1/4 sec. 26, T6S, R11E
Commodity: Au
Description of Deposit: N70°E trending veins.
Geology: Deposition of ore along fractures in Tertiary monzonite.
Production: 2579 ounces of gold produced.

8. North Homestake Mine
Location: SE1/4 sec. 26, T6S, R11E
Commodity: Au
Geology and Description of Deposit: Gold is in veins in Tertiary lamprophyre dike.
Production: 20,039 oz.

12. Helen Rae and American Mines
Location: NW1/4 sec. 13, T9S, R12E
Commodities: Au, Pb, Zn
Ore Materials: Auriferous pyrite, sphalerite, galena.
Description of Deposit: N-striking, steeply dipping fissure veins.
Geology: Mineralization in veins filling fractures in Tertiary Sierra Blanca volcanics.
Production: Yes.

13. Parsons Mine
Location: NE1/4, NE1/4, NE1/4 sec. 34, T9S, R11E
Commodity: Au
Ore Materials: Free gold from weathering of auriferous pyrite.
Description of Deposit: Veinlets in breccia.
Geology: Gold is present in veinlets in kaolinitized andesite breccia of the Tertiary Sierra Blanca volcanics.
Production: Yes, total unknown.

14. Turkey Creek
Location: SW1/4 sec. 33, T9S, R11E
Commodity: Au
Production: Small production reported.

17. Renowned Mine
Location: NE1/4 sec. 3, T10S, R11E
Commoditities: Pb, Zn, Ag
Ore Materials: Galena, sphalerite, chalcopyrite.
Description of Deposit: W-trending vein.
Geology: Silver-bearing galena plus sphalerite and chalcopyrite are present in a quartz vein in Tertiary andesite.
Production: 25 tons of Pb-Ag concentrates were shipped in 1957.

20. Hope Prospect
    Location: SE1/4 sec. 1, T10S, R12E
    Commodity: Ag
    Ore Material: Galena(?).
    Geology: Rock is sericitized and kaolinitized andesite porphyry.
    Production: Small production is reported.

25. Idaho Mine
    Location: East-central sec. 8, T9S, R11E
    Commodities: Cu, Pb, Ba
    Ore Materials: Cu- and Pb-sulfides, barite.
    Description of Deposit: Vein trends E and dips steeply north.
    Geology: Mineralization is in a fissure-filling vein at contact of a Tertiary syenite dike with Tertiary Sierra Blanca volcanics.
    Production: 160 tons of copper ore were shipped prior to 1944.

27. Coal Mines of the Sierra Blanca Coalfield
    Location: NE1/4 sec. 32, T9S, R9E; center sec. 5, T10S, R9E; SW1/4 sec. 10, T8S, R10E and W1/2 sec. 2, T9S, R10E
    Coal field: covers parts of T6S, R11, 12 and 13E; T7S, R10, 11, 12E; T8S, R9, 10, 12, 12 and 13 E; T9S, R9, 10 and 11E; T10S, R9E.
    Commodity: Coal
    Ore Materials: Bituminous coal.
    Geology and Description of Deposit: 1644 million tons of bituminous coal are estimated to be present in the Sierra Blanca coal field. Several thin coal horizons that are folded and faulted are present in the Cretaceous Mesaverde Group.
    Production: 600,000 tons has been produced from the coal field but much of the production may have been outside the GRA at the Capitan and White Oaks workings.

29. Ace Mine, Cravens Property
    Location: Sec. 8, T9S, R11E
    Commodities: Ag, Cu, Pb
    Geology: Deposit is in Tertiary Sierra Blanca volcanics.
    Production: 145 tons of ore.

Known Prospects and Mineralized Areas with no Production Recorded

6A. Rite Mine
    Location: SE1/4 sec. 26, T6S, R11E
    Commodity: Au
    Description of Deposit: The Rita shaft was used to haul ore out of the North Homestake mine after a shaft fire destroyed the timbers in the original shaft.
    Production: None. See North Homestake for production.

10. House Prospect
Carolyn O patented claims, Las Cinco Reinas Mine, Prince Mine
Commodities: Fe, U
Ore Material: Magnetite.
Description of Deposit: Small replacement deposit.
Geology: Magnetite is pyrometasomatic replacement of limestone and gypsum of Permian Yeso Formation. Very little 60% Fe ore is present. Uranium is present in minor amounts.
Production: Unknown.

11. Black Knight and Good Night Mine
Location: Sec. 23, T6S, R11E
Commodity: Fe
Ore Materials: Magnetite.
Description of Deposit: Lense shaped deposits.
Geology: Magnetite is pyrometasomatic replacement of limestone that has been intruded by Tertiary granitic rocks.
Production: Unknown.

15. Rialto Prospect
Location: SE1/4 sec. 27, T9S, R11E
Commodities: Mo, Cu
Ore Materials: Molybdenite, chalcopyrite.
Description of Deposit: Veinlets and disseminations.
Geology: Ore minerals occur in veinlets and as disseminations in altered Tertiary monzonite.
Production: None.

16. Old Abe
Location: NW1/4 sec. 3, T10S, R11E
Commodities: Pb, Zn, Ag
Ore Material: Galena.
Geology and Description of Deposit: W-trending galena-quartz vein in andesite breccia.
Production: Unknown.

18. Maud Mine
Location: SW1/4 sec. 3 , T10S, R11E
Commodities: Pb, Ag
Ore Material:s Argentiferous galena.
Description of Deposit: W-trending vein.
Geology: Galena present in W-trending quartz vein in altered andesite.
Production: Unknown.

19. Water Dog Prospect
Location: NE1/4 sec. 36, T9S, R12E
Commodities: Pb, Mo
Ore Materials: Galena, molybdenite.
Description of Deposit: Galena in veinlets, molybdenite as disseminations.
Geology: Veinlets and disseminations in altered latite porphyry.
Production: Unknown.

21. Creek Lead
Location: Center sec. 7, T10S, R13E
(range 12E is approx. 1 mile wide)
Commodity: Au
Ore Material: Auriferous pyrite.
Description of Deposit: N-trending mineralized zone.
Geology: Mineralization is in altered andesite.
Production: Unnknown.

22. Homestake Mine
Location: NE1/4 sec. 5, T9S, R11E
Commodity: Cu, Pb
Ore Materials: Cu- and Pb-sulfides.
Description of Deposit: Ore-bearing veins fill fissures.
Geology: Mineralization occurs at the boundary between two E-trending Tertiary porphyry dikes and intruded Tertiary Sierra Blanca volcanics. Post-emplacement movement is indicated. Quartz and calcite are present as gangue.
Production: No significant production.

23. Commercial Mine
Location: SE1/4 sec. 5, T9S, R11E
Commodities: Cu, Pb
Ore Materials: Cu- and Pb-sulfices.
Description of Deposit: Fissure-filling veins striking N75°
Geology: Two parallel veins are present in a fault breccia zone in Tertiary Sierra Blanca andesites.
Production: No significant production.

24. Junction Mine
Location: NW1/4 sec. 8, T9S, R11E
Commodities: Cu, Pb
Ore Materials: Cu- and Pb-sulfides.
Description of Deposit: Mineralization in a N70° striking, 60°N dipping shear zone.
Geology: Silicification of a shear zone in Tertiary Sierra Blanca andesites.
Production: No significant production.

26. New Mexico Copper Corporation Claims
Location: SW1/4 sec. 20, and NE1/4 sec. 30, T9S, R11E
Commodities: Cu, Pb, Ba
Ore Materials: Cu- and Pb-sulfides, barite.
Description of Deposit: Two principal veins strike NW.
Geology: The northern vein is at contact of Tertiary syenite dikes and Tertiary andesites of the Sierra Blanca volcanics. Mineralogy of the south vein, which strikes NE, is similar but no barite is present.
Production: None

28. Rockford Canyon Prospects
Location: S1/2 sec. 24, T9S, R12E
Commodity: Au
Ore Material: Auriferous pyrite.
Description of Deposit: N-striking veins.
Geology: Au-bearing pyrite present in veins filling N-striking fractures in Tertiary Sierra Blanca volcanics.
Production: Unknown.

30. Lady Godiva Mine
Location: NE1/4 sec. 25, T6S, R11E
Commodity: Au
Geology: Mineralization is in Tertiary monzonite
Production: Unknown.

31. Unnamed Vermiculite Occurrence
Location: SW1/4 sec. 25, T6S, R11E
Commodity: Vermiculite
Geology: The deposit is close to outcropping of Tertiary volcanic breccia and syenite and monzonite intrusives.
Production: Unknown.

32. Julie Ann Fluorspar Deposit
Location: SW1/4 sec. 22, T6S, R11E
Commodity: F
Ore Materials: Fluorite.
Description of Deposit: Vein.
Geology: Impure vein of fluorite occurs in a brecciatee zone cutting limestone and gypsum of the Permian Yeso Formation.
Production: Unknown.

33. Smuggler (Compromise) Mine
Location: SE1/4 sec. 26, T6S, R11E
Commodity: Au
Production: Unknown.

34. Unnamed Uranium Occurrences
Location:
1. NW1/4 sec. 25, T5S, R7E
2. SW1/4 sec. 12, T9S, R7E
3. NW1/4 sec. 23, T9S, R8E
4. SW1/4 sec. 15, T9S, R9E
5. SE1/4 sec. 19, T9S, R11E
6. Center E1/2 sec. 16, T6S, R11E
7. Center E1/2 sec. 21, T6S, R11E
8. Center of boundary between secs. 14 and 23, T6S, R11E
9. Center W1/2 sec. 24, T6S, R11E
10. Center W1/2 sec. 24, T6S, R11E

Commodity: U

Geology: Three of the deposits are located in Quaternary alluvium and bolson deposits; one is located close to the Jones Iron district in the NW part of the GRA and is present in Permian limestones, one deposit is in the Tertiry Sierra Blanca volcanic pile and the rest are located in and around the Tertiary Lone Mountain monzonite and syenite intrusive.

Production: Unknown.

35. El Cibola Claims

Location: Secs. 9 and 16, T7S, R10E

Commodity: U

Ore Materials: None; 5 to 10 x background radiation.

Geology: High background readings associated with limonite-stained Cretaceous Dakota sandstone in kipuka in Quaternary basalt flows.

Production: None.

Dry Exploration Wells

Locations: Center sec. 29, T7S, R9E
SE1/4 sec. 33, T6S, R9E
SW1/4 sec. 23, T6S, R10E
W1/2 sec. 30, T6S, R10E
Center sec. 26, T6S, R10E
Sec. 1, T6S, R9E
Sec. 9, T10S, R9E
NW1/4 sec. 23, T6S, R10E

Eight wells, none with any appreciable showing, having been drilled to total depths of 1250 to 8050 feet.

Mining Claims, Leases and Material Sites

For this study the BLM office in Roswell, New Mexico has provided us with up-to-date (April 1982) records of all valid patented and unpatented claims and leases. Several unpatented claims are located in or near the Little Black Peak WSA and much of the land covered by both WSAs is leased for oil and gas. Claim density is summarized in table 1 and claims and lease information is presented graphically in figure 5.

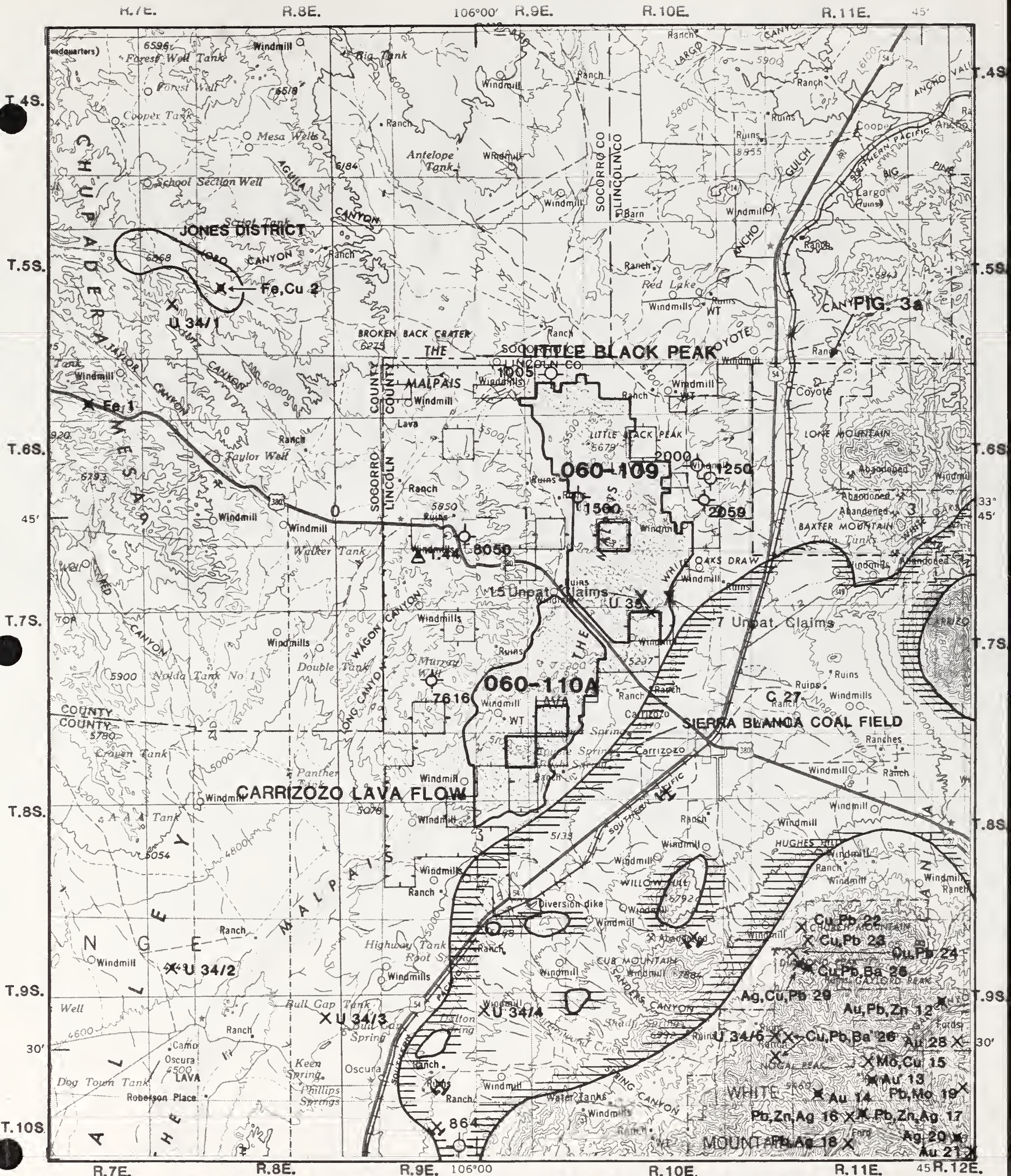


FIG. 5. OIL AND GAS LEASING STATUS MAP OF THE CARRIZOZO AREA, NEW MEXICO.

Note: hachured lines enclose oil and gas leases; numbers are claims per section.

Table 1. Claim density records of the Wilderness Study Areas (WSAs) of the Carrizozo GRA. Data from the BLM, Roswell, New Mexico, Office, 1982.

Township	Range	Section	Claims per Section	Claimants
75	10E	9	15	L.A. Hodges
		10	7	L.A. Hodges

Mineral Deposit Types

Geological environments to be considered as potentially favorable for the occurrence of mineral or energy resources are: Paleozoic sedimentary rocks, specifically limestones and possibly redbeds, Cretaceous coal beds, fossil hydrothermal systems associated with Tertiary to Quaternary igneous activity, late Tertiary valley-fill sediments and Quaternary alluvium.

Paleozoic Sedimentary Rocks

Oil and gas have long been produced from the Paleozoic rocks of southeastern New Mexico, with much of the oil production coming from Permian rocks. In the Carrizozo GRA, potential source rocks are the black marine shales of the Mancos Shale and Pennsylvanian and Permian marine sediments, and the potential reservoir rocks are sandstones and limestones of the Abo, Yeso and San Andres and Dakota Formations. The majority of oil shows in the surrounding area have been from the San Andres Limestone, with small showings in that formation and one from the Dakota sandstone within the GRA (Havenor, 1964). Havenor (1964) reports that the San Andres Limestone has a fetid to petroliferous odor and often is quite porous and suggests that more exploration is necessary in the area in order to adequately evaluate oil and gas potential. King and Harder (1982) concur with Havenor´s (1964) evaluation, mention shows in Pennsylvanian and Permian rocks to the south in the Tularosa basin and suggest that the Tularosa basin has some oil and gas potential.

Eight dry wells have been drilled within the area (U.S. Geological Survey, 1981; King and Harder, 1982).

Permian Limestones

Permian limestones are host to pyrometasomatic replacement deposits in several locations within the GRA. The deposits have been described in detail in the previous section, and are similar to deposits of the Iron Springs District, Utah (Kelley, 1949).

Iron deposits of the Jones District (northwestern part of the GRA) and White Oaks District (northeast-central part of the GRA) all occur as replacements of San Andres limestones and Yeso Formation limestones and gypsum beds, and have been described by Kelley (1949) and Griswold (1959, 1964). The principal iron minerals are magnetite and specularite, with earthy hematite and limonite present in weathered outcrops and pyrolusite reported from some deposits. The sediments have been intruded at a shallow level by Tertiary monzonites and syenites. Deuteric leaching of farromagnesian minerals with subsequent deposition of iron in the easily replaced limestone beds adjacent to an enclosure within the intrusives is suggested as the mode of origin for this type of deposit by Mackin (1968).

Ore produced from this area contained between 35 and 65 percent Fe. 683,000 tons of reserves are estimated to exist in the Jones District (U.S. Geological Survey, 1965) and 100,000 tons are estimated for the White Oaks District (Kelley, 1949).

Permian Redbeds

Redbed copper deposits, often containing silver, are found in Permian and Triassic rocks and are widely distributed throughout central and north-central New Mexico (LaPoint, 1974a). Outside the GRA, redbed-type copper mineralization is found in the Estey district, Oscura Mountains (Bachman, 1968) and in the Scholle district to the northeast of Socorro (LaPoint, 1974b). In the Estey district, uneconomic concentrations of malachite, azurite and lesser hematite, pyrite, bornite, chalcocite, covellite, chalcopyrite and melaconite are found mainly in arkosic channel deposits within the Bursum and Abo Formations. The copper-rich zones are 1-3 feet thick and copper minerals cover fractures, fill voids, coat detrital grains and are most abundant replacing and surrounding plant debris. In the Scholle district chalcocite replaces wood in reddish brown sandstone and organic-rich shales below fluvial channels in the Abo Formation. In the Nacimiento region of north-central New Mexico, chalcocite, covellite, bornite, chalcopyrite and pyrite are associated with carbonaceous materials such as fossil log jams in arkosic sandstone paleochannels. The deposits occur in the Abo Formation and the Agua Zarca member of the Chinle Formation.

The redbed copper deposits of New Mexico were first studied in Lindgren et al., (1910) who favored an origin involving hydrothermal fluids rising along faults and spreading out along permeable aquifers. Most recent workers, such as LaPoint (1974a, 1974b) and Woodward et al. (1974), favor deposition from circulating groundwater in response to a local lowering of Eh. The ultimate source of copper is considered to be Precambrian copper deposits and/or copper-enriched lithologies.

The Yeso Formation also contains abundant gypsum-rich evaporites. Fifteen miles northeast of Socorro Weber and Kottlowski (1959) report

100-150 feet of gypsum within the Canas member. Such evaporitic sequences suggests the possibility of "sabkha"-type copper deposits being present within the formation.

Cretaceous Coal Beds

The Sierra Blanca coal deposit of the southern part of the GRA occurs in the terrestrial part of the Mesaverge Group. Several thin coal seams measuring four feet, ten inches in thickness extend over more than 100 square miles. 1644 million tons of bituminous coal is estimated to be present.

Tertiary to Quaternary Hydrothermal Deposits

These hydrothermal deposits have been described in the previous section. Hydrothermal gold and silver associated with base metals, and copper-lead with barite are found in the eastern half of the GRA.

Gold deposits in the White Oaks and Nogal Peak districts all occur in brecciated zones at the contacts of Tertiary dikes and country rock and in fractured zones in the intrusives. In the White Oaks district, the intruded rocks are Cretaceous sedimentary rocks and in the Nogal Peak district andesites and latite of the Eocene to Oligocene Sierra Blanca volcanics are intruded. The principal gold minerals are auriferous pyrite and free gold where the sulfide has been weathered. Quartz, sphalerite, galena and barite are also present. Huebnerite ($MnWO_4$) occurs in some deposits of the White Oaks district.

The silver deposits of the Nogal Peak area are similar in occurrence to the gold deposits. The principal silver-bearing mineral is argentiferous galena, with sphalerite, chalcopyrite, barite and quartz also occurring.

Copper and lead deposits without silver or gold are also present in the Schelerville mining district a few miles northwest of the Nogal Peak district. Chalcopyrite is present with galena, quartz, and minor barite in these hydrothermal deposits.

It is possible that the above types of hydrothermal deposits as well as the single fluorite and molybdenum deposits are associated with Tertiary igneous activity. Kesler (1977) has suggested that manto fluorite deposits lie on a north- to northeast-trending belt from northern Coahuila, Mexico, through central New Mexico and are associated with alkaline volcanics and normal faulting. Damon et al. (1981) and Clark et al. (1982) also show a northeast- to north-trending belt of fluorite mineralization that runs slightly west of the GRA and a molybdenum belt which runs through the GRA and includes the Cave Creek, Nogal Peak (Rialto deposit), Questa, Urad, Henderson and Climax deposits. These belts are considered to be related to high-K calc-alkaline to alkaline magmatism of Oligocene age, represented by the Sierra Blanca volcanics and assorted intrusions in the GRA. They were erupted at a time when the Farallon plate was dipping at a shallow angle beneath North America. The Rialto molybdenum deposit is classified as small (less than 50,000 tons Mo) by Westra and Keith (1981).

One occurrence of vermiculite is found on Lone Mountain. It is likely that the vermiculite formed from alteration of ferromagnesian minerals (probably biotite) in lamprophyre dikes. The alteration may be hydrothermal in origin or could have resulted from ground water circulation.

Late Tertiary Valley-Fill Sediments

Valley-fill sediments of the Pliocene Ogallala Formation crop out in the southeastern part of the GRA, and may be present elsewhere within the GRA as extensive outcroppings in the Jicarilla Mountains to the east of the GRA were not included on the state geologic map of Dane and Bachman (1965).

In the Jicarilla Mountains the Ogallala Formation is host to extensive placer gold deposits that produced much of the Lincoln County's gold in the first half of this century. Also present in the sediments are boulders of magnetite. These deposits were locally derived from gold veins and pyrometasomatic iron deposits (Segerstrom and Ryberg, 1974). It is possible that the Ogallala Formation is also present in the Nogal Peak district and may contain the placer deposits noted in that area.

The Ogallala Formation may also represent a potentially favorable environment for stratabound uranium deposits. In order to form uranium deposits by the agency of circulating groundwater, it is necessary to have adequate source rocks, permeable sediments and a suitable reductant. The Ogallala sediments contain clasts of Sierra Blanca volcanics which may be a suitable source of uranium. No chemical analyses of Sierra Blanca volcanics are available and the dominantly andesitic (latites are present in the upper part of the volcanic pile) nature of the rocks may lessen the possibility of the presence of adequate amounts of uranium. The Ogallala sediments are only slightly consolidated and are likely quite permeable, but it is not certain if adequate reductants are available. Suitable reductants might include organic matter within the sediments or reducing geothermal fluids. There apparently is little geothermal activity in the area at present.

Quaternary Alluvium

Quaternary alluvium represents a possible site where placer gold might be concentrated. Second-cycle placer deposits derived from erosion of the Ogallala Formation are found in Quaternary alluvium in the Jicarilla Mountains area (Segerstrom and Ryberg, 1974).

Mineral Economics

The following is a discussion of the economics of mineral and energy production in the Carrizozo GRA.

Iron was produced from deposits within the GRA only during World Wars I and II. Although an estimated 780,000 tons of ore are present in the area, individual deposits are small. Although the huge iron deposits in North American are diminishing, it is not likely that the iron deposits of the area will be economic unless there is an increased need for iron.

The hydrothermal gold, silver and copper deposits in the GRA have been important producers in the past; the White Oaks district being Lincoln County's largest producer of gold. The amount of gold reserves present is not known. Mining of gold placer deposits in the area is made difficult by the extreme lack of water even at higher elevations. It seems unlikely that either the lode deposits of gold, silver and copper, all of which are reported to be small, or the placer gold deposits are economic.

Exploration for molybdenum was ongoing in the mid-1960s, but the only deposits reported in the literature are small and the ore is not rich. The 1970s saw discovery and development of large deposits in Colorado, which are part of the molybdenum belt mentioned in the previous section. It seems possible that the Nogal Peak area may contain larger deposits than reported in the mid-1960s.

Only one fluorite deposit and a few uranium deposits are reported in the area. None of the deposits have produced and it seems unlikely that they will be economic in the near future.

Eight dry oil exploration wells were drilled in the area. More exploration is necessary to determine oil and gas potential in the area. The Permian

San Andres Limestone, which underlies or crops out in much of the GRA, is considered to be a possible source of oil (Havenor, 1964; King and Harder, 1982).

Impure gypsum-bearing sediments occur in the Yeso Formation, however, gypsum of higher purity and easy access is common in central New Mexico, so that the deposits within the Yeso are unlikely to be of economic value.

Basalt, sand and gravel, and limestone (especially the San Andres Formation) are present in the GRA and could be useful in the local building industry. However, the absence of important population centers precludes large scale use of these commodities.

LAND CLASSIFICATION FOR GEM RESOURCES POTENTIAL

The area covered by the GRA and the WSAs are classified with respect to their resources potential and level of confidence according to the schemes provided by the Bureau of Land Management (attachment 9, dated 3/24/82). The data on which this classification is based is presented in the preceding part of this report. The potential resources are divided into locateable, leaseable and saleable categories.

Locateable Resources

Potential locateable resources include metallic minerals, uranium and thorium, and non-metallic minerals.

Metallic Minerals

Potentially favorable environments for the occurrence of metallic minerals within the Carrizozo GRA include: Pyrometasomatic iron deposits; stratabound copper $\pm$ silver in Permian redbeds; structurally controlled hydrothermal deposits of gold (with minor lead, zinc and tungsten); silver (with minor lead, zinc and copper); copper (with lead and barite); porphyry molybdenum (with copper), all probably associated with Tertiary igneous activity; and gold in placers.

1. Replacement deposits of iron. Several iron deposits are located in the northwestern and northeastern parts of the GRA. Magnetite is present as a pyrometasomatic replacement of limestone or gypsum in sedimentary rocks intruded by Tertiary igneous rocks. Several thousand tons of up to 65% iron ore have been produced from the mines. The GRA is assigned a high favorability (4) at a confidence level of D.

    Permian limestones are present in both WSAs but no intrusions appear to be close to these sedimentary rocks and, therefore, a low favorability (2) at a confidence level of C is assigned (fig. 6).

2. Stratabound copper ± silver deposits. This type of deposit is not known to occur within the GRA but occurrences and mines are widespread in central and north-central New Mexico (LaPoint, 1974a). Geologically, the Permian redbeds are moderately favorable for the occurrence of this type of deposit. The GRA is assigned a moderate favorability (3) at a confidence level of B.

    In the Little Black Peak WSA, Permian redbeds are absent; therefore the WSA is not favorable (1) for the occurrence of stratabound copper deposits at a confidence level of D.

    Permian redbeds of the Yeso Formation crop out in the Carrizozo Lava Flow WSA, therefore the WSA is assigned a moderate favorability (3) at a confidence level of B (fig. 7).

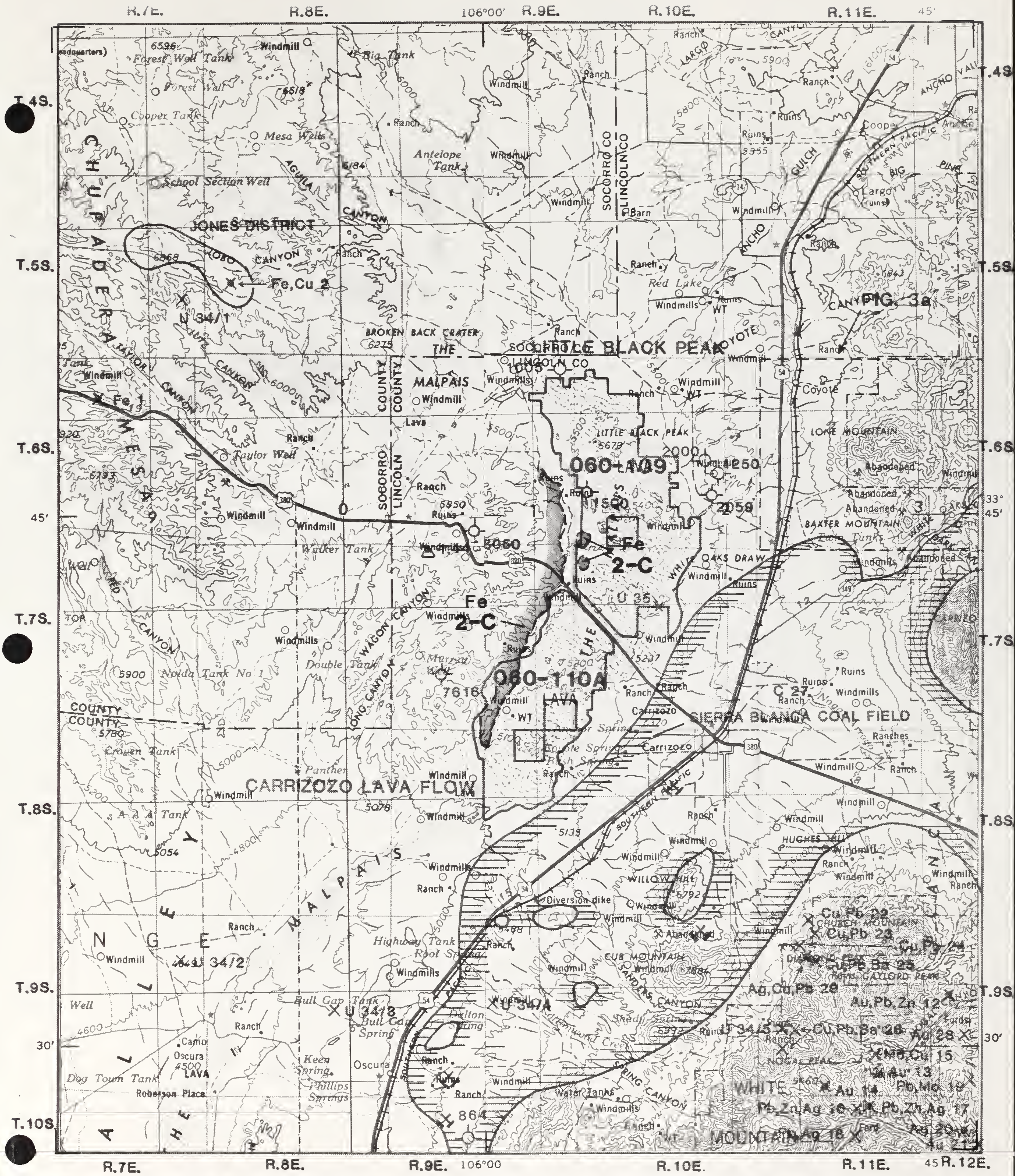


FIG.6 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR REPLACEMENT IRON RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

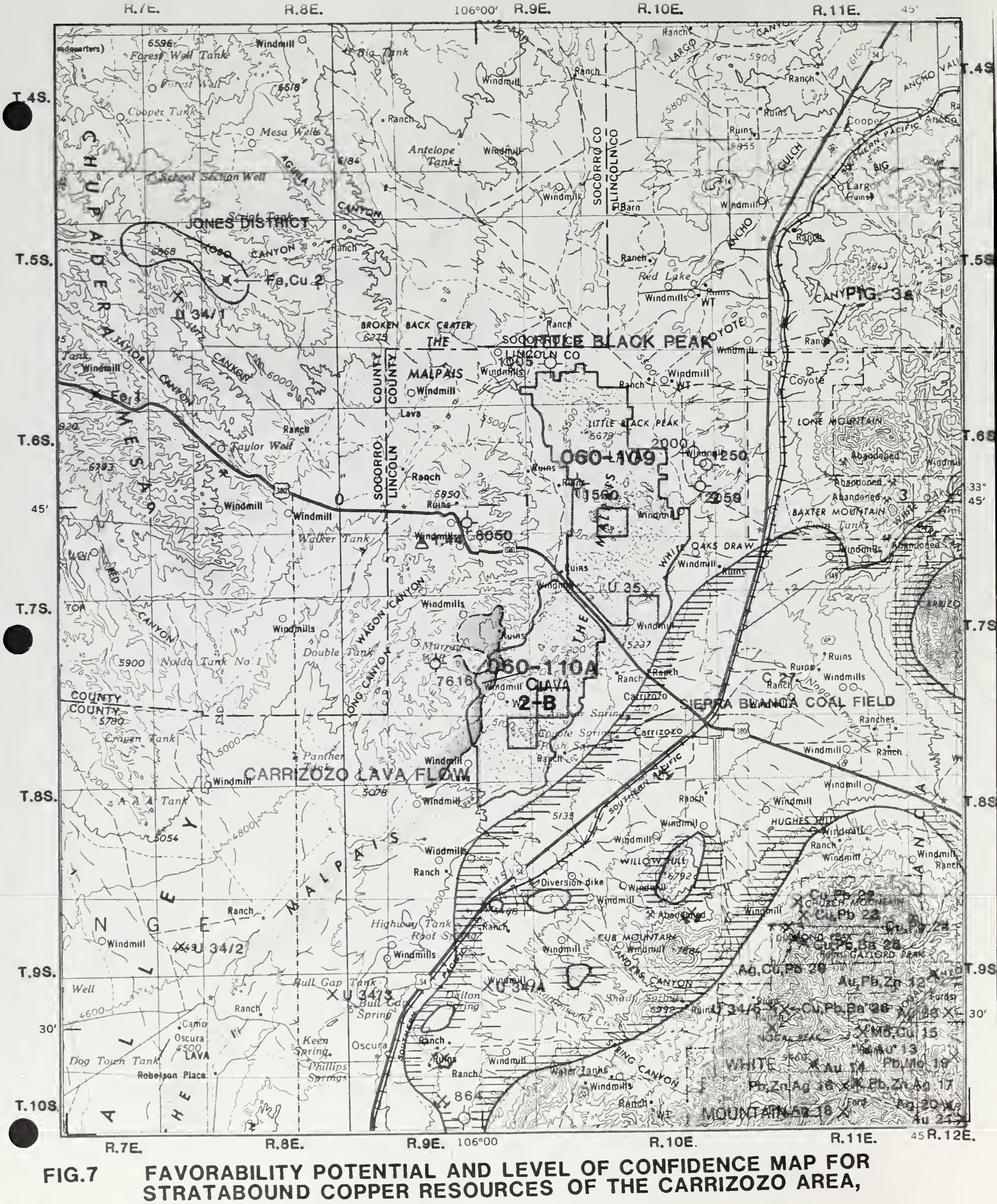


FIG.7 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR STRATABOUND COPPER RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

3. Hydrothermal gold deposits. Mines in the GRA produced more than 100,000 ounces of gold. Intrusions are present in other areas in the GRA besides the White Oaks and Nogal Peak districts which produced the gold. The GRA is assigned a high favorability (4) at a confidence level of D.

   The two WSAs contain or are near small Tertiary intrusives and gold mineralization may be present. Up to 160 feet of basalt cover most of the WSAs and thus the WSAs are assigned a low favorability (2) at a confidence level of C (fig. 8).

4. Hydrothermal silver deposits. There has been small production of silver from the Nogal Peak district within the GRA. The mineralization is associated with the intrusion of monzonite dikes into volcanic rocks. The GRA is assigned a moderate favorability (3) at a confidence level of C.

   The Little Black Peak WSA contains a small Tertiary intrusive and both WSAs are near small intrusive bodies. The basalt cover in most of each WSA lessens the favorability of exploitable silver deposits. The WSAs are assigned a low favorability (2) at a confidence level of B (fig. 8).

5. Hydrothermal and porphyry copper deposits. Small production is reported from a copper zone in the Rialto stock of the Sierra Blanca Mountains. Porphyry-type mineralization is present in the argillic zone of alteration in the Rialto stock. Copper with lead in hydrothermal veins is reported in volcanic rocks intruded by dikes north of the Rialto stock. The GRA is assigned a moderate favorability (3) at a confidence level of B.

FIG. 8 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR METALLIC AND FLUORITE RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

The two WSAs are assigned a low favorability (2) at a confidence level of B due to the presence of thick basalts which likely would cover any deposits (fig. 8).

6. Porphyry molybdenum deposits. A small porphyry molybdenum deposit, with copper also present in part of the deposit, is located in the Nogal Peak area. There has been no production from this deposit of less than 50,000 tons of mineralized rock but there is potential for production in the future. The GRA is assigned a high favorability (4) at a confidence level of D.

   Only small intrusives are present near the two WSAs. This, coupled with the presence of thick basalts, gives the WSAs a low favorability (2) at a confidence level of C (fig. 8).

7. Placer gold. Placer deposits of gold are present in the White Oaks and Nogal Peak mining districts. With the abundance of alluvium present in the GRA, it is assigned a high favorability (4) at a confidence level of D.

   The WSAs have little (Carrizozo Lava Flow) or no (Little Black Peak WSA) alluvium present and thus are not favorable (1) for placer gold deposits at a confidence level of D.

Uranium and Thorium

Potentially favorable environments for the occurrence of uranium minerals within the Carrizozo GRA include: Structurally controlled uranium deposits in Paleozoic limestone and Tertiary igneous rocks that are possibly related to Oligocene magmatism; and stratabound uranium in late Tertiary or Quaternary valley-fill sediments. There are no known favorable environments for thorium.

1. Uranium deposits in Paleozoic limestone and Tertiary igneous rocks, and no production has been reported. All the deposits

are located near Tertiary intrusives and are likely related and may be structurally controlled. The GRA is assigned a low favorability (2) at a confidence level of C.

Both WSAs contain Paleozoic limestones and Dakota sandstone associated with a Tertiary intrusive in the Little Black Peak WSA has higher than background radiation. Both WSAs are assigned low favorability (2) at a confidence level of C (fig. 9).

2. Stratabound uranium in late Tertiary or Quaternary valley-fill sediments. Two deposits with no known history of production are located in Quaternary alluvium and one uranium deposit may be located in Pliocene valley-fill sediments of the Ogallala Formation. These may be roll-type stratabound uranium deposits. Tertiary volcanic rocks may be uranium-rich and are among the source rocks for the sediments. The sediments contain permeable horizons and may contain organic matter to act as reductants. Therefore, the GRA is assigned a moderate favorability (3) at a confidence level of B.

   The two WSAs contain little or no alluvium and are not favorable (1) at a confidence level of C.

Non-Metallic Minerals

Potentially favorable environments for the occurrence of non-metallic minerals in the Carrizozo GRA include: Hydrothermal, structurally controlled barite and fluorite (with lead, zinc and copper) deposits, and vermiculite deposits in altered lamprophyre dikes.

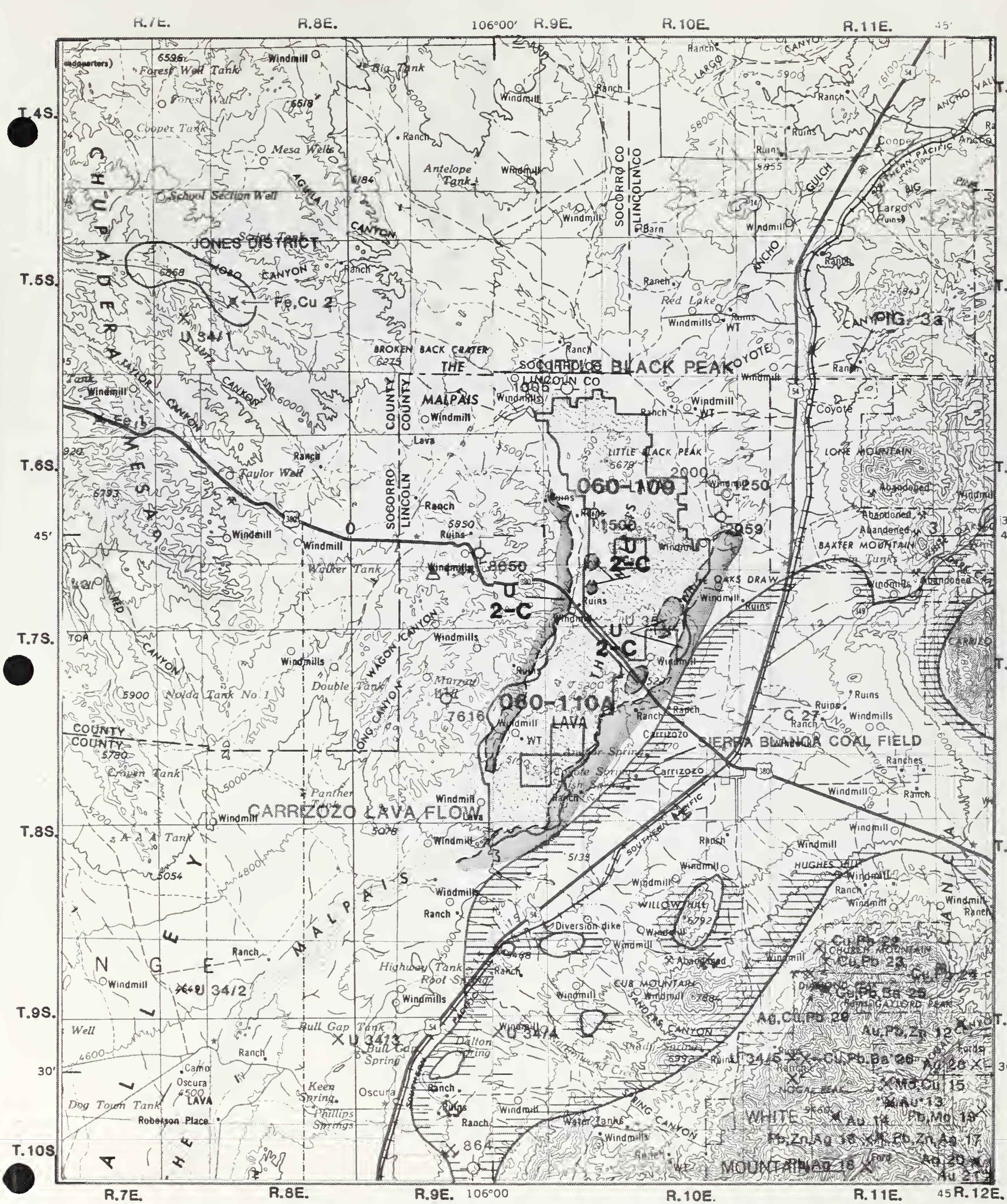


FIG. 9 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR URANIUM RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

1. Hydrothermal barite and fluorite deposits. Barite is reported to occur in minor amounts in structurally controlled hydrothermal deposits in the Nogal Peak area. One fluorite deposit is located in the White Oaks hydrothermal gold district. The barite deposits are associated with galena, sphalerite and, locally, chalcopyrite. The GRA lies at the eastern edge of a zone extending from Coahuila to New Mexico (Kesler, 1977) in which similar deposits occur and are thought to be associated with Tertiary alkaline magmatism. The Hansonburg mining district, where fluorite, barite and lead were mined, lies a few miles west of the GRA. The GRA is assigned a low favorability (2) at a confidence level of B, as it lies to the east of the barite-fluorite belt and a few deposits are reported.

   The two WSAs are assigned low favorability (2) at a confidence level of B (fig. 8).

2. Vermiculite deposits. One vermiculite deposit occurs within the GRA and probably occurs in altered lamprophyre dike rock. Deposits of this kind are either hydrothermal or result from circulating groundwater. The GRA is assigned a moderate favorability (3) for this kind of deposit, due to the presence of lamprophyres, at a confidence level of C.

   The WSAs do not contain lamprophyres and are not favorable (1) at a confidence level of D.

Leaseable Resources

Potential leaseable resources include oil and gas, geothermal, coal, gypsum and salt.

Oil and Gas

Eight oil exploration wells have been drilled within the GRA and all were dry. Paleozoic formations present within the area include adequate sources and reservoir rocks, and more exploration may be necessary to determine if there is oil and gas present. The GRA and two WSAs are assigned a low favorability (2) at a confidence level of B (fig. 10).

Geothermal

No hot springs are present in the area and heat flow measurements are low (1.44 hfu). Basalts of the Carrizozo malpais may have been erupted in historical times indicating the area is still volcanically active. The GRA and WSAs are assigned low favorability (2) at a confidence level of B (fig. 11).

Coal

Several thin coal beds are present in the Mesaverge Group and are described in a previous section. There has been production of bituminous coal from mines within the GRA but most of the production from the Sierra Blanca coalfield has come from mines near White Oaks and Capitan, to the east of the GRA. The GRA is assigned a high favorability (4) at a confidence level of D. It is highly doubtful that Mesaverde Group sediments underlie either WSA and therefore both WSAs are considered unfavorable (1) for the occurrence of coal deposits, at a confidence level of B (fig. 12).

Gypsum

Gypsum is present in Permian Yeso, San Andres (lower part) and Artesia Formations of the GRA. Between 1912 and 1922, the San Andres Limestone in the Jicarilla Mountains was mined for gypsum which was used for plaster

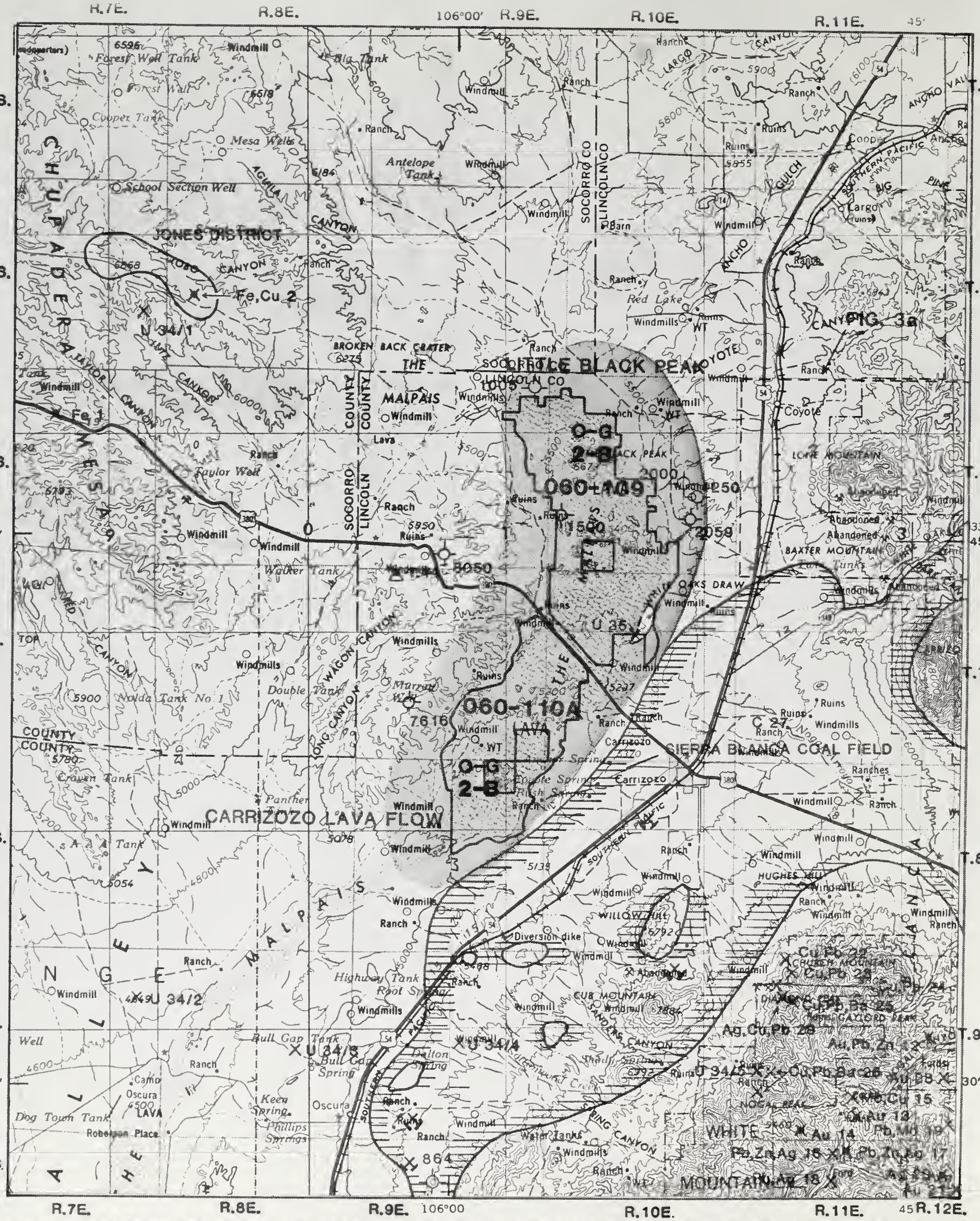


FIG.10 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR OIL AND GAS RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

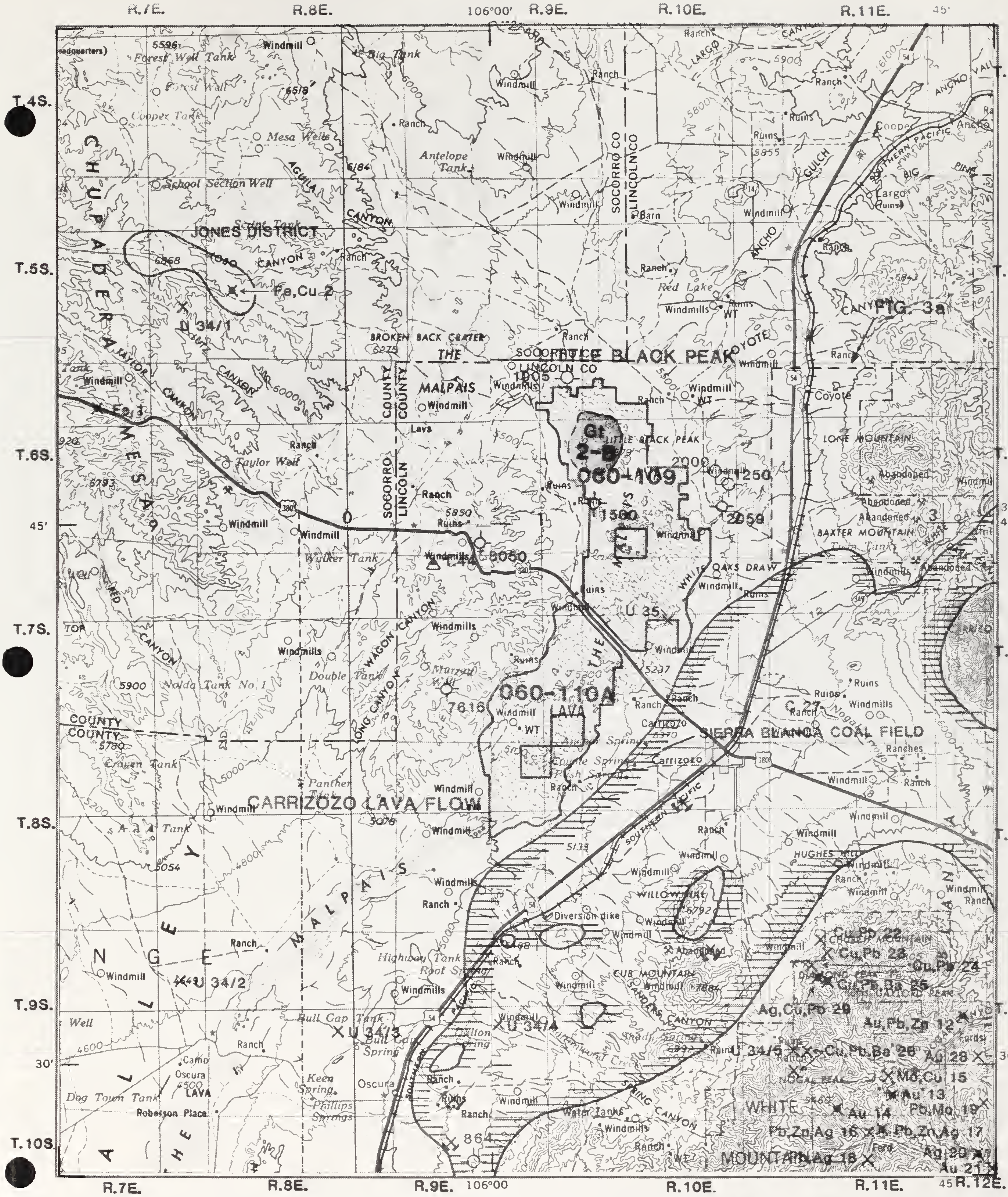


FIG.11 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR GEOTHERMAL RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

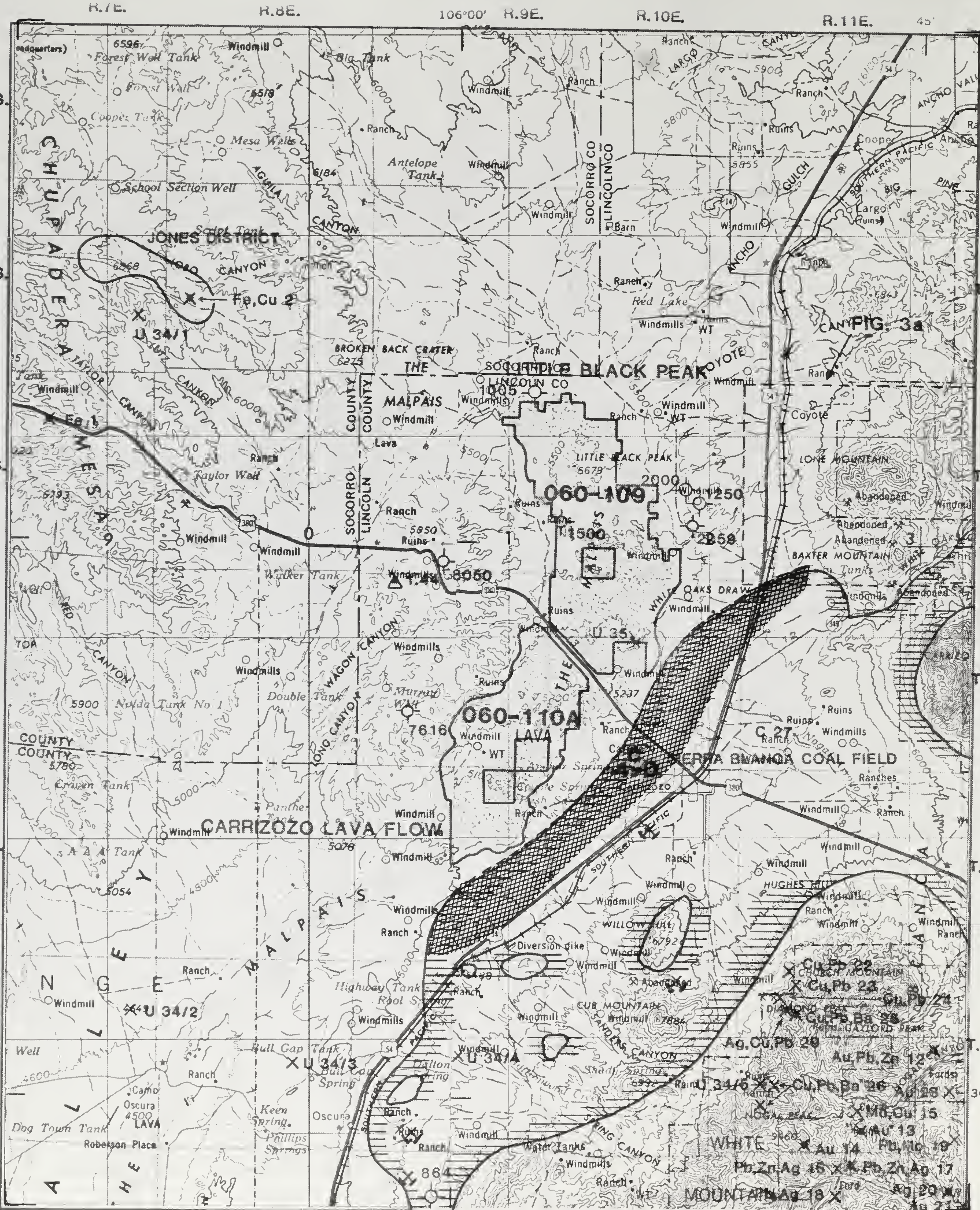


FIG.12 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE MAP FOR COAL RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

(Budding, 1964). The GRA is assigned a high favorability (4) at a confidence level of D. The Little Black Peak WSA contains outcroppings of San Andres Limestone, but it is not known if any gypsum horizons crop out. Therefore, the northern WSA is considered moderately favorable (3) at a confidence level of B (fig. 13). In the Carrizozo Lava Flow WSA both the Yeso Formation, which contains much gypsum, and the San Andres Limestone crop out, giving a low favorability (2) of gypsum deposits at a confidence level of C.

Salt

Salt beds are present in the Yeso Formation, which crops out in the western half of the Carrizozo GRA. There is no record of salt production from the area. The GRA is classified as highly favorable (4) for the occurrence of salt deposits, at a confidence level of D. In the Little Black Peak WSA, the Yeso Formation is deeply buried and thus is considered not favorable (1) at a confidence level of D. The Carrizozo Lava Flow WSA contains outcroppings of Yeso sediments, but it is not known whether salt beds occur in the area. The Carrizozo Lava Flow WSA is assigned low favorability (2) at a confidence level of C.

Potassium

There are no reported occurrences of sylvite or associated potassium-bearing evaporite minerals in the Carrizozo GRA.

Saleable Resources

Potential saleable resources include sand and gravel, limestone and crushed rock.

Sand and Gravel

Abundant sand and gravel is present in Quaternary deposits and in the Pliocene Ogallala Formation, which consists of poorly consolidated fan gravels and stream sediments. The GRA is considered highly favorable (4) for this type of deposit, at a confidence level of D. The Little Black Peak WSA contains no outcroppings of Quaternary alluvium or Ogallala Formation sediments and is deemed unfavorable (1) for deposits of sand and gravel, at a confidence level of D. The Carrizozo Lava Flow GRA includes deposits of Quaternary alluvium and is given a high favorability (4) at a confidence level of D.

Limestone

Limestone beds are present in the Permian Bursum, Yeso and San Andres Formations of the GRA. There is no history of limestone production in the area. The GRA is considered highly favorable (4) for limestone resources, due to the abundance of limestone present in the area, at a confidence level of D. Both WSAs contain outcroppings of San Andres Limestone and are given a low favorability (2) at a confidence level of D, as the quality of limestone is unknown.

Crushed Rock

Sandstones, volcanics and intrusive rocks present in the GRA should provide adequate sources of crushable rock of sufficient quality for use in highway construction, as fill and as rip-rap. Although the basalts present in the WSAs are suitable for use as crushed rock, it is unlikely that it would ever be necessary to utilize them. The two WSAs are assigned a low favorability (2) for deposits of suitable material, with a confidence level of D.

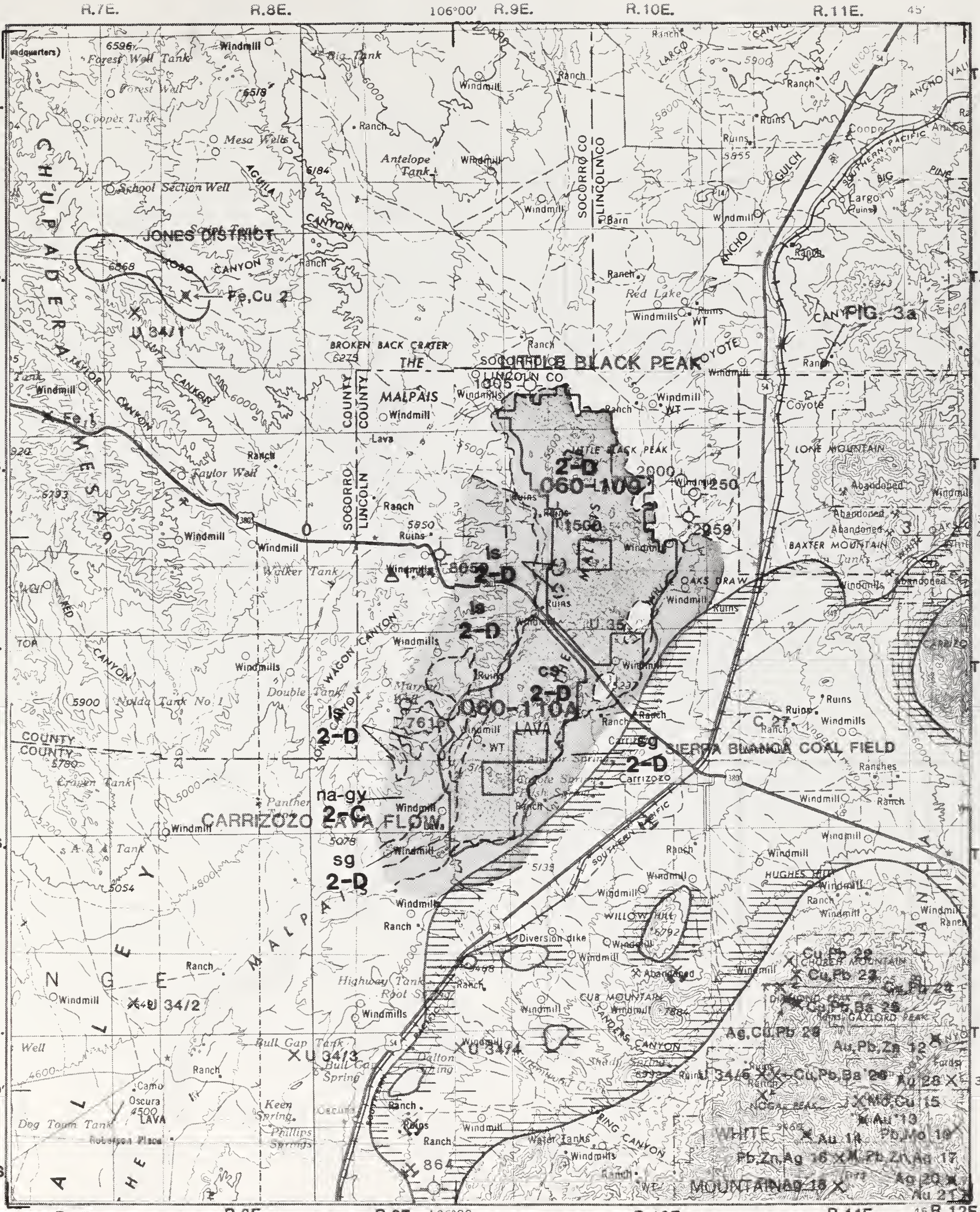


FIG.13 FAVORABILITY POTENTIAL AND LEVEL OF CONFIDENCE FOR INDUSTRIAL MINERALS RESOURCES OF THE CARRIZOZO AREA, NEW MEXICO.

RECOMMENDATIONS FOR ADDITIONAL WORK

The recommendations presented in this section pertain to the two WSAs within the Carrizozo GRA. They describe proposed work that would allow a more specific definition of mineral potential for various minerals deposit types for which the geologic environment appears favorable.

The WSAs chiefly overlie a Quaternary basalt flow which is about 160 feet maximum in thickness. The basalt overlies the Yeso, San Andres and Artesia Formations, the Dockum group, Cretaceous sediments, and possibly Sierra Blanca volcanics and Tertiary intrusives. The Yeso Formation could host stratabound redbed copper mineralization, the San Andres and Yeso Formations could host pyrometasomatic iron deposits near Tertiary intrusives and Tertiary intrusives and nearby country rocks could host hydrothermal gold and silver deposits and porphyry molybdenum-copper deposits.

Stratabound Copper Deposits

Numerous occurrences of copper ± silver are located within Permian redbeds in central and north-central New Mexico. Most occurrences are associated with local reducing conditions which caused precipitation. It is possible that copper and silver may also have been concentrated by a "sabkha"-type process within the Yeso Formation. It is recommended that in the vicinity of the WSAs:

1. The Permian sediments be field checked for presence of locally reducing facies that may have acted as precipitants for copper and/or silver.

2. The Yeso Formation be field checked for "sabkha"-type environments where copper and silver may have been concentrated.

3. Furthermore, it is recommended that groundwater wells and springs be sampled and analyzed for copper, silver, chloride, carbonate, reduced sulfur, Eh and pH, and that the solubility index be calculated for each sample. This would make it possible to determine whether copper and silver were being leached or deposited within each aquifer sampled.

Deposits Associated with Tertiary Intrusives

Pyrometasomatic iron deposits, hydrothermal gold, silver and base metal deposits, and porphyry molybdenum-copper deposits are associated with Tertiary intrusives in the GRA. For the one Tertiary intrusive located near both WSAs it is recommended that:

1. It be examined in the field for evidence of associated hydrothermal activity.
2. Selected samples should be examined petrographically in order to determine primary rock type and nature of hydrothermal alteration.
3. Promising lithologies should be chemically analyzed for major elements Nb, Rb, Sr, Ti, F, Sn and Mo and classified according to favorability for molybdenum mineralization using the scheme proposed by Westra and Keith (1981).

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