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

BY

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Prepared for:

United States Department of the Interior

BUREAU OF LAND MANAGEMENT

December 31, 1982

Geo-Scientific, Professional and Engineering Services

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

by

Susan K. Cruver, Antoni Wodzicki and Jan Krason

SUMMARY

The Humphrey Canyon Geological Resource Area (GRA) is located within the southwestern part of the Guadalupe Mountains, the Brokeoff Mountains and the northern part of the Salt Basin of southeastern New Mexico. Included in the GRA is one Wilderness Study Area (WSA), the Brokeoff Mountains WSA (030-112), comprised of 28,600 acres (115.75 sq. km) of the rugged Brokeoff Mountains.

The Brokeoff Mountains WSA is underlain by Permian sediments, dominantly limestone and dolomite, and minor Quaternary alluvial fan deposits. Although similar Permian rocks produce oil in areas east of the GRA, the Brokeoff Mountains WSA is considered to be of low favorability for the occurrence of oil and gas resources. Areas of the WSA that are underlain by Quaternary sediments are moderately favorable for sand and gravel, but abundant sand and gravel resources are available in the basin west of the WSA and quarrying would likely be much easier and less costly in the flatter land of the basin.

No further geological work is recommended for the Brokeoff Mountains WSA.

INTRODUCTION

Purpose, Scope and Methodology

The need and desirability of Geological, Energy and Minerals (GEM) Resources Assessment of Wilderness Study Areas (WSA) has been recognized and a series of studies was recently undertaken by the Bureau of Land Management (BLM). The execution of the objective work is being performed by various contractors.

The selected Wilderness Study Areas, scattered within the "Sonoran Desert and Mexican Highlands" of Region 5, have been studied and assessed by Geoexplorers International, Inc. This report pertains to the Brokeoff Mountains WSA (number 030-112) of the Humphrey Canyon Geological, Energy and Mineral Resources Area (GRA).

The purpose of this present study is to assess the potential for locatable, leasable and salable resources within the GRA and specifically within the WSA. This assessment has been carried out through literature study of the geology, structure and economic geology of the GRA with consideration of the regional paleogeographic, plate tectonic and metallogenic setting of the GRA. Thus, the assessment is based not only 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)

For 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; these resources cannot be considered as available.

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

1) The size of the GRA is 211,064 acres (853.8 km^2) or less, which if shown on a map with a scale of 1:250,000 (also required by the BLM) does not exceed 8.5 by 11 inches,
2) GRA boundary does not cut across a Wilderness Study Area, and
3) The geologic environment and mineral occurrences are taken into primary consideration.

The criteria for establishment of the Wilderness Study Areas are not the subject of this report. Their boundaries, code numbers and names have been established by the Bureau of Land Management prior to this study.

Location and Access

The Humphrey Canyon GRA is located within Otero and Eddy Counties, in southeastern New Mexico, and lies within the Las Cruces District. The GRA occupies the south-central part of the Carlsbad 1:250,000 quadrangle, approximately between latitude 32° and 32°22′ and longitude 104°45′ and 105°15′. A single WSA, the Brokeoff Mountains WSA (number 030-112), encompasses 28,600 acres (115.75 sq. km).

Access to the GRA is limited. New Mexico Highway 506 traverses the western part of te GRA, running north-south, and another secondary road, New Mexico Highway 137, extends less than ten miles into the easternmost part of the Humphrey Canyon GRA (fig. 1). Several unimproved dry-weather

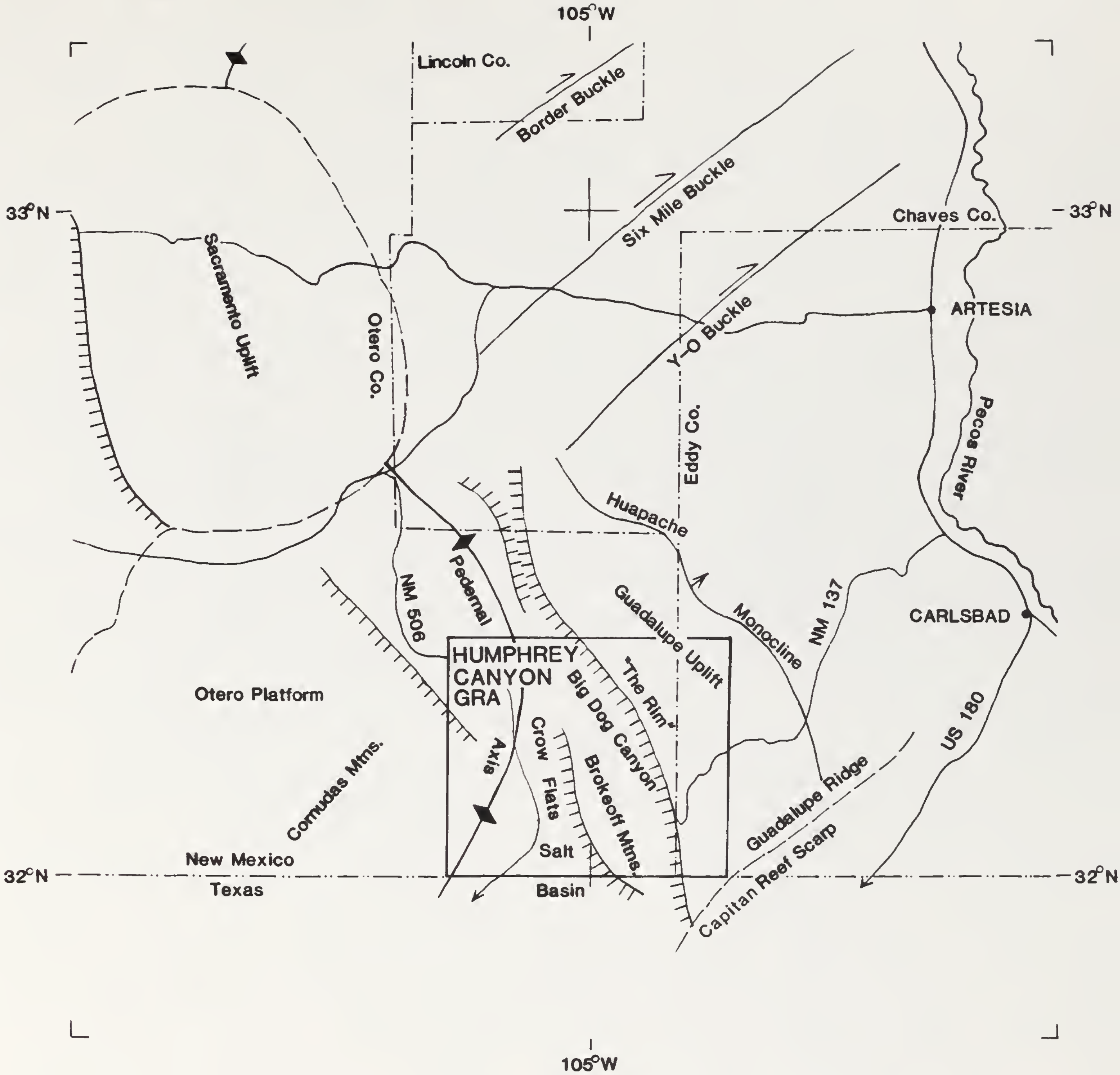


FIG. 1 PHYSIOGRAPHY AND MAJOR STRUCTURES OF PART OF SOUTHEASTERN NEW MEXICO AND WEST TEXAS, SHOWING LOCATION OF HUMPHREY CANYON GRA. Modified from King and Harder, 1982.

roads run through Crow Flats and Big Dog Canyon but access to mountainous areas is more limited. No towns are located within the GRA; the nearest is Carlsbad, 35 miles northeast of the GRA.

PHYSIOGRAPHY

The Humphrey Canyon GRA lies entirely within the Sacramento section of the Basin and Range Province (New Mexico Bureau of Mines and Mineral Resources, 1965; Fenneman, 1931). The southeastern corner of the GRA lies close to the Pecos Valley section of the Great Plains Province, in this area defined by the trend of the Capitan reef scarp (see fig. 1 for scarp location).

The GRA can be divided into two distinct physiographic terrains (fig. 1): mountainous-to-hilly and lowland terrains.

The mountainous-to-hilly terrain includes the Brokeoff Mountains in the center of the GRA, the Guadalupe Mountains in the east and northeast and the unnamed hills in the west. The intensely block-faulted Brokeoff Mountains are bounded on both east and west sides by normal faults while the Guadalupe and, apparently, the hills in the west of the area are faulted only on their western edges (Black, 1973).

The lowlands of the Crow Flats, a closed basin and subarea of the Salt Basin (Bjorklund, 1957), in the west center of the area and Big Dog Canyon, in the northeast and east-center, are tectonic depressions in which valley-fill sediments have been deposited. Both the lowland and mountainous-to-hilly physiographic terrains probably reflect Basin and Range faulting (Black, 1973; Kelley, 1971).

GEOLOGY

The lithology and stratigraphy, structural geology and tectonics, paleontology and geologic history of the Humphrey Canyon GRA are discussed in this section in order to facilitate the assessment of mineral potential within the GRA and specifically within the enclosed WSAs. The regional geologic setting and geology of the Humphrey Canyon GRA are summarized in figures 2 and 3 respectively.

Lithostratigraphy - Rock Units

In the Brokeoff Mountains area of southeastern New Mexico, Precambrian crystalline basement is overlain by Paleozoic marine sediments, with Quaternary sediments filling valleys. All younger rocks which may have been deposited in the area have since been eroded. Knowledge of rocks of Precambrian through lower Permian age is based on subsurface data as only Leonardian and Guadalupian rocks, along with Quaternary sediments, crop out at the surface.

Precambrian

Subsurface Precambrian rocks have been encountered in several test wells in and near the Humphrey Canyon GRA. Precambrian rocks do not crop out on the surface.

Approximately the western third and the northernmost part of the GRA are underlain by Precambrian metavolcanic and metasedimentary rocks of varying metamorphic grade (King and Harder, 1982; Condie and Budding, 1979 and Flawn, 1956). These rocks, unnamed by Flawn (1956), are termed De Baca terrane by Condie and Budding (1979) and are part of a 1.2 to 1.65 b.y.B.P. belt of Precambrian igneous and metamorphic rocks, which they suggest extends northeast to Illinois.

The rest of the GRA is underlain by Precambrian plutonic rocks of granitic to granodioritic composition, termed the Texas craton by Flawn (1956). The age of these rocks is between about 1.3 and 1.0 b.y. and may be part of another belt, this one trending northeast to Ohio, adjacent to the

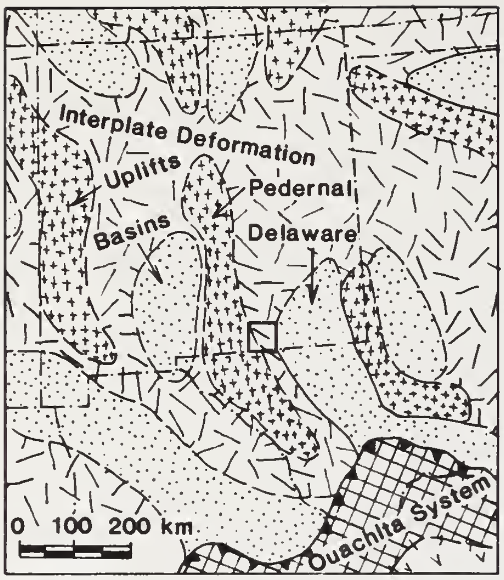
FIGURE 2: Paleotectonic and paleogeographic maps of the Southern Cordillera, New Mexico and adjoining areas, showing location of the Humphrey Canyon GRA (small squares). 2a and 2c after Dickinson, 1981. 2b modified from West Texas Geological Society et al., 1962. 2d modified from Dickinson, 1981, and Burchfiel, 1979.

a. Paleotectonic map, Mid-Carboniferous (Mississippian-Pennsylvanian boundary) to mid-Triassic (325-225 m.y.B.P.), featuring basins and uplifts of the Pennsylvanian and Permian. Dotted areas = basins; plusses (+) = uplifts, triangles mark thrust front, and diagonal crossed lines mark thrust plate.

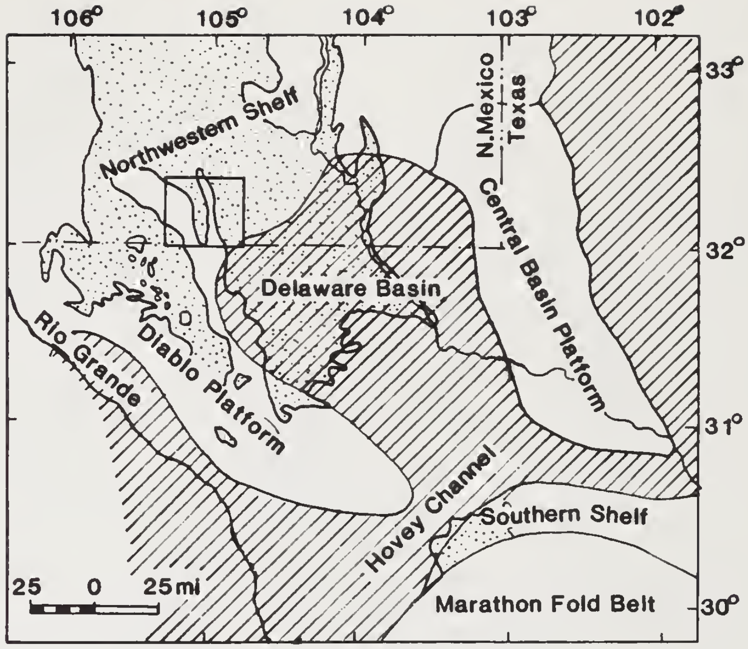
b. Paleogeographic map showing Permian provinces. Dotted areas = present day mountains.

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

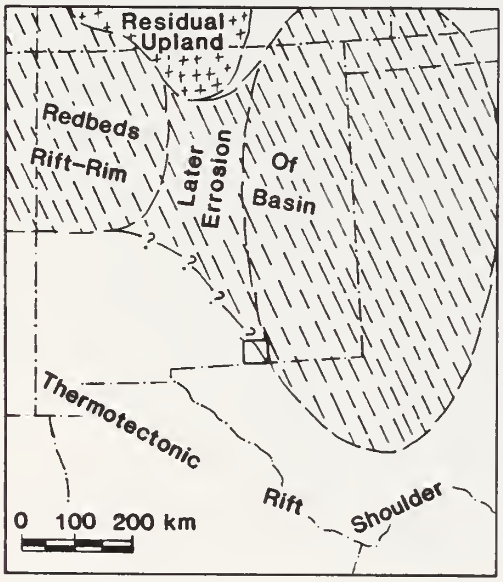
d. Paleotectonic map, latest Oligocene to Recent time (25-0 m.y.B.P.), showing extent of block faulting.


Interplate Deformation
Uplifts
Pedernal
Basins
Delaware
Ouachita System
0 100 200 km

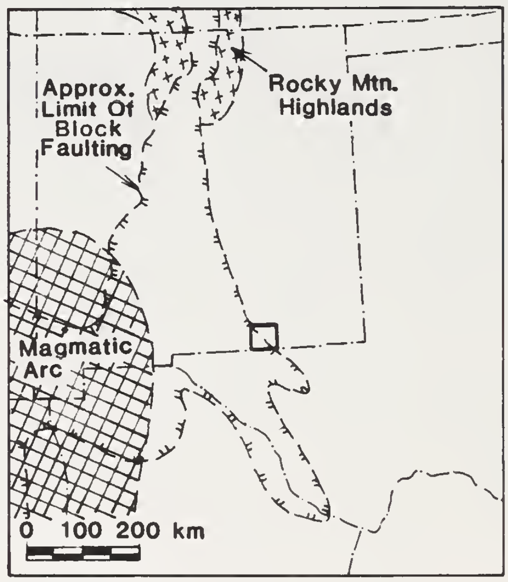
2a.


106°
105°
104°
103°
102°
33°
32°
31°
30°
Northwestern Shelf
N.Mexico
Texas
Central Basin Platform
Delaware Basin
Diablo Platform
Rio Grande
Hovey Channel
Southern Shelf
Marathon Fold Belt
25 0 25 mi

2b.


Residual Upland
Redbeds
Rift-Rim
Later Errosion
Of Basin
Thermotectonic
Rift
Shoulder
0 100 200 km

2c.


Approx. Limit Of Block Faulting
Rocky Mtn. Highlands
Magmatic Arc
0 100 200 km

2d.

above-mentioned 1.2 to 1.65 m.y.B.P. belt (Condie and Budding, 1979). King and Harder (1982) and Condie and Budding (1979) term these rocks Chaves (or Chavez) terrane.

Condie and Budding (1979) suggest that this sequence is similar to associations formed in modern continental rift systems while Dickinson (1981) states that a convergent environment would more likely produce the voluminous granites, calc-alkaline volcanics and widespread metamorphic belts.

Cambrian and Ordovician

The Bliss Sandstone, of Late Cambrian to Early Ordovician age in areas west of the GRA, is entirely of Early Ordovician age within the Humphrey Canyon GRA, on the basis of paleontology (Hayes and Cone, 1975; Hayes, 1964; New Mexico Geological Society, 1954). Unconformably overlying Precambrian crystalline rocks and also present only on the subsurface, the Bliss Sandstone consists of up to 100 feet of light gray to white orthoquartzite, and locally conglomeratic arkose (Hayes and Cone, 1975; Hayes 1964) which was deposited in warm, shallow marine water (Meyer, 1966) during a marine transgression from the southeast. Glauconite-rich beds and hematitic oolites occur in the Bliss Sandstone of south-central and southwestern New Mexico (Hayes and Cone, 1975), but are not reported to occur in or near the GRA.

Conformably overlying the Bliss Sandstone is the Early Ordovician El Paso Group or El Paso Limestone. Up to approximately 500 feet of El Paso Group sediments are present in the subsurface of the Humphrey Canyon area, but it is not known if rocks of the uppermost Padre Formation of the El Paso Group survived subsequent erosion (Hayes and Cone, 1975; Hayes 1964). Medium gray, fine- to medium-crystalline, often siliceous dolomite predominates in the Brokeoff Mountains-Guadalupe Mountains area. Sandy dolomite is common near the base and top of the El Paso and white to light gray fine-grained chert is common (Hayes, 1964).

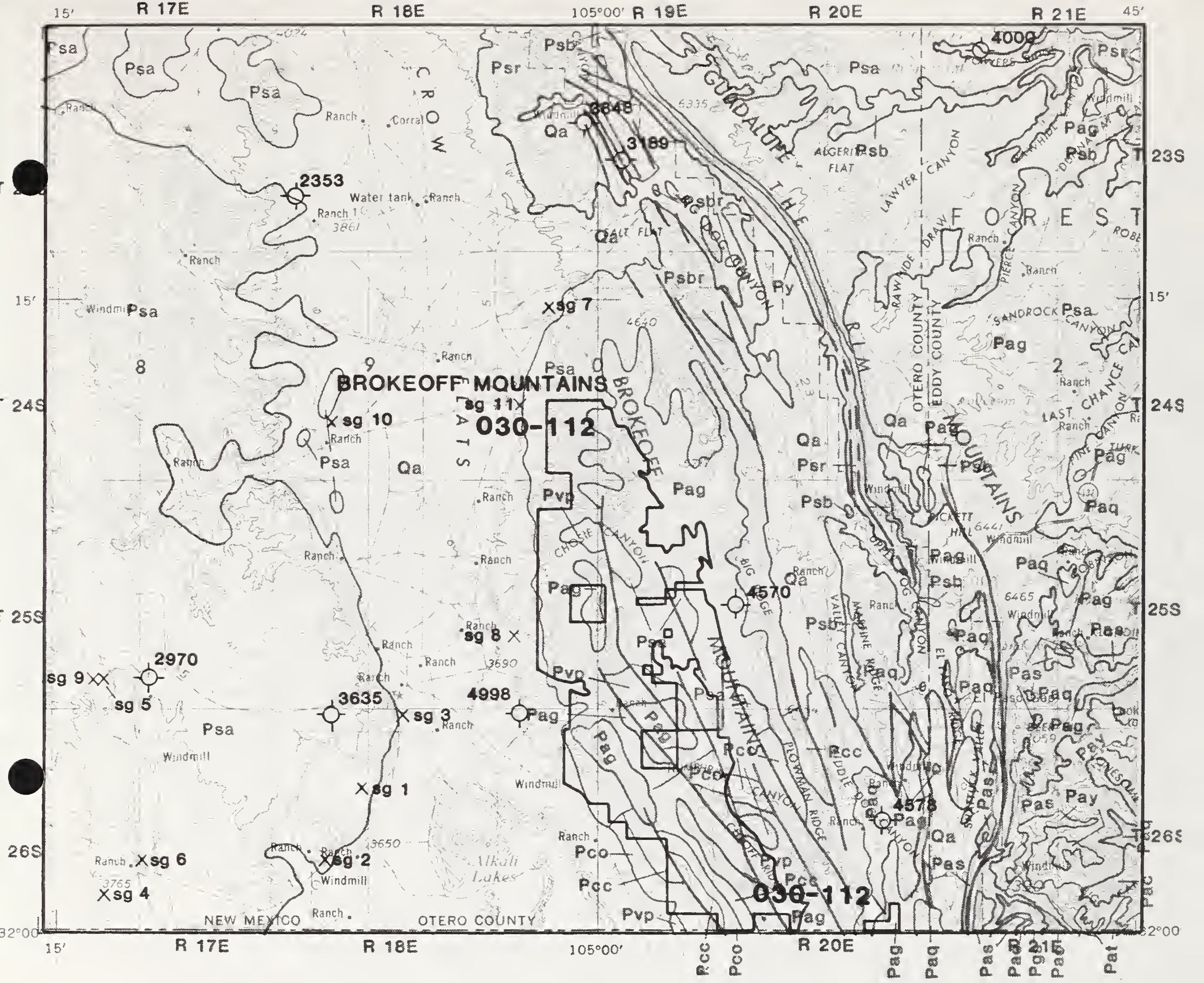


FIG. 3. GEOLOGIC, ENERGY AND MINERAL RESOURCES MAP OF THE HUMPHREY CANYON AREA, NEW MEXICO

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 Kelley (1971) and Dane and Bachman (1965)

QUATERNARY

- **Qa** — Alluvium and bolson deposits, including evaporites of Crow Flats

PERMIAN

GUADALUPE

SHELF FACIES (ARTESIA GROUP)		TRANSITIONAL AND BASIN FACIES	
Pat	Tansill Formation- Dolomite	Pac	Capitan Limestone – Limestone, dolomite and calcarenite of organic bank deposition
Pay	Yates Formation – Dolomite, siltstone, fire sandstone, minor gypsiferous sandstone		
Pas	Seven Rivers Formation – Light gray dolomite with minor sandstone		
Paq	Queen Formation – Sandstone with lesser carbonate	Pgs	Goat Seep Dolomite – White to light gray bioclastic dolomite of reef or bank deposition
Pag	Grayburg Formation – Dolomite and pink to brown sandstone		

LEONARD

SHELF FACIES		TRANSITIONAL AND BASIN FACIES (Bone Spring Fm.)	
Psa, Psf, Psb, Psbr, Psr	San Andres Formation – Cherty limestone and dolomite, sand- and silt-rich carbonate, gypsum; includes patch reefs Psa – San Andres undivided Psf – Fourmile Draw Member Psb – Bonney Canyon Member Psr – Rio Bonito Member Psbr – Bonney Canyon and Rio Bonito Members	Pcc	Cherry Canyon Sandstone Tongue – Varicolored arkose and blue-green shale; dolomite in lateral transition with San Andres Formation
		Pco	Cutoff Shale – Black shale and dark gray limestone
Py	Yeso Formation – Gray dolomite and limestone with minor shale, siltstone and gypsum	Pvp	Victorio Peak Limestone – Gray dolomite and limestone, orange sandstone

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

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
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

(2, 3, 4: 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

Unconformably overlying the El Paso is the Late Ordovician Montoya Group or Montoya Dolomite, up to 200 feet thick in the Humphrey Canyon GRA (Hayes and Cone, 1975; Hayes, 1964). Sediments correlated with the middle Ordovician Simpson Group, which conformably underlie Montoya and unconformably overlie the El Paso group in the subsurvace east of the GRA, do not occur within the GRA (Hayes, 1964). Greater than 200 feet of Montoya sediments are present in the subsurface of parts of the GRA. In the Guadalupe Mountains-Brokeoff Mountains area the Montoya is divided into three members: the lower Upham Dolomite Member, the Aleman Cherty Member and the uppermost Cutter Member. The Upham Dolomite is light gray, fine- to medium-crystalline calcareous dolomite. Medium to light gray fine-crystalline dolomite with 10 to 50% white to light gray chert of the Aleman Cherty Member conformably overlies the Upham. Conformable to and overlying the thinly-bedded Aleman is the medium gray microcrystalline dolomite of the Cutter Member (Hayes and Cone, 1975; Hayes, 1964).

Silurian

Unconformably overlying the Montoya Limestone is the Silurian Fusselman Dolomite, which is about 600 feet thick in the subsurface of parts of the GRA The Fusselman Dolomite is comprised of light gray to white coarse- to medium-crystalline dolomite which is massively bedded and locally contains limestone (Hayes and Cone, 1975; Hayes, 1964).

Devonian

Less than 100 feet of dark gray locally silty shale with a few feet of medium to dark gray chert at its base unconformably overlies the Silurian Fusselman Dolomite. These sediments are tentatively correlative with the Late Devonian Percha Shale, and are considered by some workers to be equivalent to the Woodford Chert of Oklahoma and may be in part Mississippian (Hayes, 1964).

Mississippian

Unconformably overlying the Devonian Percha Shale in the subsurface are two Mississippian units. The lower cherty limestone unit is comprised of 250 to 365 feet of light to dark gray fine-crystalline limestone with abundant medium to dark gray chert. Some dark gray silty shale and medium to light gray calcareous shale beds are intercalated with the limestone and chert (Hayes, 1964). Conformably overlying the limestone unit are 200 to 250 feet of sediments identified by Hayes (1964) as the Helms Formation and by the New Mexico Geological Society (1954) as the Barnett Shale. This upper unit is composed of dark gray, often silty, shale and light to medium gray, calcareous, very fine-grained sandstone and siltstone (Hayes, 1964).

Pennsylvanian

A maximum of 1250 feet of subsurface Pennsylvanian sediments unconformably overlie the Mississippian rocks. Argillaceous limestone and lesser shale was deposited in the Early Pennsylvanian. Two units are of Derryan age (Middle Pennsylvanian), a lower unit consisting mostly of tan to brown fine-grained limestone and argillaceous limestone, and an upper unit of tan to brown very fine-grained limestone, commonly containing milky chert, and minor gray shale. During Desmoinesian time, white to light brown, very fine-grained cherty limestone and red shale were deposited in the southeastern part of the GRA, and dark brown, cherty, argillaceous limestone with lesser gray shale and minor gray to white medium-grained quartzose sandstone was deposited in the very northeastern most part of the area. Carbonates predominated in Missourian time, with lesser red shale and quartzose sandstone. Sandstone, shale and fine-grained to chalky limestone were deposited at the end of Pennsylvanian time. Deposition of Pennsylvanian sediments was continuous but local unconformities are known (Meyer, 1966).

Permian

All the rock units which crop out in the Humphrey Canyon GRA are Permian in age (see lithostratigraphy section of figure 4). Also, the Wolfcampian Hueco Limestone (Hayes 1964), including Abo Formation (Meyer, 1966) equivalents, and the Wichita Formation are reported to exist in the subsurface.

Hueco, "Abo" and Wichita Formations

Late Pennsylvanian sediments and the Early Permian Hueco limestone are lithologically indistinct with the contact determined using fusilinids. The lower member is similar to the Bursum Formation of central New Mexico and is composed of medium gray, locally siliceous, fine-grained limestone with interbedded reddish brown, greenish gray and gray shale and minor fine-grained sandstone. The upper member includes medium gray fine-crystalline dolomite, subordinate green-gray shale and rare grayish red shale. The proportion of red shale likely increases northward as the Hueco grades laterally into the Abo red beds (Hayes, 1964). Thickness of this formation varies with the underlying surface - the Hueco is the oldest subsurface unit which covers all of the Pedernal uplift in the GRA (Meyer, 1966; Hayes, 1964).

Meyer (1966) reports a Leonardian formation in the subsurface, between the Wolfcampian sediments (Hueco Formation as described by Hayes, 1964) and the younger Leonardian formations. From the north, red beds and fine-grained dolomite grade to the south into a narrow zone of white, coarse-grained dolomite. This dolomite in turn grades south into the black, massive limestones of the lower Bone Spring Formation. The white, coarse-grained dolomite is the "Abo" reef reported from the subsurface further east in the Permian Northwestern Shelf and the red-bed and dolomite unit has been called the Abo Formation of the subsurface (Meyer, 1966). As the Abo Formation is Wolfampian in outcrop, Meyer (1966) correlates the subsurface unit with the Wichita Formation which is Leonardian and of similar lithology.

Yeso Formation and Victorio Peak Limestone

Conformably overlying the Wichita Formation are the Yeso Formation and the Victorio Peak limestone which are laterally gradational. The hypersaline marine Yeso Formation crops out in the north-central part of the GRA, where Boyd (1958) reported that 200 feet, not a full section, of the shelf sediments are exposed. Kelley (1971) reported that 890 feet of Yeso sediments, again not a full section of the partially subsurface unit, are exposed somewhere along the Guadalupe Escarpment ("The Rim", see fig. 1). Within the GRA the Yeso Formation consists of light gray to light olive gray thin-bedded dolomite, some beds with abundant chert nodules, and limestone, most with thin intercalations of shale, grayish yellow siltstone and gypsum. Thin oolites, indicative of deposition above wave-base are present in some of the dolomites (Boyd, 1958). Percent of clastics and evaporites increase to the north as colors of the sediments change to orange, red and yellow (Kelley, 1971).

The Yeso is laterally transitional into the Victorio Peak Limestone (Hayes, 1964) or Victorio Peak Member of the Bone Spring Formation (Boyd, 1958). Boyd (1958) measured 340 feet of the unit where it crops out in the south-central part of the Humphrey Canyon GRA. The lower 50 feet of the unit consists of alternating beds of thin-bedded, fine-grained, grayish orange sandstone and thicker-bedded, dense, light gray dolomite. Overlying these sediments are fossiliferons light olive gray to light medium gray dolomite and limestone in beds two feet or less in thickness (Boyd, 1958). Hayes (1964) states that the Victorio Peak Limestone was deposited on the hingeline of the Bone Spring Monocline which dipped southeast into the subsiding Delaware Basin, with a strike similar to the Capitan Reef Scarp (fig. 1). The

Victorio Peak was the first unit to form a barrier between the Northwestern Shelf and the Delaware Basin (see figure 2b; Hayes, 1964). Newell (1953; reported in New Mexico Geological Society, 1954) contradicted earlier workers by suggesting that the Victorio Peak represented bank, rather than reef, deposition and provided a base for the Goat Seep Reef. The upper part of the Victorio Peak unit grades laterally to the north into the San Andres Formation (Boyd, 1958).

San Andres Formation, Cutoff Shale and Cherry Canyon Sandstone

The San Andres conformably overlies the Yeso Formation and this Leonardian Formation has been subdivided into three members by Kelley (1971). The Rio Bonito is the lowest member; 300 to 600 feet of thick- to thin-bedded, light gray, fossiliferous fine-grained limestone and dolomite, with abundant chert in localities where it is beneath the Cherry Canyon Formation, make up this member. Percent dolomite increases to the north. The middle unit is the Bonney Canyon Member, a thin-bedded, dark grayish brown, medium gray and light gray, very fine-grained carbonate with some yellowish sand- and silt-rich carbonate beds. The upper 50 feet of the up to 300 foot thick Bonney Canyon Member is disturbed, possibly from the dissolution of gypsum and salt noted in the Bonney Canyon of the subsurface. The Fourmile Draw Member is the upper evaporitic part of the San Andres Formation and consists of approximately 380 feet of dolomite, gypsum and sandy dolomite. The amount of gypsum increases northward with red bed clastics appearing and increasing, too (Kelley, 1971). Boyd (1958) and other workers have suggested that the San Andres may be in part Guadalupian, and also states that patch reefs are present on the San Andres Formation.

Two other units were deposited in the Bone Spring Arch area (the southern part of the GRA) during the same time interval. The Cutoff Shale, or Cutoff Member of the Bone Spring Formation consists of 100 feet of dark gray, thin-bedded limestone intercalated with the thin beds of black shale, with much black chert and minor siltstone. This unit, which overlies the Victorio Peak limestone, is fetid and fossiliferous. Limestone gives way to dolomite in the northern areas of Cutoff exposure, with the Cutoff Shale grading into the San Andres Formation. Unconformably overlying the Cutoff Shale is the Cherry Canyon Formation, a Delaware Basin unit that lapped over the arch and onto the shelf. The yellowish gray, light brown and light greenish gray arkosic sandstone contains distinctive light blue-green shale beds. Marine fossils and small reefs occur in the often cross-bedded Cherry Canyon Tongue. A transitional belt of dolomitic limestone is between the Cherry Canyon and the upper San Andres in the south-central part of the GRA (Boyd, 1958). Local uplift on the Bone Spring arch resulted in localized erosion of the San Andres and Cherry Canyon Formations, therefore unconformaties are present at the top of these units in some localities (Hayes, 1964).

Artesia Group, Goat Seep Dolomite and Capitan Limestone

The Artesia Group, clastic and evaporitic facies of back-reef and shelf deposition, and contemporaneous reef deposits conformably (for the most part) overly the older Permian sediments. From oldest to youngest, the Grayburg, Queen, Seven Rivers, Yates and Tansill Formations make up the Artesia Group. In the southeastern part of the GRA, the Grayburg and Queen Formations grade into the Goat Seep Dolomite reef unit and the Seven Rivers, Yates and Tansill Formations grade into the Capitan Limestone reef deposit (Kelley, 1971). All the units are Guadalupian.

The Grayburg and Queen Formations crop out in much of the eastern half of the GRA. A gradational contact exists between the Grayburg and underlying Cherry Canyon tongue in the southeastern part of the GRA. Boyd

(1958) measured 30 feet of continuously deposited Grayburg-Queen sequence on the southeastern part of the GRA and 170 feet in Big Dog Canyon further north. There is much controversy about where to divide the Grayburg and Queen Formations, but general agreement exists that the upper Queen Formation is the clastic-rich upper portion. The Grayburg varies from dominantly clastic near the reef to dolomitic and then evaporitic to the north. Adjacent to the reef, it is composed of interbedded dolomite and medium orange-pink to light brown medium-grained sandstone. Pink to gray dolomite predominates elsewhere on the GRA. The Queen Formation contains two times as much clastic material as the Grayburg and also changes laterally northward. A distinctive, arealy persistent sandstone bed marks the top of the Queen Formation (Kelley, 1971; Boyd, 1958).

In the southeastern part of the GRA, the Grayburg and Queen Formations grade laterally into the Goat Seep Dolomite, a massive to thick-bedded, white to light gray, bioclastic, coarsely crystalline dolomite. This reef unit is fossiliferous, with sponges, corals, fusilinids and brachipods occurring. Cross-bedded reef talus us common.

Sedimentation was continuous during deposition of the Artesia Group; the Seven Rivers, Yates and Tansill Formations continue the conformable sequence. The Seven Rivers, Yates and Tansill Formations all crop out in the southeastern corner of the GRA and all grade laterally northward from carbonate at the shelf margin into evaporitic and red-bed facies, although later erosion has likely stripped away much, if not all, of the evaporites and clastic sediments. The upper three formations of the Artesia Group grade laterally to the south into the Capitan Limestone, a reef or organic bank deposited contemporaneously.

Five hundred to 750 feet of Seven Rivers sediments were measured by Boyd (1958) in the southeastern part of the GRA. As with the Grayburg

Formation, the Seven Rivers is distinguished from the Queen Formation on the basis of a lower percentage of clastics. Very light gray, thin-bedded dolomite with a few thin sandstone interbeds characterizes the Seven Rivers Formation (Kelley, 1971; Boyd, 1958).

The Yates Formation consists of about 350 feet of dolomite interbedded with siltstone, fine-grained sandstone and minor gypsiferous siltstone (Kelley, 1971). A basal sandstone, very similar to sandstones of the Grayburg, Queen and Seven Rivers Formations, separates the Yates from the Seven Rivers (Boyd, 1958).

The Tansill Formation crops out only on the very southeasternmost corner of the Humphrey Canyon GRA. Three hundred to 325 feet thick, it is comprised mainly of dolomite.

The Capitan Limestone grew in a low energy environment in Seven Rivers, Yates and Tansill time. Lack of a higher energy environment led Achauer (1969) to term the unit an organic bank deposit rather than a barrier reef. The Capitan Limestone consists of massively-bedded, light colored, calcitic limestone with associated dolomitic limestone, a structureless limestone core and basinward calcarenites formed from reef talus, all overlying the Goat Seep Dolomite (Kelley, 1971; New Mexico Geological Society, 1954). The reef or bank spread basinward (southward) several miles but grew only 1300 to 2000 feet vertically (Kelley, 1971). By the end of Tansill time the basin became very restricted and hypersalinity of the water killed the reef-building organisms.

Triassic to Tertiary

No rocks of these ages crop out in the GRA. Triassic red beds of the Dockum Group and other sediments may have been deposited in the area but periodic uplifts have resulted in erosion of all material younger than the Guadalupian Artesia Group and Capitan Limestone.

Quaternary

Unconsolidated alluvial fan and valley-fill sediments cover Big Dog Canyon and Crow Flats. Crow Flats, the northern extension of the Salt Basin of Texas, is a closed basin with recently formed evaporites containing gypsum, dolomite, aragonite, halite, quartz and celestite (Dunham, 1972) occurring in the Alkali Lakes of the southwest central part of the GRA. Gypsum dunes sands are also persent in Crow Flats (New Mexico Geological Society, 1954).

Structural Geology

The area lies within the North American craton which, during the Proterozoic, underwent two periods of deformation and igneous intrusion (Condie and Budding, 1979). The area remained relatively quiet tectonically, except for one period of uplift probably in the latest Mississippian or earliest Pennsylvanian, until the later Pennsylvanian to Permian when the region underwent warping and minor folding and faulting (Kelley, 1971; Meyer, 1966), probably as a result of the Ouachita Orogeny in the southeast (fig. 2a; Dickinson, 1981). The area was uplifting again in Triassic to Jurassic time, possibly as a result of rifting to the southeast (fig. 2c; Dickinson, 1981). Little effect of the Laramide orogeny was felt in southeastern New Mexico, although arching may have occurred during that time (Kelley, 1971). Early Miocene to the present has been a time of intense tectonic activity along and near the Rio Grande, with much normal faulting occurring within the Humphrey Canyon GRA.

Late Paleozoic tectonic activity produced the Pedernal uplift, the N - S trending axis of which goes through the western part of the GRA (fig. 2a). Activity was periodic during the Pennsylvanian and Permian, and some folding and faulting was associated with warping. Subsidence in the Delaware Basin (fig. 2a and 2b) accelerated during the early Permian, with flexing and faulting occurring along the now buried Bone Spring Monocline (fig. 1; location of Capitan Reef Scarf approximately parallels the earlier monocline) which was the northern boundary of the Delaware Basin.

There is no record in the GRA, save erosion of all the post-Permian and a large part of the Permian section, of further tectonic activity until the Tertiary. The GRA is intensely block-faulted, with a major break occurring on the western edge of the Guadalupe uplift (figure 1; "The Rim"). All the Miocene to recent faults trend NNW or N-S. The Brokeoff Mountains are not only bordered by faults but are faulted throughout the range (fig. 3). The Salt Basin (fig. 3) is a graben, and rocks of the western part of the GRA are also faulted, although to a lesser extent (Hayes, 1964). Alluvial fans located less than 15 miles due north of GRA have been offset by dip-slip faulting, indicating the area may still be tectonically active (Kelley, 1971).

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 extraordinarily well preserved can be beneficial to science and/or tourism, and

c) fossils can be excellent indicators of the paleogeographic and paleocological 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 fossils present in the Permian rocks of the Humphrey Canyon GRA. To the authors´ knowledge, there are no fossil localities of outstanding importance, either scientifically or as curiosities.

The Brokeoff Mountains and Guadalupe Mountains contain rock units of the American Permian Section, with the Guadalupian Stage named for fauna of the Guadalupe Mountains. Intense interest in oil-producing Permian rocks of southeastern New Mexico and Texas spawned numerous paleontological studies. Boyd (1958), Meyer (1966) and Girty (1908) produced detailed studies of the fossils which occur in Permian rocks, and in the case of Meyer, older Paleozoic rocks of the subsurface as well.

Boyd (1958) summarized his data into a chart which is reproduced in this report as table 1. As so much information is available and no collection sites for outstanding specimens are known to occur in the area, the Boyd (1958) table is all that will be presented in this report. More detailed information is available in the above-mentioned works and is included in the file which Geoexplorers will provide to the BLM.

Geologic History and Paleogeographic Development

The geologic history of the area is long and relatively complex; only a brief synopsis is presented here. Excellent summaries of the main geological events that affected New Mexico are given by Dickinson (1981) and Burchfiel (1979). More detailed accounts of the geologic history of southeastern New Mexico are presented by Black (1973), Kelley (1971), Meyer (1966), Hayes (1964), and Kelley and Thompson (1964).

TABLE 1. Fossils in Permian rock units present in the Humphrey Canyon GRA, from Boyd, 1958.

	Basin phase		Basin-margin phase				Shelf phase					
	Cutoff	Cherry Canyon	Victorio Peak	L. San Andres transition†	U. San Andres transition	Goat Seep reef	Yeso	San Andres	Grayburg‡	Grayburg§	Queen‖	Seven Rivers
Fusulinids		×	×	×	×		×	×	×	×	×	×
Smaller foram.				×								
Sponges, calc.		×		×	×	×						
Sponges, silic.		×										
Corals	×	1	×	×	×	×		×				
Brachiopods	×	×	×	×	×	×		×		×	×	
Bryozoans				×		1		×			×	
Chitons				×								
Scaphopods				×						×	×	
Gastropods	×		×	×				1	×	×	×	×
Nautiloids	×			×	×	1					×	
Ammonoids	×			×							1	
Pelecypods	×	1		×	1	1					×	
Worm trails (?)	×								×		×	
Trilobites				×	×							
Ostracods				×							×	
Crinoids		×	×	×	×	1	×	×			×	
Echinoids		×		×	×				×		1	
Fish				×								
Algae (?)						×			×	×	×	×

• "1" indicates that only one specimen was found.
† Junction of Last Chance and Whiteoaks Canyons, Bandanna Point quadrangle.
‡ Basal sandstones zone, southern Brokeoff Mountains.
§ Queen Mesa, west scarps.
‖ Queen Mesa.

The Humphrey Canyon GRA lies within the North American craton and is underlain by two ENE-trending belts. A 1.2 to 1.65 b.y. belt of meta-sedimentary and meta-igneous rocks goes through the northwest part of the GRA and the rest of the area is underlain by a 1.0 to 1.3 belt of granite rocks which extends northeast to Ohio (Condie and Budding, 1979).

The post-Precambrian geologic history is summarized as follows:

1) Periodic southward tilting took place from Cambrian to Mississippian time. During trangressions the marine shallow-water clastics and carbonates of the Early Ordovician Bliss sandstone and El Paso group, the Late Ordovician Montoya group, the Silurian Fusselman Dolomite, Late Devonian Percha Shale equivalents, and Mississippian sediments were deposited.

2) Uplift and erosion occurred in the late Mississippian or early Pennsylvanian. Pennsylvanian carbonates and lesser clastics were deposited subsequently.

3) During the Late Pennsylvanian to early Permian, the Ouachita orogeny to the south caused uplift and folding of the north-trending Pedernal Mountains, a range of the ancestral Rockies (figs. 1 and 2a). Dominantly carbonate marine sediments were deposited on the Northwestern Shelf with bank and reef material deposited at the margin of the Delaware Basin (fig. 2b). The Permian Basin was a restricted basin and, at some times including the latest Permian, a closed basin. Guadalupian fauna include only those species which could survive highly saline conditions. By the end of Capitan time salinity of the basin water was too great for reef- or organic bank-building

creatures and the reefs died. Ochoan sediments include a high percentage of evaporites with sylvite and halite occurring as well as gypsum, suggesting the basin was completely closed and that the sea was drying up.

4) During the Triasic the area was uplifted, possibly as a result of increased thermal activity associated with rifting southeast of the area (fig. 2c). Erosion of the uplift and deposition of the continental red beds of the Dockum group followed. It is not known if the Triassic red beds were deposited within the GRA (see fig. 2c).

5) The area remained uplifted during the Jurassic, and probably during the Cretaceous, and no sedimentation occurred.

6) The effects of the Laramide orogeny were slight in Central New Mexico, but arching may have recurred along the Pedernal uplift.

7) Magmatism and tectonism began in New Mexico in the mid-Tertiary. No post-Precambrian igneous rocks have been found in the GRA during subsurface studies but Tertiary intrusives, some dated as 32.2 to 33.9 m.y. old (Calzia and Hiss, 1978) crop out 3 to 20 miles west, south, southeast and east of the Humphrey Canyon GRA. The area has been intensely block-faulted, with some movement occurring in the Holocene.

8) Valley-fill sediments were deposited in the structural basins of the area, most notably the Crow Flats region. This area also contains playa lakes with active evaporite deposition and dunes of gypsum sand.

ENERGY AND MINERAL RESOURCES

The following are descriptions of known deposits and occurrences of mineral and energy resources in the Humphrey Canyon GRA. Known resources consist of eleven materials pits. Nine dry oil and gas exploration wells have been reported. Sources of information were U.S. Bureau of Mines MILS (1982), King and Harder (1982), DeCicco and Patterson (1979), Hayes and Cone (1975), Black (1973) and Hayes (1964). Also consulted but providing no information were U.S. Geological Survey CRIB (1982), Finch (1967), New Mexico Bureau of Mines and Mineral Resources (1965) and Harrer and Kelly (1963). Figure 3 shows locations of the listed materials pits and dry wells.

Known Materials Sites and Oil Exploration Wells,
No Recorded Production

1. Materials Pit
   Location: Sec. 9, T26S, R18E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4868; DeCicco and Patterson, 1979.

2. Materials Pit
   Location: Sec. 20, T26S, R18E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4869; DeCicco and Patterson, 1979.

3. Materials Pit
   Location: Sec. 34, T25S, R18E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4870; DeCicco and Patterson, 1979.

4. Materials Pit
   Location: Sec. 29, T26S, R17E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4874.

5. Materials Pit
   Location: Sec. 29, T25S, R17E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4875; DeCicco and Patterson, 1979.

6. Materials Pit
   Location: Sec. 21, T26S, R17E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4876; DeCicco and Patterson, 1979.

7. Materials Pit
   Location: Sec. 5, T24S, R19E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4885; DeCicco and Patterson, 1979.

8. Materials Pit
   Location: Sec. 19, T25S, R19E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: U.S.G.S., 1982, MILS, p. 4886.

9. Unnamed Sand and Gravel Pit
   Location: Sec. 29, T25S, R17E.
   Commodity: Sand and gravel.
   Production: Unknown.
   References: DeCicco and Patterson, 1979.

10. Unnamed Sand and Gravel Pit
    Location: Sec. 20, T24S, R18E.
    Commodity: Sand and gravel.
    Production: Unknown.
    References: DeCicco and Patterson, 1979.

11. Unnamed Sand and Gravel Pit
    Location: Sec. 19, T24S, R19E.
    Commodity: Sand and gravel.
    Production: Unknown.
    References: DeCicco and Patterson, 1979.

Dry Oil and Gas Test Wells

4000 ft./Sinclair Federal-Eddy 1-19S
- Location: Sec. 32, T22S, R21E.
- Commodity: Oil and gas.
- Production: None, dry - abandoned
- References: Hayes, 1964.

4578 ft./Campbell, E.P., No. 1 Spiegel-Fed.
Location: Sec. 14, T26S, R20E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

4570 ft./W.W. West, No. 1 West Dog Canyon Unit
Location: Sec. 18, T25S, R20E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

4998 ft./Dunnigan, E. J. Jr. No. 1 Alpha Fed.
Location: Sec. 31, T25S, R19E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

3635 ft./Pennzoil Co. No. 1 Southland "32" State
Location: Sec. 32, T25S, R18E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

2970 ft./Pennzoil Co. No. 1 Southland "28" State
Location: Sec. 28, T25S, R17E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

3189 ft./E.P. Campbell No. 1 McMillan Fed.
Location: Sec. 15, T23S, R19E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

3848 ft./W.R. Weaver, No. 1 Thompson
Location: Sec. 9, T23S, R19E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

2353 ft./Coral Oil and Gas Co. No. 1, Warren
Location: Sec. 19, T23S, R18E.
Commodity: Oil and gas.
Production: None, dry - abandoned.
References: King and Harder, 1982.

Mineral Deposit Types

Geological environments considered as potentially favorable for the occurrence of mineral and energy resources, and those deposit types, include the following:

Paleozoic sedimentary rocks	- Oil and gas,
	- Red bed copper deposits,
	- Pyrometasomatic replacement deposits
Quaternary basin-fill sediments and playa lakes	- Sand and gravel, evaporites.

Paleozoic Sedimentary Rocks

<u>Oil and gas</u> - Black (1975; cited <u>in</u> King and Harder, 1982, but not listed in their references) considers the oil-producing Central Basin Platform (fig. 2b) as a close analog to the northwest shelf on the eastern flank of the Pedernal uplift (see figs. 2a and 2b for locations). In the Central Basin Platform, Permian carbonates act as caprock above the unconformity between the Permian rocks and the pre-Permian reservoirs. Devonian Woodford/Percha equivalent and some Mississippian and Pennsylvanian units, all known to be present in the subsurface of parts of the GRA, are considered by Black to be potential source rocks. Hayes and Cone (1975) state that although source rocks are present they are not abundant.

All oil and gas production to date has been from areas east of the Huapache monocline (see fig. 1 for location). Exploration in the northwest shelf west of the Huapache monocline has been minimal and sporadic (King and Harder, 1982). Plio-Pleistocene uplift and erosion uncovered much of the Permian section west of the monocline and has destroyed or flushed hydrocarbon reservoirs that may have been present in those Permian rocks. Fresh water intake points are now present along the Guadalupe Mountains escarpment and in the tectonically disrupted Brokeoff Mountains have resulted in flushing of hydrocarbons. Black suggests that the Salt Basin (fig. 1) has potential for oil and gas in Wolfcamp reef-rock reservoirs. Hayes and Cone (1975) rate oil and gas potential for the Humphrey Canyon GRA as poor to fair. DeCicco and Patterson (1979) rate the area as prospectively valuable land for oil and gas resources.

Red bed copper deposits - Red bed 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). No occurrences are known in the Humphrey Canyon GRA, but copper and lead mineralization is reported to occur in Abo red beds of the southern Sacramento Mountains, northwest of the area, possibly a red bed-type deposit (West Texas Geological Society, 1949). In north-central New Mexico, uneconomic concentrations of malachite, azurite and lesser hematite, pyrite, bornite, chalcocite, covellite, chalcopyrite and melaconite are found mainly in arkosic channel deposits within the Permian Bursum and Abo Formations. Copper-rich zones are one to three feet thick and copper minerals cover fractures, fill voids, coat detrital grains and are most abundant replacing and surrounding plant debris.

The red bed copper deposits of New Mexico were first studied by 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 resonse to a local lowering of Eh. The ultimate source of copper is considered to be Precambrian copper deposits and/or copper-enriched lithologies.

Red bed sandstones and shales are present in a few of the Pennsylvanian and Permian formations and hydrocarbons may have provided localized lowering of Eh. The Humphrey Canyon GRA is far from known sources of copper, however.

Pyrometasomatic replacement deposits - Harrer and Kelly (1963) note a replacement deposit of iron in limestone, known as the Little Walt Canyon Hematite-Limonite, occurring ten to fifteen miles east of the Humphrey Canyon GRA in Sec. 2, T.22S., R.24 E. Nearby Tertiary igneous intrusions are likely the source. No deposits of this type are known in the GRA but there is a possibility that Tertiary intrusions exist at depth beneath the area.

Quaternary Basin-fill Sediments and Playa Lakes

Sand and gravel - Several sand and gravel deposits are located in Quaternary sediments of the GRA (fig. 3). The presence of alluvial fans and other basin-fill material suggests further resources may exist.

Evaporites - Quaternary playa evaporites containing gypsum, dolomite, argonite, halite, quartz and celestite are reported to occur just north of the Alkali Lakes area of the Salt Basin (see fig. 3 for location; Dunham, 1972). The thickness and extent of the deposits is not known.

Mineral Economics

The only known resources in the Humphrey Canyon GRA are Quaternary sand and gravel deposits. Several ranches located in the Crow Flats section of the Salt Basin, and the two improved roads within the GRA (fig. 1) are likely the only potential users of sand and gravel at this time, and it seems probably that resources will exceed demand in the foreseeable future.

No occurrences of strategic and critical materials are reported to occur in the GRA.

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

In this section, the Brokeoff Mountains WSA is discussed with respect to its physiography, geology, mineral occurrences, resource potential, and recommendations for further work. The classification of resource potential and level of confidence is according to the scheme provided by the Bureau of Land Management (attachment 9, dated March 24, 1982). The classification is summarized on the maps in figures 5 and 6 and 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 to support or refute the possible existence of mineral resources.

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

Brokeoff Mountains WSA (030-112)

Physiography

The WSA lies within the Sacramento section of the Basin and Range Province, just west of the Guadalupe Mountains. The topography is steep with a maximum relief of about 3000 feet.

Geology

Rock units that crop out in the Brokeoff Mountains WSA are Early Permian sediments of the Victorio Peak Limestone, Cutoff Shale, Cherry Canyon Sandstone, San Andres Formation and the Grayburg and Queen Formations of the Artesia groups, and Quaternary alluvial fan deposits.

Permian rocks crop out in all but the very westernmost part of the WSA and have been described by Boyd (1958). Permian rocks of nearby areas within the Humphrey Canyon GRA have been described by Black (1973), Kelley (1971) and Hayes (1964). The sediments consist of nearly continuously deposited (some local unconformities exist) carbonates with lesser clastics, mainly sandstone, and gypsum. The rocks were deposited on a shallow shelf in a restricted sea. The basinward edge of the shelf was located in and just south of the southernmost part of the WSA. The Victorio Peak limestone represents the initial reef or organic bank built on the Permian Shelf margin. Overlying are the black shales and fetid limestones of the Cutoff Shale. Permian reefs restricted circulation of sediments between the northwest shelf and Delaware basin, with the exception being the Cherry Canyon Sandstone tongue which spread northward over the basin edge and onto the shelf. During the period of Cutoff shale and Cherry Canyon sandstone deposition, the San Andres Formation was deposited to the north with a facies change and transitional zone existing between the two groups of sediments (see fig. 3). The limestones, dolomites, clastic-rich dolomites, gypsum and patch reefs of the San Andres Formation cover much of the WSA. Conformably, for the most part, overlying the San Andres and Cherry Canyon are the continuously deposited Grayburg and Queen Formations of the Artesia Group. The Grayburg Formation consists mainly of dolomite with lesser limestone and pink to brown sandstone. The Queen Formation is distinguished by having a much higher percentage of sandstone and lesser carbonate.

On the western edge of the WSA, along the margin between the Brokeoff Mountains and the Salt Basin graben, are Quaternary alluvial fan deposits derived drom erosion of the Permian sediments.

Mineral Deposits

No mineral deposits are reported to lie within the Brokeoff Mountains WSA. Two sand and gravel deposits (sg 8 and sg 11) are located in Quaternary sediments less than a mile west of the WSA and one oil and gas test well (W.W. West, No. 1 West Dog Canyon Unit - 4570 ft.) was drilled less than a mile east of the WSA.

Land Classification for GEM Resources Potential

Oil and gas

The entire WSA is considered to have low favorability at a confidence level of B (area 1, fig. 5) for the following reasons:

a) oil is recovered from Permian formations of the Northwestern shelf east of the Huapache Monocline, but

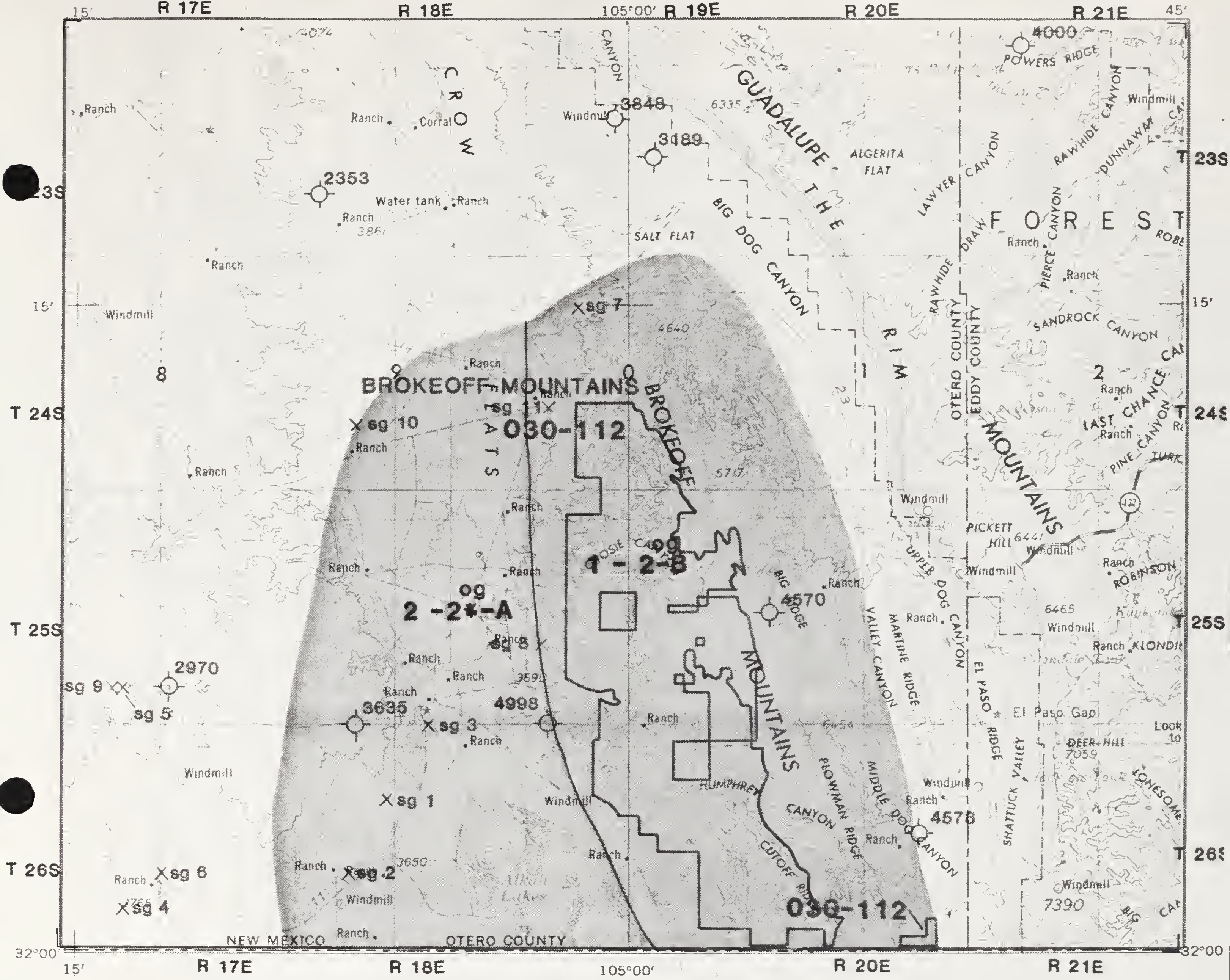


FIG. 5. FAVORABILITY AND LEVEL OF CONFIDENCE MAP FOR OIL AND GAS RESOURCES OF THE HUMPHREY CANYON AREA, NEW MEXICO

b) In the Brokeoff Mountains area, only a few thousand feet of Paleozoic sediments overly the Precambrian crystalline basement, and

c) The area has been intensely faulted, allowing flushing of hydrocarbons.

d) Few test wells, all dry, have been drilled in the area because of these problems; the area has not been explored sufficiently to be sure that there are or are not accumulations of hydrocarbons.

The Salt Basin, adjacent and west of the WSA, is considered by King and Harder (1982) to have the best potential in the area. The Salt Basin contains far fewer faults and parts of the basin have deeper sedimentary cover. Permian reef sediments, including sediments of the Wolfcampian "Abo" reef, may extend beneath the Salt Basin, providing good reservoirs for oil and gas. For these reasons, the Salt Basin area adjacent to the WSA is classified as low to moderately favorable (2*) with a confidence level of A (area 2, fig. 5).

Sand and Gravel

Parts of the WSA underlain by Quaternary sediments are considered moderately favorable for sand and gravel resources at a confidence level of C (area 3, fig. 6). The reasons for the above classification are as follows:

a) Two nearby sand and gravel occurrences are located in Quaternary sediments

b) Although Quaternary sediments in the WSA are likely to be similar, steepness of the fans within the WSA probably make the area less attractive for sand and gravel pits than other areas in the Salt Basin.

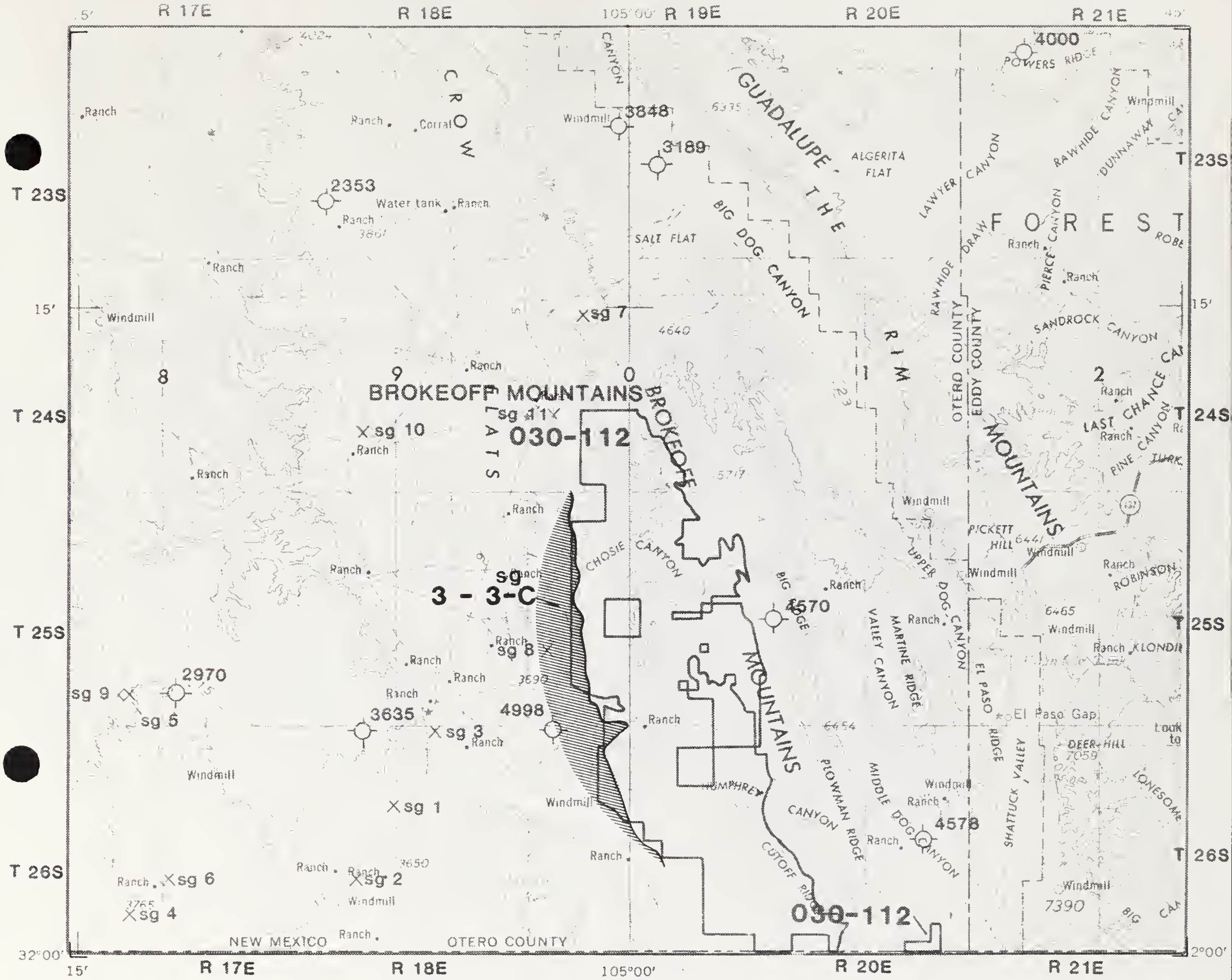


FIG. 6. FAVORABILITY AND LEVEL OF CONFIDENCE MAP FOR SAND AND GRAVEL RESOURCES OF THE HUMPHREY CANYON AREA, NEW MEXICO

<u>Recommendations and Conclusions</u>: No further work is recommended for the Brokeoff Mountains WSA. All oil and gas exploration wells that have been drilled west of the Huapache Monocline were dry. Other areas, including the Salt Basin, are more attractive targets than the heavily faulted Brokeoff Mountains. It is quite unlikely that any accumulation of hydrocarbons that may have been present in the Paleozoic sediments has survived flushing by fresh water that must have resulted due to Tertiary to Quaternary normal faulting. The probability for the occurrence of other resources within the WSA is also low.

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