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# MINERAL RESOURCES OF THE GRAY RANCH AREA, HIDALGO COUNTY, NEW MEXICO

by Sam Thompson III, Robert W. Eveleth, and James M. Barker
New Mexico Bureau of Mines and Mineral Resources
Socorro, NM 87801

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ABSTRACT

The U.S. Fish and Wildlife Service is proposing that the Gray Ranch of about 330,000 acres in southern Hidalgo County, New Mexico, be purchased and designated as the Animas National Wildlife Refuge. As long as their policy of disallowing leasing of mineral rights remains in effect, we will remain opposed to their acquisition of the ranch and their prohibition of exploration and development of the mineral resources. About 130,000 acres of State mineral leases lie within the proposed refuge boundary. We are opposed to the donation of this acreage to the refuge, or to a trade for Federal land elsewhere in the state, because of the economic need for the mineral resources and the revenues they could bring to the State.

Oil and gas resources are indicated by favorable source and reservoir rocks in the Paleozoic (up to 12,000 ft thick) and Lower Cretaceous (up to 10,000 ft thick) sedimentary rocks. Specific reservoir objectives with associated source rocks include El Paso and Montoya dolostones (Ordovician), Horquilla reef-margin dolostones and deep-marine basin sandstones (Pennsylvanian-Lower Permian), Epitaph dolostones and Concha limestones (Permian), and Mojado sandstones (Lower Cretaceous). Prior to Tertiary time, significant oil and gas fields probably were present in the Gray Ranch area and trapped within these reservoirs by stratigraphic barriers and Laramide (or earlier) structures. Whether any of these fields are preserved after the local metamorphism during Tertiary igneous intrusion and volcanism, the extensive Basin and Range fracturing, and fresh-water flushing, can only be determined by drilling exploration wells. If the Tertiary metamorphism is more extensive than presently indicated, the probability of oil and gas resources will be decreased, but the probability of geothermal, carbon dioxide, and other mineral resources will be increased.

Metallic mineral resources, especially manganese, silver, and lead, have been identified in and near the Gray Ranch area. Manganese deposits have been found near Animas Peak (Peace prospect), in the Winkler anticline area in the central part of the Animas Mountains, and in the Whitewater Mountains (Rusty Ruthlee prospect). In the Winkler anticline area, fracture zones up to 10 ft wide in the Oak Creek Tuff (a Tertiary volcanic unit) contain black, manganiferous calcite which has been oxidized to psilomelane. Ores grade up to 40% manganese; a few dozen tons have been produced. Also in the Winkler anticline area, silver and lead deposits were discovered in the Gillespie mine in 1880. Along trend, about four miles to the northeast, the Red Hill mine produced about $100,000 in lead and silver prior to 1950; ore occurs in fissure veins within the Oak Creek Tuff. An excellent exploration target for base and precious metals on the Gray Ranch lies along the trend of the Winkler anticline to the southwest, where hydrothermal solutions from the Walnut Wells Monzanite probably mineralized fracture zones in Tertiary volcanic rocks and fracture or replacement zones in Paleozoic-Lower Cretaceous limestones and dolomites.

Industrial mineral resources include fluorspar, limestone and dolomite, sand and gravel, stone, nitrate, perlite, and zeolite. In the Winkler anticline area, hydrothermal fluids from the Walnut Wells stock deposited fluorite in silicified breccia zones up to 30 ft thick in Horquilla limestones (Permian). Drilling during 1970-1976 proved at least 150,000 short tons of ore reserves, grading 25 to 35% calcium fluoride. Only 10,000 short tons were produced. Several other fluorspar deposits have been located in this area. Paleozoic and Lower Cretaceous limestones and dolomites crop out in the northern and central parts of the Animas Mountains and may be present at shallow depths beneath the Tertiary volcanic rocks in other parts. Both the carbonate and volcanic rocks can be used for building stone or crushed stone. Sand and gravel deposits are found in the Quaternary alluvium on the flanks of the Animas Mountains and in the adjoining Animas and Playas Valleys. Potassium-calcium nitrates have been mined from the Fitch claims, located southwest of the Winkler anticline area. They appear to be surface concentrates from groundwater leaching. Because so much of the exposed bedrock in the Gray Ranch area consists of volcanic rock, significant deposits of perlite and zeolite may be present.

## INTRODUCTION

The U.S. Fish and Wildlife Service (USFWS), Department of Interior, is proposing that the Gray Ranch be purchased and designated as the Animas National Wildlife Refuge. Figure 1 shows the location of this ranch of about 330,000 acres in southern Hidalgo County, New Mexico. Much of the area lies within the Animas, San Luis, and Whitewater Mountains, but parts lie in the adjoining Animas and Playas Valleys.

Our main objection to this proposal is that this huge block of acreage would be placed effectively off limits to commercial exploration and development of mineral resources, including oil and gas, which are so vital to our State and National economies. The policy of USFWS is to disallow leasing of any mineral rights they own, even if it would help to fund their acquisitions and operations and relieve the burden of the taxpayers (personal communication to Thompson by Michael J. Spear, Regional Director of the USFWS, June 29, 1989). We believe a cooperative policy could be worked out such that industry operators would observe reasonable requirements to protect wildlife and other environmental concerns.

Other subdivisions of the U.S. Department of Interior, such as the Forest Service, Bureau of Land Management, and National Park Service, understand the concept of multiple use of the land and generally have reasonable requirements for exploration and development of mineral resources. Indeed, former Secretary of the Interior, Donald P. Hodel, stated in a 1987 report to Congress on the Arctic National Wildlife Refuge: ". . . This Nation has proven that it need not choose between an improving environment on the one hand, and exploration and development of the energy resources required for growth and survival on the other. We can have both . . . "

The no-leasing policy of USFWS is in direct conflict with the multiple-use concept. As long as that policy remains in effect, we remain fundamentally opposed to their acquisition of the Gray Ranch and their prohibition of exploration and development of mineral resources.

By law, any existing mineral leases within the boundary of a wildlife refuge would be honored by USFWS, and access would be granted to operators. However, if the recent experience in the Bitter Lakes area is any indication, such operators may expect many obstacles in the bureaucratic requirements and in human roadblocks by pro-wildlife demonstrators.

About 130,000 acres of State mineral leases lie within the proposed refuge boundary, approximately 40 percent of the total acreage. Advocates of the refuge believe that the potential for mineral operations over such a wide area would be detrimental to the wildlife. They propose that the State of New Mexico either

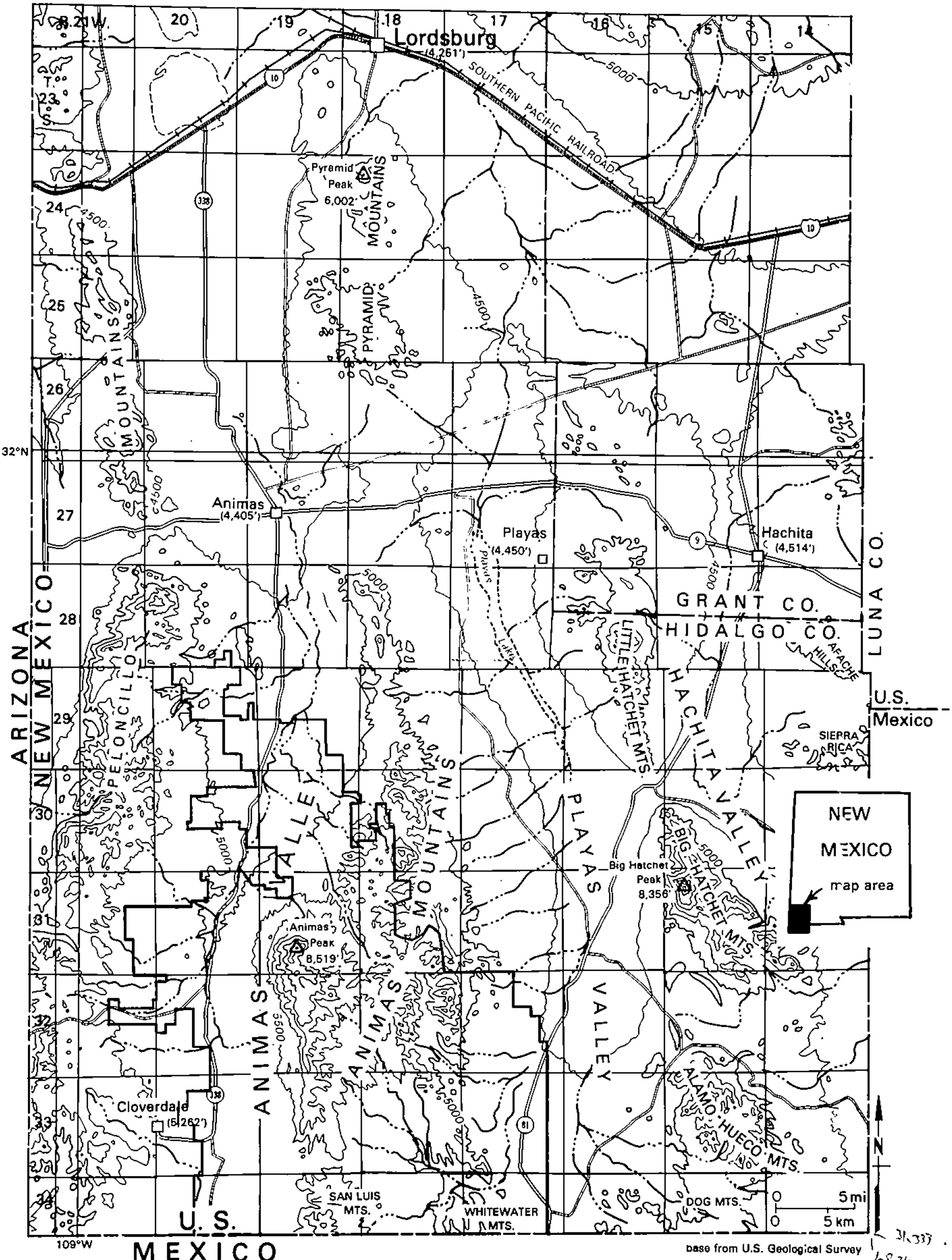


Figure 1. Location map of the Gray Ranch area (about 330,000 acres) in Hidalgo County, New Mexico, covering parts of the Animas, San Luis, and Whitewater Mountains, and parts of the Animas and Playas Valleys.

donate this land to the Federal refuge or trade it for Federal land of equivalent value elsewhere in the State.

In his letter of June 9, 1989 (see Appendix), the Commissioner of Public Lands for the State of New Mexico, William R. Humphries, expressed strong opposition to USFWS acquisition of the private land and to any trade of State land within the Gray Ranch area. He points out that the large amount of leased area indicates substantial mineral potential. The State collects a severance tax on mineral extraction from Federal, State, or private land, and receives bonuses, rentals, and royalties from leases on State land. Any acreage locked up by USFWS, and any unequal trades of more valuable State land for less valuable Federal land (which generally has been the case), will result in a loss of revenue to the State, especially depriving the trust that funds public schools. He requested that the New Mexico Bureau of Mines and Mineral Resources provide him with relative values of the various mineral resources in the Gray Ranch area and other related information that will help to protect the interests of the State. In his letter of June 19, 1989 (see Appendix), NMBMMR Director, Frank E. Kottlowski, responded to that request and expressed concern about the Gray Ranch issue and its economic importance to New Mexico.

Thus we have prepared this report in response to the request by Commissioner Humphries. The purpose of our report is to summarize currently available information on the mineral resources and make reasonable projections of prospective acreage in the Gray Ranch area. Any such work in a frontier area by a government agency, State or Federal, can only be considered a progress report. Final appraisals in dollar terms can be made only as a result of commercial exploration and development by industry operators.

Our relative evaluations are based on estimates of recovery with present technology. These should be considered as minimum estimates, because during the perpetuity planned for the wildlife refuge, methods are bound to improve and allow much deeper, yet economically feasible, extractions. Demand for such nonrenewable mineral resources is bound to increase with time and will accelerate during any crisis resulting from shortages of materials needed for normal industrial production or national security emergencies. The ultimate value of the mineral resources of the Gray Ranch may be many times the present value.

After a general discussion of the geologic setting, we have divided the main body of the report into three sections prepared by each author on oil and gas (also geothermal and carbon dioxide), metallic, and industrial mineral resources. In this report, we do not cover other geologic/engineering aspects of land use (such as for waste-disposal sites), nor do we cover the water resources, which eventually may become the most valuable commodity of all.

Although we are not qualified to discuss other considerations in detail, we have found additional reasons why the Gray Ranch should not become a wildlife refuge. Based on the sample of Hidalgo County ranchers we have contacted, we judge that all are opposed to Federal acquisition of that land. They believe that the percentage of Federal land in the region is already too high, that the spread of wilderness and other restricted-use areas is already too broad, and that taxpayer dollars should be spent on more important items. Ranchers are especially concerned about the reported plan to bring the Mexican wolf into the refuge. They believe that animal would survive mainly by preying on their cattle. Ranchers and other residents in the region are concerned that law-enforcement officers would be disallowed entry into the refuge, which because of its location on the border would become a large haven for illegal entry, drug smuggling, and other criminal activities.

Acknowledgments--We gratefully acknowledge the reviews of this report by Frank E. Kottlowski, Director of NMBMMR, and by Ernest Szabo, Senior Geologist at the State Land Office in Santa Fe. Lynne McNeil typed the text and tables, and Michael Wooldridge drafted the figures.

## GEOLOGIC SETTING

Figure 2 shows the location of the Gray Ranch area on a generalized geologic map of the southwesternmost part of New Mexico, as adapted from Dane and Bachman (1965). A more detailed map of the southern Animas, San Luis, and Whitewater Mountains was prepared by Zeller (1962). Most of the surface exposures in the mountains are of Tertiary volcanic rocks. Some Tertiary (to Quaternary) fluvial sediments were deposited in intramontane fans. Younger Quaternary alluvium and other superficial deposits are found in the intramontane drainages and in the broad Animas and Playas Valleys.

Because of the Tertiary-Quaternary cover, description of the older rocks must be based on projections from outcrop areas in nearby ranges and from drill holes. Table 1, taken from Zeller (1965, fig. 2, p. 7), shows the stratigraphic units exposed in the Big Hatchet Mountains. Above Precambrian basement, which is composed of granite and other igneous or metamorphic rocks, we may expect in the Gray Ranch area as much as 12,000 ft of Paleozoic and 10,000 ft of Lower Cretaceous sedimentary rocks. Erosional and nondepositional unconformities below, within, and above the Paleozoic-Lower Cretaceous strata may have produced areas where the section is thinner.

Paleozoic rocks include Cambrian-Ordovician sandstones and dolostones, (Silurian probably is absent), Devonian mudstones, Mississippian limestones, Pennsylvanian limestones, and Permian redbeds, limestones-dolostones, and thin sandstones. Most of these rocks appear to have been deposited in a shallow-marine shelf environment. In the middle to upper Pennsylvanian and lower Permian, a dolomitized reef margin and a deep-marine basin facies of dark mudstones, limestones, and sandstones probably is present in the Gray Ranch area.

Triassic-Jurassic rocks appear to be absent in this area. Lower Cretaceous rocks include nonmarine redbeds, shallow-marine limestones with local rudist reef buildups, and shallow-marine to deltaic sandstones and mudstones. Paleozoic and Lower Cretaceous rocks will be discussed further in the section on Oil and Gas Resources.

Tertiary volcanic rocks include latite-andesite flows, breccias, and tuffs. They may attain a total thickness of about 8,000 ft (Elston and others, 1979, fig. 2, sections 5 and 6, p. 3). Elston and others (1979) have mapped several large, overlapping volcanic cauldrons in the Gray Ranch area. Large intrusive igneous plutons may be present below these volcanic centers, and the adjacent Paleozoic and Lower Cretaceous rocks may be metamorphosed. However, most of the exposed volcanic rocks appear to be outflow deposits, including extensive and massive ash-flow tuffs.

Tertiary -lower Quaternary conglomerates and sandstones deposited in alluvial fans within the mountains may be hundreds

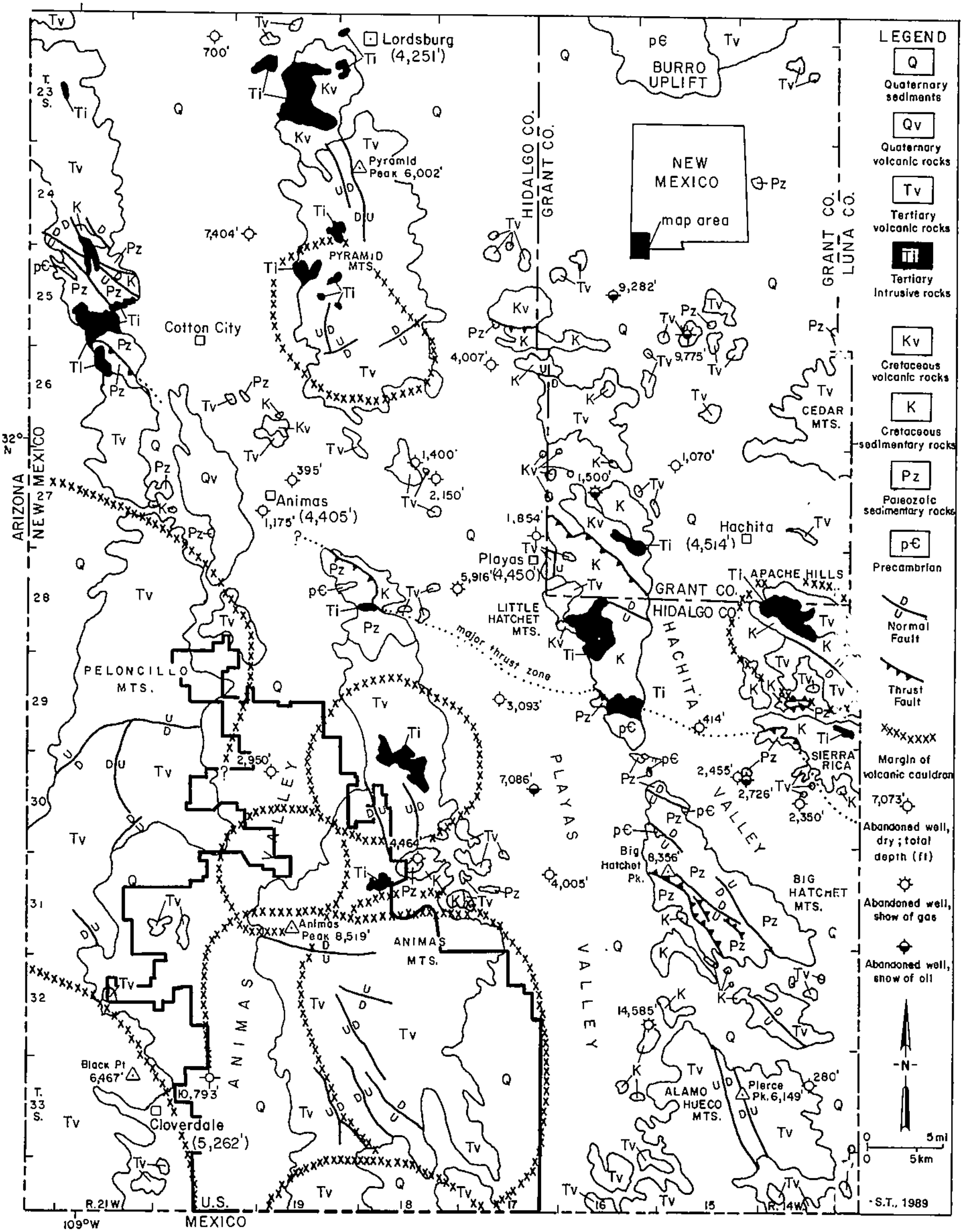

Figure 2. Generalized geologic map of southern Hidalgo and Grant Counties, New Mexico (modified from Dane and Bachman, 1965; margins of volcanic cauldrons from Elston and others, 1979); outline of Gray Ranch from Fig. 1.

Table 1 - Stratigraphic units exposed in Big Hatchet Mountains (from Zeller, 1965)

| *Age* | | | *Rock units* | | *Measured thicknesses (feet)* | *Lithology and remarks* |
|---|---|---|---|---|---|---|
| TERTIARY | | | | | | Basal unit consists of several hundred feet of limestone fanglomerate. This is overlain by thick sequence of volcanic tuffs and flows. |
| | | | *Angular unconformity* | | | |
| EARLY CRETACEOUS | Albian | Washita | Mojado Formation | Upper member<br>Lower member | 5195 | Sandstone and shale. Thin to medium beds of strongly cross-laminated brown and gray sandstone are interbedded with thin units of shale. Lens-shaped sandstone masses probably represent channel fillings. Most of formation is of terrestrial origin. Calcareous fossiliferous marine beds are present in upper member and increase in number upward. |
| | Albian<br>Aptian | Fredericksburg<br>Trinity | U-Bar Formation | Suprareef ls. mem.<br>Reef ls. member<br>Ls.-sh. member<br>Oyster ls. member<br>Brown ls. member | 3500 | Limestone. Most of formation consists of medium and thin beds of bioclastic limestone alternating with thin gray shale beds. Lenses and thin beds of sandstone are found in lower part. Massive limestone near top of formation is a reef which ranges in thickness from 500 to 20 feet within the area. |
| | ? | ? | Hell-to-Finish Formation | | 1274 | "Red beds." Composed mostly of interbedded red arkose and sandstone, red and gray shale, and red siltstone. Basal bed is conglomerate composed of chert pebbles derived from Concha Limestone. |
| | | | *Erosional unconformity* | | | |
| PERMIAN | Leonard | | Naco Group | Concha Limestone | 1376 | Limestone. Medium-bedded limestone characterized by abundance of purple chert nodules and silicified productid brachiopods. Upper beds often dolomitized. Pre-Cretaceous erosion removed varying amounts of upper beds. |
| | Leonard or Wolfcamp | | Naco Group | Scherrer Formation | 5-20 | Quartz sandstone and limestone. Sandstone occurs as strata and lenses in limestone. |
| | | | Naco Group | Epitaph Dolomite | 1480-1519 | Dolomite. Medium-bedded light to dark gray dolomite with small knots of quartz. Lower part has a few lumpy limestone and dolomitic limestone beds. A red-weathered interval in lower part has red siltstone and, in one area, massive gypsum. |
| | | | Naco Group | Colina Limestone | 355-505 | Limestone. Thin-bedded limestone which is black on fresh fracture and which weathers light gray. Upper contact lies at different levels depending upon depth in section of Epitaph dolomitization. |
| | | | Naco Group | Earp Formation | 997 | Siltstone and claystone. Composed mainly of interbedded terrestrial brown-weathered cross-laminated siltstone and light gray claystone. Upper part contains marine limestone beds which increase in abundance upward. |
| | | | | *Local disconformity* | | |
| | Wolfcamp | | Naco Group | Horquilla Limestone | 3245-3530 | Limestone. Lower third is medium-bedded bioclastic limestone which includes oolitic and crinoidal beds and some zones rich in gray chert nodules. Upper two-thirds is complicated by basin, reef, and shelf facies. The crest of the Big Hatchet Mountains in general follows the reefs; the basin lies southwest of the range; the shelf lies along the east side of the range. The reefs consist of massive bioclastic limestone with dolomitized areas. Basin deposits consist of dark shale and black thin-bedded limestone. The shelf beds consist of light-colored medium-bedded bioclastic limestone. |
| PENNSYLVANIAN | Virgil<br>Missouri<br>Des Moines<br>Derry<br>Morrow? | | | | | |
| ? | ? | | *Erosional unconformity* | | | |
| MISSISSIPPIAN | Chester | | Paradise Formation | | 318 | Limestone. Thin-bedded yellowish-brown-weathered bioclastic and oolitic limestone rich in well-preserved fossils. Quartz sandstone beds and lenses near top have plant fossils. Pre-Horquilla erosion removed varying amounts of upper beds. |
| | Meramec<br>Osage<br>Kinderhook | | Escabrosa Limestone | Upper member<br>Middle member<br>Lower member | 1261 | Limestone. Lower member composed of thin-bedded limestone and a few shale beds. Middle member consists of rhythmic succession of thin limestone strata and nodular chert strata. Upper member composed largely of crinoidal limestone. Upper two members together usually form single cliff hundreds of feet high. |
| ? | ? | | | | | |
| DEVONIAN | | | Percha Shale | | 280 | Clay shale. Basal beds include a few strata of calcareous argillaceous siltstone and black shale. Upper beds include thin strata of nodular limestone. Bulk of formation is gray shale. |
| | | | *Unconformity* | | | |
| ORDOVICIAN | Cincinnatian<br>Champlainian | | Montoya Dolomite | Cutter Member<br>Aleman Member<br>Upham Member<br>Cable Canyon Mem. | 385 | Dolomite. Basal member consists of 10 to 20 feet of dolomitic quartz sandstone interbedded with dolomite. Aleman Member composed of rhythmic succession of dark gray dolomite strata and strata of black chert nodules. |
| | | | *Disconformity* | | | |
| | Canadian | | El Paso Formation | Bat Cave Member<br>Sierrite Member | 916-1070 | Limestone and dolomite. Sierrite Member composed of dolomite and dolomitic limestone; some strata rich in chert nodules and brown reticulated chert laminae. Bat Cave Member consists of bluish-gray-weathered bioclastic limestone. Uppermost beds dolomitized. |
| ? | ? | | | | | |
| LATE CAMBRIAN | Trempealeauian?<br>Franconian<br>Dresbachian? | | Bliss Formation | | 192-327 | Arenaceous rocks. Basal beds composed of arkose and boulder conglomerate. Middle beds consist of white orthoquartzite. Upper beds composed of dolomite with varying quantities of quartz sand. Thickness and lithology of units variable. |
| | | | *Erosional unconformity* | | | |
| PRECAMBRIAN | | | | | | Coarsely crystalline porphyritic granite and quartzite. |

to thousands of feet thick, but the younger Quaternary deposits probably are less than a few hundred feet thick. Tertiary-Quaternary fill in the Animas and Playas Valleys may range in thickness up to several thousands of feet.

The tectonic history of Paleozoic-Mesozoic time generally was one of gradual regional subsidence with intermittent broad uplifts. Local folding and faulting may have occurred.

During the Laramide orogeny (Late Cretaceous-Early Tertiary time), folds, thrusts, and other faults probably deformed the pre-Tertiary rocks locally within the Gray Ranch area as seen in other Hidalgo County outcrops (Zeller and Alper, 1965; Zeller, 1975; and Drewes, 1986). Some geologists have speculated that all of the southern Hidalgo County area was involved in a regional Laramide thrust with a displacement as much as hundreds of miles toward the northeast; however, no compelling surface or subsurface evidence has been found, and many geologists discount this possibility.

During the Basin and Range deformation (Late Tertiary time), the mountains were uplifted and the valleys were downdropped along extensive normal faults. Displacement may vary from thousands of feet to only a few feet. In some places, there may be no fault boundary between the mountains and adjacent valleys. However, many faults and other fractures are seen within the mountain outcrops. Less intense faulting and gravity sliding has continued into Quaternary time.

Future exploration for mineral resources in the Gray Ranch area will provide important additional information on the geology. If the ranch is locked up in a wildlife refuge, we would be left with a gap in our knowledge of the geologic framework that in turn would hinder exploration in adjoining areas.

# OIL AND GAS RESOURCES

by Sam Thompson III, Senior Petroleum Geologist, NMBMMR

Commercial accumulations of crude oil and natural gas (methane, ethane, etc.) are present in any area only if there have been favorable conditions of generation, collection, and preservation. Evidence in Hidalgo and Grant Counties indicates favorable generation from petroleum source rocks in the Paleozoic and Lower Cretaceous sections. Evidence also indicates favorable collection as a result of migration into Paleozoic and Lower Cretaceous reservoir rocks, and entrapment within stratigraphic barriers and Laramide structures. However, the most serious question concerns the preservation of oil and gas during the local metamorphism associated with Tertiary volcanic cauldrons and plutons, the disruption of traps by extensive Basin and Range fracturing, and the flushing of reservoirs by fresh water incursion, especially in the uplifted mountain areas. Nevertheless, significant oil or gas fields may be preserved where the tectonic and igneous effects are minimal.

## Exploration Wells

In the map area of Fig. 2, covering about 4,100 square miles, a total of 28 wells have been drilled to date in exploration for oil and gas. Three shallow wells were omitted from that map because they are too near other wells to be shown at that scale. In eight of the wells, shows of oil or gas were reported.

Figure 3 shows the 13 wells in this same area that have been drilled to Precambrian, Paleozoic, or Mesozoic (Lower Cretaceous) rocks. Of these, seven have been drilled to Precambrian or lower Paleozoic rocks, thus penetrating practically all of the petroleum source and reservoir units. This subsurface control is relatively meager, but when control from surface sections is added, at least a preliminary evaluation can be made.

Table 2 lists the basic data on these 13 well in geographic order (by township, range, and section). Sources of data on wells drilled prior to 1980 are discussed in Thompson (1981) and Thompson (1982). Sources of data on later wells will be discussed in a forthcoming report.

## Petroleum Source Rocks

Table 3 summarizes the evaluations of petroleum source rocks based on analyses of drill cuttings from nine key wells in Hidalgo and Grant Counties, New Mexico. These analyzed wells are shown (left to right) in the same geographic order as they are

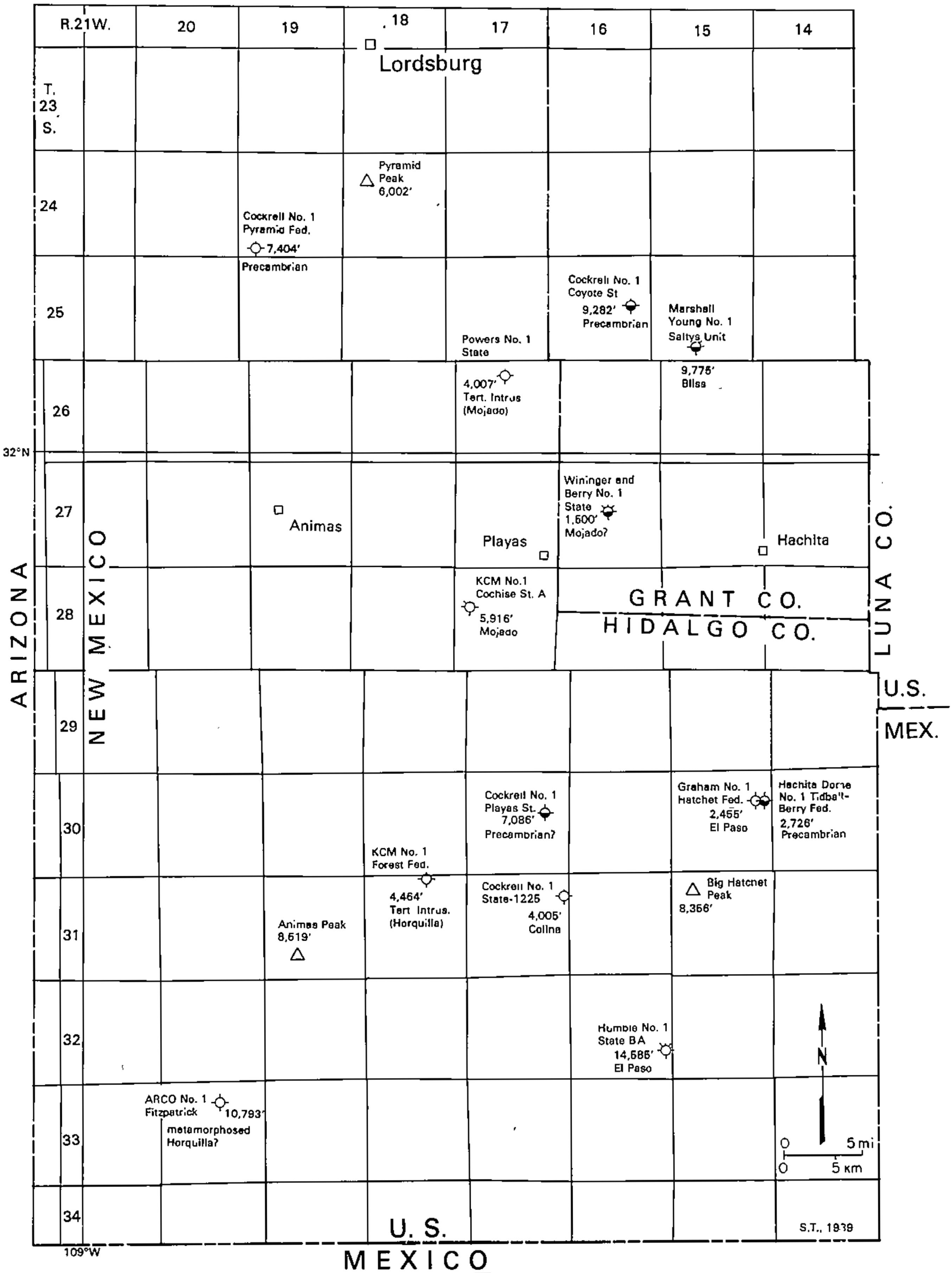


Figure 3. Location map of petroleum-exploration wells drilled to Precambrian, Paleozoic, or Mesozoic rocks (same area and well symbols as in Fig. 2); stratigraphic unit at total depth (ft) of each well is identified.

Table 2. Exploration wells drilled to Precambrian, Paleozoic, or Mesozoic rocks in southern Hidalgo and Grant Counties, New Mexico (modified from Thompson, 1982, table 2).

| Location | Name | Completion date | Elevation | Formation tops (Ti = Tertiary intrusive rock) | Total depth | Oil, gas shows |
|---|---|---|---|---|---|---|
| sec. 31, T.24S., R.19W.; 1,980' FNL; 660' FEL | Cockrell No. 1 Pyramid Fed. | 9-30-69 | 4,244' KB | Surface-Quaternary; 385'-Gila?; 1,890'-Tertiary volcanic rock (Ti); 5,795'-Escabrosa (Ti); 6,680'-Percha (Ti); 6,860'-Montoya (Ti); 6,980'-El Paso (Ti); 7,130'-Bliss (Ti); 7,340'-Precambrian | 7,404' Precambrian | None |
| sec. 33, T.25S., R.15W.; 660' FNL; 660' FEL | Marshall Young No. 1 Saltys Unit | 12-21-85 | 4,408' KB | Surface-Tertiary volcanic rock; 710'-Tertiary conglomerate; 770'-Epitaph; 1,020'-Colina; 1,168'-Earp; 2,154'-Horquilla; 2,660'-Paradise; 2,773'-Escabrosa; 3,588'-Percha; 3,756'-Montoya; 4,238-El Paso; 4,466'-Bliss; 4,494'-thrust fault, Mojado; 7,564'-U-Bar; 7,705'-Hell-to-Finsh (Ti); 8,344'-Montoya; 8,960'-El Paso (Ti); 9,718'- Bliss | 9,775' Bliss | Oil: 5,530-5,570'; 5,820-5,870'; 5,890-5,940'; 6,010-6,060'; 7,710-7,725'; Gas: 1,400-1,750' |
| sec. 14, T.25S., R.16W.; 700' FSL; 700' FWL | Cockrell No. 1 Coyote State | 8-24-69 | 4,354' KB | Surface-Quaternary; above 360'-Tertiary (or Cretaceous) volcanic rock; 1,790'-Mojado (Ti); 6,400'-U-Bar (Ti); 7,100'-Hell-to-Finish; 7,240'-Montoya; 7,720-El Paso; 8,360'-Bliss; 8,580'-Precambrian | 9,282' Precambrian | Oil: 4,140' |
| sec. 4, T.26S., R.17W.; 330' FSL; 1,980' FEL | Powers No. 1 State | 12-3-72 | 4,377' KB | Surface-Quaternary; above 920'-Tertiary (or Cretaceous) volcanic rock; 1,190'-Mojado; 3,930'-Tertiary intrusive rock | 4,007' Tert. intrus. | None reported |
| sec. 16, T.27S., R.16W.; 1,600' FSL; 850' FEL | Wininger and Berry No. 1 State | 9-13-43 | 4,675' GL | Surface-Quaternary; 28'-Ringbone?; 580'-Mojado? | 1,500' Mojado? | Oil: 610'-620'; Oil, Gas: 1,270'-1,330'; Gas: 1,415'-1,430' |
| sec. 18, T.28S., R.17W.; 1,980' FNL; 1,980' FEL | KCM No. 1 Cochise St. A | 3-22-75 | 4,416' KB | Surface-Quaternary; above 70'-Gila; 2,370'-Mojado | 5,916' Mojado | Gas: 2,050'; 2,220'; 2,650' |
| ec. 12, T.30S., .15W.; 1,655' FSL; ,012' FWL | Hachita Dome No. 1 Tidball-Berry Fed. | 5-23-57 | 4,349' DF | Surface-Quaternary; 224'-Escabrosa; 800'-Percha (Ti); 1,395'-Montoya; 1,653'-El Paso; 2,590'-Bliss; 2,723'-Precambrian | 2,726' Precambrian | Gas: 1,500'; 2,310'; 2,430'; Oil: 2,590' |
| ec. 12, T.30S., .15W.; 1,980' FSL; 60' FWL | Graham No. 1 Hatchet Fed. | 11-21-78 | 4,331' GL | Surface-Quaternary; 540'-Escabrosa (Ti); 960'-Percha; 1,240'-Montoya; 1,710'-El Paso | 2,455' El Paso | None |
| ec. 14, T.30S., .17W.; 600' FNL; 1,980' FEL | Cockrell No. 1 Playas State | 6-11-70 | 4,455' KB | Surface-Quaternary; 100'-Gila; 2,480'-Horquilla; 3,836'-Paradise; 4,127'-Escabrosa; 5,192'-Percha; 5,568'-Montoya; 5,890'-El Paso; 6,764'-Bliss; 7,030'-Precambrian | 7,086' Precambrian | Dead oil: 5,780' |
| ec. 12, T.31S., .17W.; 1,980' FNL; 60; FEL | Cockrell No. 1 State-1125 | 11-24-70 | 4,480' KB | Surface-Quaternary; 150'-Gila; 2,465'-Tertiary volcanic (and sedimentary?)rock; 2,595'-Epitaph; 3,770'-Colina | 4,005' Colina | None reported |
| ec. 3, T.31S., .18W.; 1,494' FNL; ,753' FEL | KCM No. 1 Forest Fed. | 1-22-75 | 5,156' KB | Surface-Earp (Ti); 225'-Horquilla (Ti); 2,225'-metamorphosed Horquilla and Tertiary intrusive rock | 4,464' Tert. intrus. | None |
| ec. 25, T.32S., .16W.; 990' FNL; ,980' FEL | Humble No. 1 State BA | 12-24-58 | 4,587' KB | Surface-Quaternary; 230'-U-Bar; 648'-Hell-to-Finish; 995'-Concha; 1,522'-Scherrer; 1,532'-Epitaph; 3,310'-reverse fault, Epitaph repeated; 4,450'-Colina; 5,258'-Earp; 6,265'-Horquilla; 10,995'-Paradise; 11,425'-Escabrosa; 12,500'-Percha; 12,830'-Montoya; 13,214'-El Paso | 14,585' El Paso | Gas: 4,190'-4,219' |
| ec. 10, T.33S., .20W.; 2,220' FSL; 90' FWL | ARCO No. 1 Fitzpatrick | 4-5-85 | 5,191' KB | Surface-Quaternary to Tertiary; 939'-Tertiary volcanic rock; 5,582'-U-Bar?; 7,209'-Epitaph; 8,090'-Colina; 8,718'-metamorphosed Paleozoic rock, probably including lower Colina, 8,920'-Earp, and 10,600'-Horquilla | 10,793' metamorphosed Horquilla? | None |

Table 3. Summary of source-rock evaluations of drill cuttings from nine wells in Hidalgo and Grant Counties, New Mexico (modified from Thompson, 1981, table 10). Symbols are: for organic richness, P = poor, F = fair, G = good, VG = very good, E = excellent; for tendency for oil or gas generation at maturity, O = oil generation, G = gas generation, - = neither; for stage of thermal maturation, I = immature, M = mature, O = overmature, T = thermally metamorphosed.

| Well: | Cockrell No. 1 Pyramid Fed. | Marshall Young No. 1 Saltys Unit | Cockrell No. 1 Coyote St. | KCM No. 1 Cochise St. A | Hachita Dome No. 1 Tidball-Berry Fed. | Cockrell No. 1 Playas St. | KCM No. 1 Forest Fed. | Humble No. 1 State BA | ARCO No. 1 Fitzpatrick |
|---|---|---|---|---|---|---|---|---|---|
| Formation: | | | | | | | | | |
| Mojado | absent | absent | P-E;G,O;M | P-F;G,O;O | absent | absent | absent | absent | absent |
| U-Bar | " | " | P-G;G,O;M | not drilled | " | " | " | G;O;M | F-G |
| Hell-to-Finish | " | " | P;G;M | " | " | " | " | P | absent? |
| Concha | " | " | absent | " | " | " | " | P | absent |
| Epitaph | " | P-F;O;M | " | " | " | " | " | P-VG;O,G;M | no anal. |
| Colina | " | P-F | " | " | " | " | " | F;G,O;M | " |
| Earp | " | P-G;G,O;M | " | " | " | " | F;O,G;M | P | metamorphosed |
| Horquilla | " | P-VG;G,O;M | " | " | " | P-F;O,G;M | P-VG;G,O;M-T | P-G;G,O;M-O | " |
| Paradise | " | F | " | " | " | P-VG;G,O;M-O | not drilled | P-F;G;O | not drilled |
| Escabrosa | P-F;O,G;M | P-F;G,O;M | " | " | P;O;M | P-G;G,O;M-O | " | P-F | " |
| Percha | P-F;G,O;M | P;G,O;M | " | " | P-F;G,O;M-O | P-F;-;M-O | " | P-F;G,O;O | " |
| Montoya | P;O;M | P | P;O;M | " | P;O;M | F-G;O;O | " | P-F | " |
| El Paso | P;O;M-O | F-G | P;O;M | " | P-VG;O;O | P-G;O;O | " | P-F;G?,O;O | " |
| Bliss | no anal. | P | no anal. | " | no anal. | F;O;O | " | not drilled | " |
| | below thrust | | | | | | | | |
| | Mojado | P-G;G,O;M | | | | | | | |
| | U-Bar | G-VG | | | | | | | |
| | Hell-to-Finish | F?;G;M | | | | | | | |
| | (unconformity) | | | | | | | | |
| | Montoya | P;G?,O;M | | | | | | | |
| | El Paso | P-F;G?,O;M | | | | | | | |
| | Bliss | P-F;G?,O;M | | | | | | | |

listed in Table 2. Analyses on the seven older wells are presented in more detail in Thompson (1981). Analyses on the Marshall Young No. 1 Saltys Unit and ARCO No. 1 Fitzpatrick wells are available in open-file reports and will be discussed in more detail in a forthcoming report.

Results indicate that adequate source rocks are present in nearly every formation of the Paleozoic-Lower Cretaceous. Organic richness is determined as poor in the red-bed facies of the Earp and Hell-to-Finish. (The fair rating of the Hell-to-Finish in the Marshall Young well is questioned because caved limestone and other marine sediments appear to have been analyzed instead of the red mudstone.) Only one sample of the Concha has been analyzed and that poor rating does not appear to be representative. Fair or better ratings have been determined at least locally in the other formations. Good to very good richness has been determined in El Paso limestones and dolostones, Montoya dolostones, Escabrosa limestones, Paradise limestones, Horquilla limestones and mudstones, U-Bar limestones, and Mojado mudstones and limestones.

Types of kerogen were used to determine whether oil or gas tended to be generated when sediments reached thermal maturity. Generally speaking, algal-sapropelic kerogens tend to generate oil and herbaceous-woody kerogens tend to generate gas. In the Bliss, El Paso, and Montoya, only oil should be indicated because land plants producing herbaceous-woody kerogens did not appear until Silurian time. The designations of gas generation in these units are questioned, and may be the result of caved or apparently structured kerogens. In many of the younger units gas generation dominates, but oil generation is dominant in parts of the Escabrosa, Horquilla, Earp (limestone facies), Epitaph, and U-Bar.

Alteration of kerogen was used as an index of thermal maturity. In an immature stage, sediments have not been deeply buried, and only biogenic gas may be generated. In a mature stage, sediments have been buried sufficiently, and oil may be generated if the proper kerogen is present. In an overmature stage, sediments have been buried very deeply, and any oil would be thermally cracked to generate gas along with the normal gas-producing kerogens. At some higher temperature not yet determined, even gas is thermally altered to graphite and carbon dioxide. With extreme thermal alteration, the sedimentary rock becomes metamorphosed.

No Paleozoic-Lower Cretaceous source rocks have been determined as immature in this area, probably because of the thick sedimentary and volcanic overburden. Thermal alteration has not exceeded the mature stage in units as old as Bliss in the northern part of the area, but the overmature stage has been reached in the older Paleozoic rocks in the southern part. Local metamorphism has been documented in the KCM No. 1 Forest Federal well (Thompson and others, 1977) and in the ARCO No. 1 Fitzpatrick well, but the zone of metamorphism normally does not extend more than a few thousand feet.

During the drilling of the Marshall Young No. 1 Saltys Unit well, an excellent set of canned cuttings was collected (generally every 30 feet). This procedure provided a rare opportunity to analyze the light hydrocarbon gases. These gases are exceptionally rich in the Mojado (found below the thrust fault), and this richness is more direct evidence that the Mojado is capable of generating significant quantities of petroleum.

Figures 4, 5, 6, and 7 are petroleum-source maps showing the evaluations of source units from key wells drilled to the El Paso, Horquilla, Epitaph, and Mojado Formations, respectively (modified from Thompson, 1981). Maps of these formations were selected because they also include fair to good reservoir units (see next section). These maps are prepared at the same scale as Figures 1, 2, and 3. Petroleum source data are taken from Table 3. Areas where the formations are absent by erosion (or nondeposition) are indicated as accurately as present control permits. On the Burro uplift, in the northern part of the map area, the El Paso and Horquilla probably were removed by erosion in Early Permian (mid-Wolfcampian) time, the Epitaph probably was removed in Late Permian to Early Cretaceous time, and the Mojado probably was removed in Late Cretaceous time or later. On the small anticlinal structures in the southern part of the map area, Horquilla, Epitaph, and Mojado were removed by local erosion in Early Cretaceous or Late Cretaceous-Early Tertiary time.

From Figure 1, the present eroded edge of the major thrust fault zone (black triangles on upper plate) exposed in the northern Animas Mountains, southern Little Hatchet Mountains, and the Sierra Rica is drawn on Figures 4, 5, 6, and 7. The inferred maximum extent of this major Laramide structure is plotted a few miles to the northeast (open triangles on upper plate). Prior to erosion in Late Cretaceous-Early Tertiary time, the overburden of Precambrian, Paleozoic and Lower Cretaceous rocks may have reached 20,000 ft on the upper plate. Such great depths of burial produced overmature thermal alteration of the Lower Cretaceous and other rocks in the lower plate, as seen by overmature alteration of the Mojado in the KCM No. 1 Cochise State A well (Fig. 7, T.28S., R.17W.). This major thrust zone probably did not extend farther northeast because all of the units down to the El Paso in the Cockrell No. 1 Coyote and Marshall Young No. 1 Saltys Unit wells show thermal alteration no greater than the mature stage (Fig. 4, T.25S., R.16W. and T.25S., R.15W.).

## Petroleum Reservoir Rocks

General evaluations of reservoir quality have been made (Thompson, 1982, table 1, p. 523) and specific studies are in progress. The best reservoir units found so far in Hidalgo and Grant Counties are good ones in Horquilla dolostones and Mojado

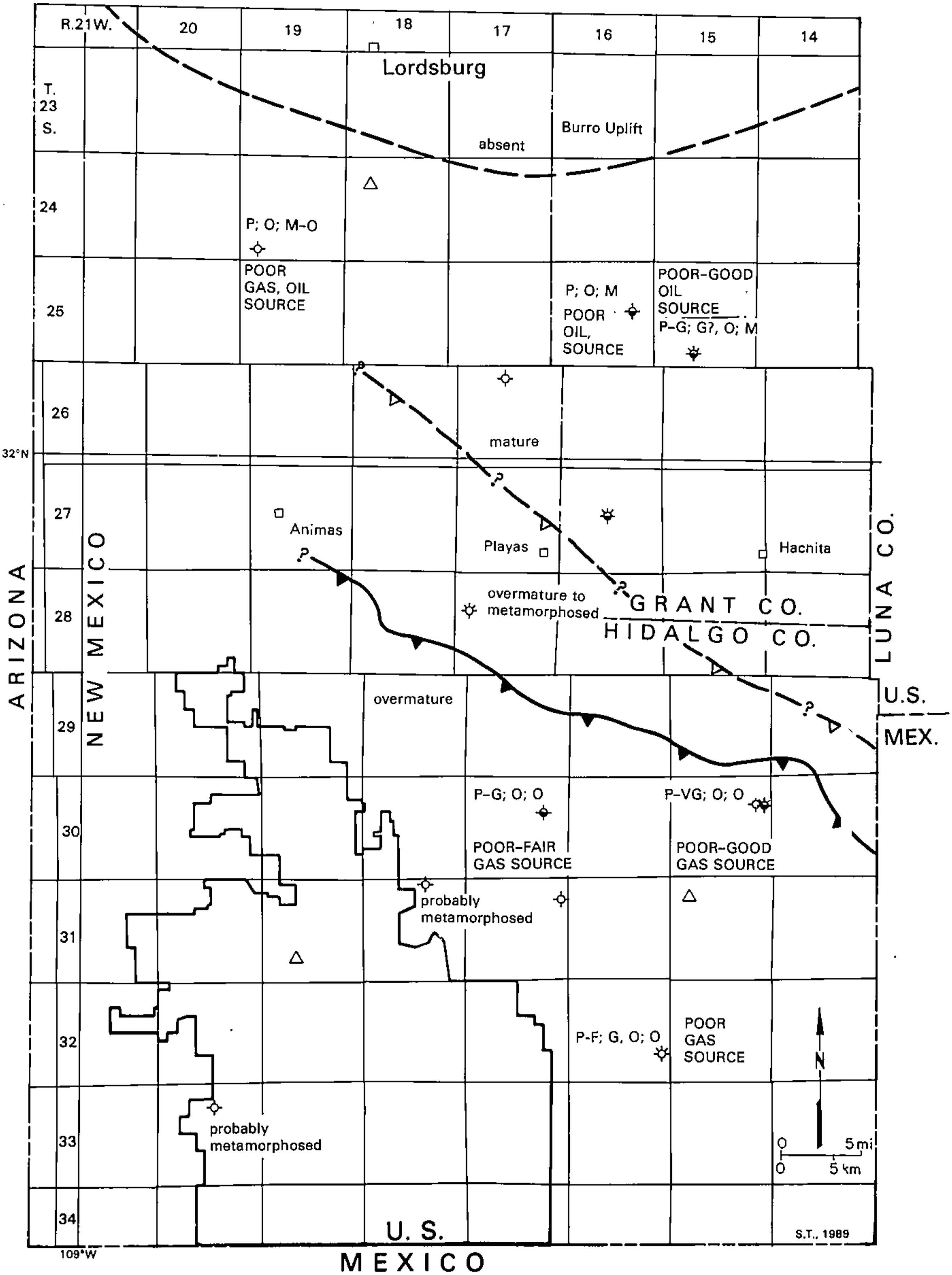


Figure 4. Petroleum-source map of El Paso Formation (Ordovician); see Table 3 for explanation of basic-evaluation symbols spotted at wells.

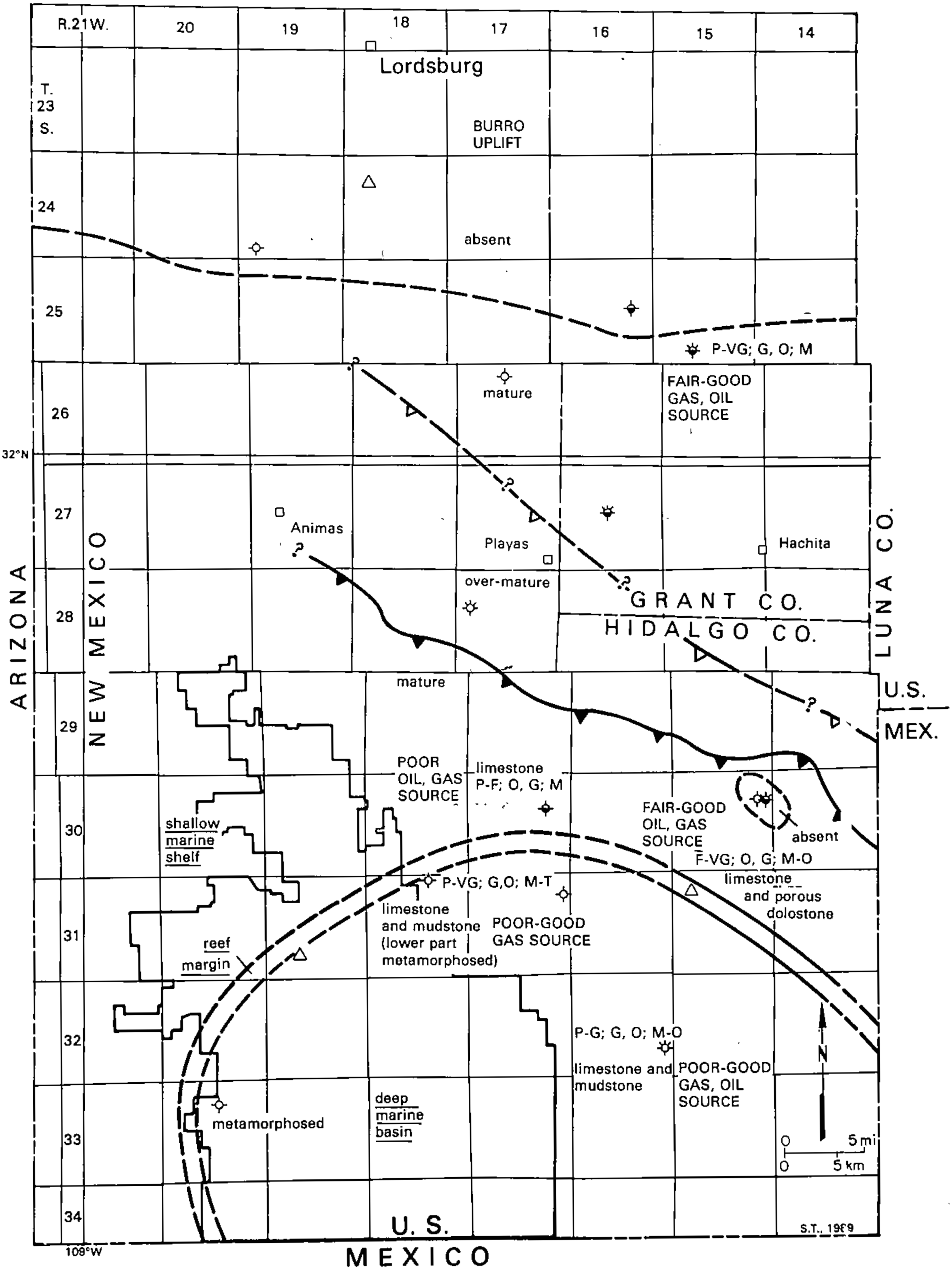


Figure 5. Petroleum-source map of Horquilla Formation (Pennsylvanian–Permian).

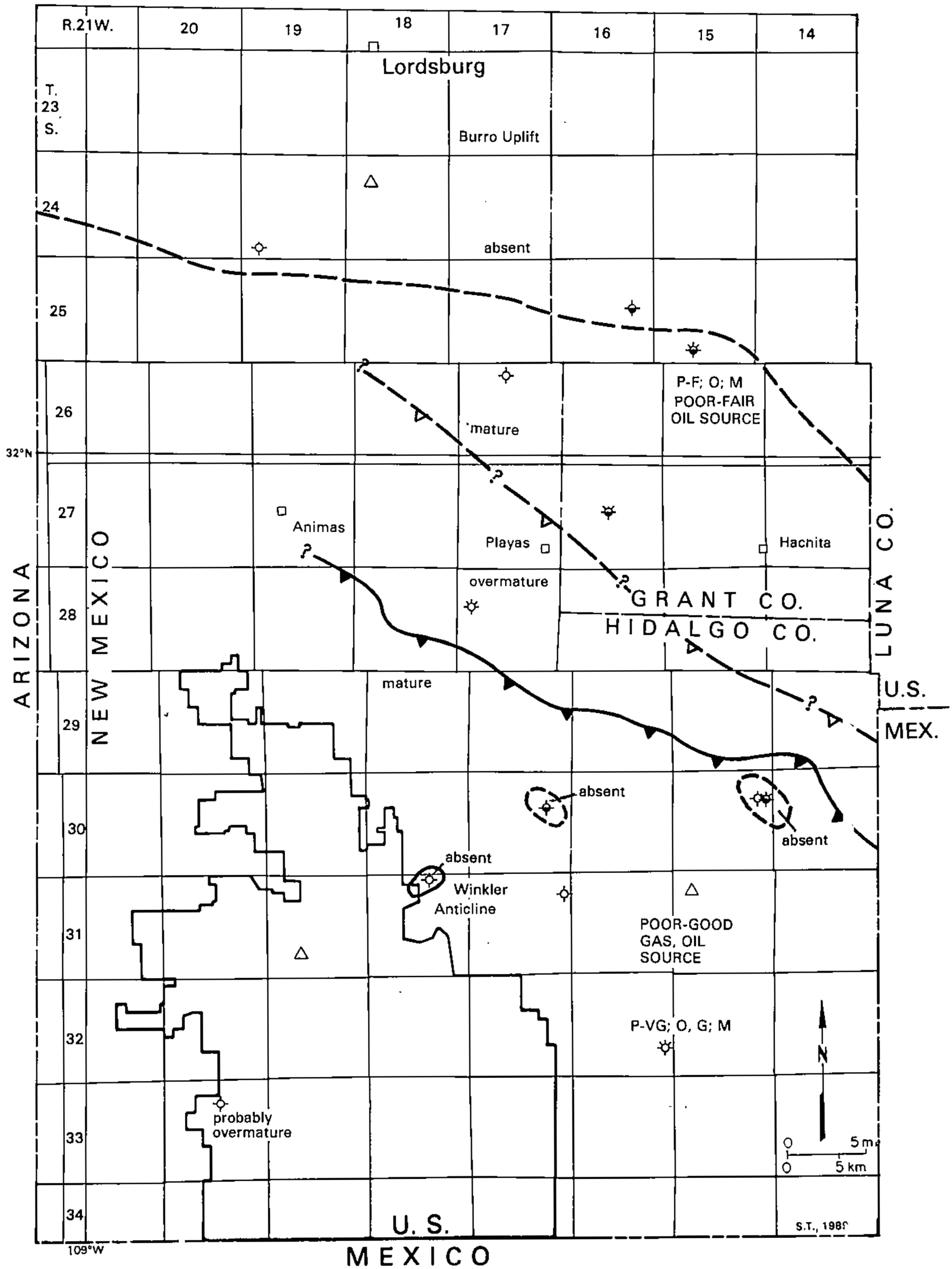


Figure 6. Petroleum-source map of Epitaph Formation (Permian).

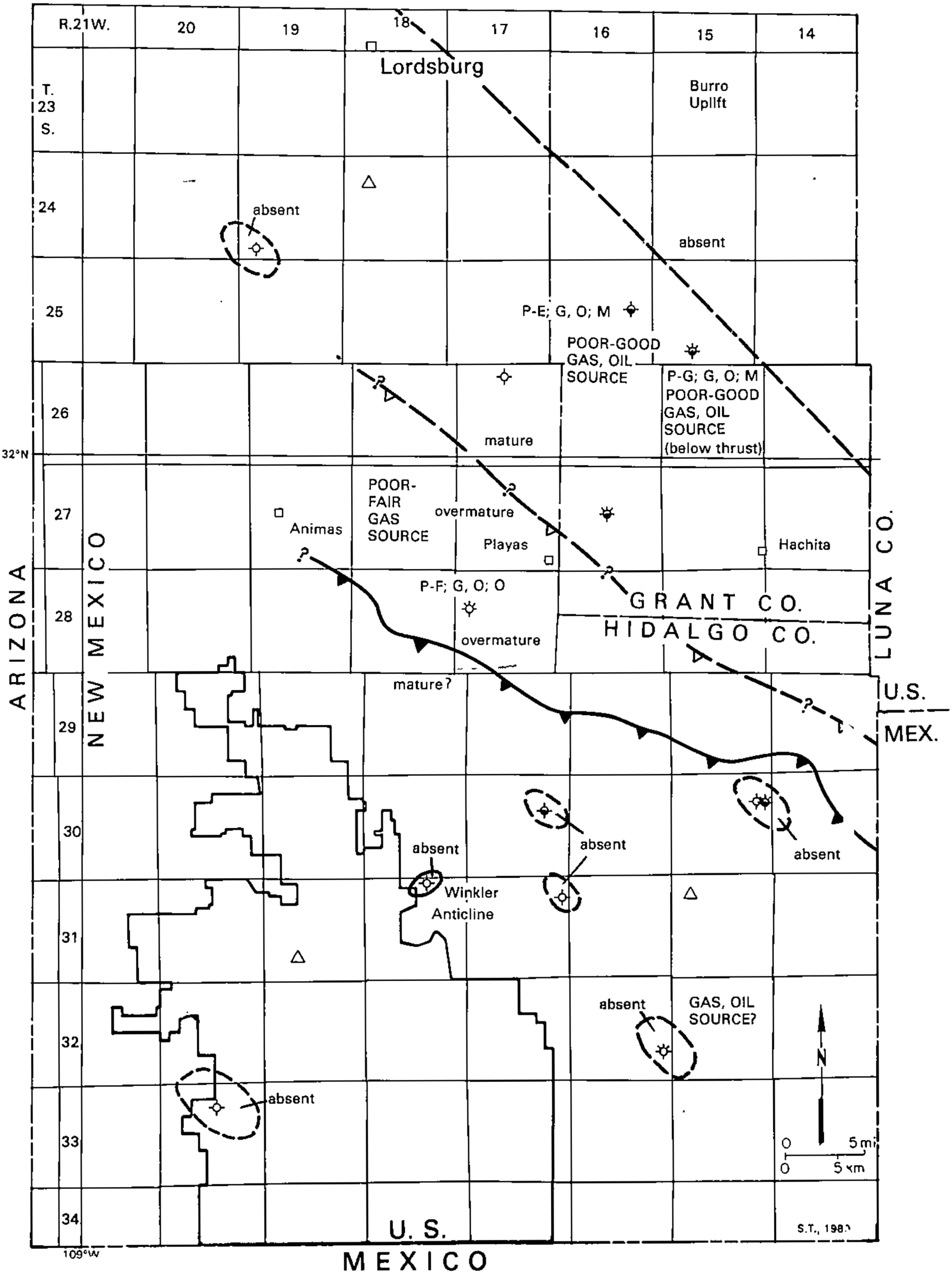


Figure 7. Petroleum-source map of Mojado Formation (Lower Cretaceous).

sandstones. Fair reservoir units have been observed in dolostones of the El Paso, Montoya, and Epitaph, and indicated in limestones of the Concha. Only poor reservoir units have been observed in the Bliss, Percha, Escabrosa, Paradise, Colina, Scherrer, Hell-to-Finish, and U-Bar; these formations probably contain only poor units throughout the area, but they should be evaluated in any exploration well.

Thus, any commercial accumulations of oil and/or gas in this area most likely will be found in reservoirs of the El Paso, Montoya, Horquilla, Epitaph, Concha, and/or Mojado. The following discussions of these reservoirs and their relationships to source rocks will be made with reference to Figures 4, 5, 6, and 7.

El Paso (Fig. 4). El Paso dolostones exhibit scattered traces of intercrystalline and small vuggy porosity in some wells and outcrops. By themselves, these minor occurrences of porosity would be classified as poor reservoirs. However, because of the extensive fracture porosity seen in the correlative Ellenburger, a major producer in the Permian Basin of western Texas and southeastern New Mexico, the reservoirs of the El Paso are inferred to be fair. Where mature, as in the northern part of the area, indigenous source units in the El Paso should generate oil. Where overmature, as in the southern part, gas is expected in El Paso reservoirs.

Montoya. Because the distribution of the Montoya is so similar to the El Paso, a separate map is not shown here (see fig. 15 in Thompson, 1981, p. 118). Nevertheless, a vuggy porosity zone up to 50 ft thick has been observed in the Upham Member dolostones in the Humble No. 1 State BA well (T.32S., R.16W.), in the Big Hatchet Mountains, and in other parts of the region. With further documentation, the Montoya may be upgraded from a secondary to a primary objective.

Horquilla (Fig. 5). Horquilla dolostones constitute the best reservoir objective seen so far in this area (Thompson, 1980). In the cliff exposures on the north side of Big Hatchet Peak (T.31S., R.15W.), a total net thickness of 484 ft of porous dolostones has been measured within a stratigraphic interval of 1,320 ft in the upper part of the Horquilla (Thompson and Jacka, 1981). Nearly all these dolostones contain traces to 10 percent of vuggy porosity. Many vugs appear to be molds of dissolved anhydrite. On fresh surfaces, the vugs are 1-3 mm in diameter; on weathered surfaces vugs are 10-100 mm and constitute up to 30 percent of the surface. At least part of the enlargement of vugs on the weathered surfaces may be attributed to Quaternary solution. Unfortunately, these dolostones contain only a small amount of matrix porosity because the dolomite crystals generally grew to compromise boundaries and formed a tight mosaic. However, in a more distal area where dolomitizing fluids may not have been active for so long a time, intercrystalline voids may not have been filled, and the resulting sucrosic porosity would improve the reservoir quality. Nevertheless, the observed vuggy porosity appears to be interconnected by way of solution channels and fractures, and compares favorably with productive Pennsylvanian reservoirs in southeastern New Mexico and western Texas.

Between the porous dolostones are limestone buildups, or reefs, of phylloid algae. They indicate that the porous dolostones lie at the reef margin between the shallow-marine shelf and the deep-marine basin facies of the upper Horquilla. In the Sheridan Canyon area of the Big Hatchet Mountains, deep-marine deposits of mudstone, sandstone, and conglomerate can be seen onlapping phylloid algal buildups at the reef margin. In the opposite direction (to the northeast), the buildups and dolostones are absent and shallow-marine shelf limestones are dominant. The reef margin, about one mile wide, trends northwest-southeast in these exposures. As shown on Fig. 5, the reef margin has been projected approximately with available subsurface control as curving to the west, southwest, and southeast.

No well has drilled this reef margin as yet. It was a major objective of the recent ARCO well (T.33S., R.20W.), but that well apparently was drilled on the basinward side. The dark gray to black color characteristic of the basin limestones and mudstones is preserved in the rock that has been metamorphosed to hornfels.

Limestones below and above the porous dolostones in the reef margin have characteristics of fair to good source rocks. This close relationship of good source and good reservoir rocks makes the Horquilla reef margin an excellent objective for exploration. Moreover, degraded herbaceous kerogens in the associated limestones tend to generate oil.

No porosity has been observed so far in the limestones of the shallow-marine shelf facies. However, sporadic porosity occurs in similar limestones in southeastern New Mexico. Some fair to good source rocks for gas and oil are indicated.

Some porosity has been observed in the deep-marine sandstones of the basin facies, and future work will provide documentation. Sandstones in channels near the reef-basin boundary indicate that submarine fan deposits may be expected within the basin. Such sandstone bodies are important producers in the analogous (but younger) Bell Canyon sandstones of the Delaware Basin in southeastern New Mexico. In the basin facies limestones and mudstones of the upper Horquilla, good source rocks are present, but they appear to have generated more gas than oil.

In the northern part of the area, thermal alteration has reached only the mature stage in both the lower and upper members of the Horquilla. In the southern part, the lower member has been altered to the overmature stage at many localities. Where more deeply buried, the upper member may be overmature also, and any oil in the reef dolostones may have been altered to gas.

Epitaph (Fig. 6). Thin zones of vuggy porosity have been observed in Epitaph dolostones drilled in the Humble No. 1 State BA well (T.32S., R.16.W). On a drill-stem test in the Epitaph, a small amount of gas flowed to the surface; it was reported at an estimated rate of 10,000 cubic feet per day. In a later workover attempt, the same zone was acidized and flowed 86,000 cubic feet of gas per day on a production test. Later, the zone was swabbed dry and the well was abandoned. One report indicated that during acidization the pressure rose so high that the casing was split, and the subsequent production tests may not have recorded the total volume of gas. Although this zone may not be a commercial reservoir, this show of gas is the best one reported so far in the area.

In the Petroleos Mexicanos No. 1 Espia well, drilled about 30 miles southeast of the Humble well in adjacent Chihuahua, Mexico, another show of gas was found in the Epitaph. However, it could not be tested because of mechanical difficulties, and the well was abandoned.

In the Marshall Young No. 1 Saltys Unit well (T.25S., R.15W.), circulation of drilling mud was lost in the upper part of the Epitaph, indicating that cavernous porosity may have developed along the unconformity before the overlying Tertiary volcanic rocks were deposited. Any indigenous petroleum probably would have been generated previously and would have escaped during subaerial exposure in Tertiary time. Indeed, no shows of oil or gas were found in the Epitaph in this well.

In the surface exposures of the Winkler anticline area (T.31S., R.18W.), the Epitaph is absent locally as a result of erosion during Late Permian to Early Cretaceous time, and Hell-to-Finish rests unconformably on Colina. In the subsurface, on the flanks of this anticline where Hell-to-Finish rests on Epitaph, cavernous porosity may be present in the upper Epitaph. Oil or gas could have been generated after sufficient burial during Lower Cretaceous time. Similar prospective Epitaph reservoirs may be found on the flanks of older anticlines now buried by volcanics or valley fill.

No porosity was observed in the Epitaph in a preliminary study of the ARCO No. 1 Fitzpatrick well (T.33S., R.20W.). No shows of oil or gas were found. No source analyses were run in the Epitaph, but the vitrinite reflectance values in the overlying U-Bar are in the overmature range, so the Epitaph probably is overmature also in this local area.

Nevertheless, the fair to good source rocks and the normally mature stage of thermal alteration seen in the Humble and Marshall Young wells indicates that oil or gas may be preserved in any significant reservoirs found in the Epitaph of the Hidalgo-Grant Counties area.

Concha. Because the distribution of the Concha is so similar to that of the Epitaph, a separate map is not shown here (see fig. 7 in Thompson, 1981, p. 110). In the Humble No. 1 State BA well, beneath the unconformity at the base of the Hell-to-Finish, cavernous porosity was found in the upper part of the Concha. A major effort to plug the lost-circulation zone failed, and the well was drilled without returns to the basal part of the Concha, where casing was set. Thus no cuttings are available for nearly all of the Concha in this well, the only one drilled through this formation in this area. The samples of limestone from the basal part indicate a poor source and a poor reservoir. The cavernous porosity in the top part is inferred to be a fair to good reservoir, but because the top lies at a depth of only 995 ft, the reservoir is probably too shallow for oil or gas to be preserved. In the southern part of the nearby Big Hatchet Mountains, no porosity was found in a brief reconnaissance of the Concha limestones, including a study of the unconformable contact with the overlying Hell-to-Finish. Thus the cavernous porosity in the Humble well probably is a local phenomenon. However, because the equivalent San Andres Formation is such an important producing reservoir in southeastern New Mexico and western Texas, the Concha should be evaluated in any exploration well.

Mojado (Fig. 7). In the Cockrell No. 1 Coyote (T.25S., R16.W.) and Marshall Young No. 1 Saltys Unit (T.25S., R.15W.) wells, the Mojado Formation contains some slightly friable sandstones that are judged to be fair reservoirs. Some oil and minor gas shows were reported. Intercalated dark mudstones and limestones contain poor to good source units for generating gas and oil. Thermal alteration is only in the mature stage, even below an important thrust fault.

As discussed previously, the geochemical analyses of canned cuttings collected in the Marshall Young well indicate a richness of light hydrocarbon gases in most of the Mojado. Conventional hydrocarbon logging recorded only a trace of gas in the richest interval. Such conventional logging may be missing significant gas reservoirs (as indicated in other areas).

Also in the Marshall Young well, a drill-stem test was run in the 5,530-5,569 ft interval, including a Mojado sandstone with fluorescence and fair oil cut, but with no gas anomaly on the hydrocarbon log. Neither oil nor gas were recovered, and pressures were low, indicating a very poor reservoir. That is the only drill-stem test of the Mojado that has been reported in this area. However, it may not be representative, and several more tests should be run of the best Mojado sandstones before the evaluation is considered conclusive.

In the Little Hatchet Mountains (T.28S., R.16W.), outcrops of a fairly complete Mojado section expose highly indurated sandstones with kaolinitic to chloritic clay matrices. This generally poor reservoir quality may be the result of great overburden beneath the major thrust sheet projected across this area.

Mojado is absent locally around the deep exploration wells drilled in southern Hidalgo County. These wells were drilled on Laramide anticlines or other structural highs. Erosion occurred probably in Early Tertiary (Eocene) time.

In the exposures at the type section of the Mojado (T.32S., R.15W.), good porosity is indicated in the thick, very friable, coarse-grained, sandstones. Covered intervals between the sandstones appear to be dark gray to black mudstones, which should be fair to good source rocks.

## Petroleum Prospects in the Gray Ranch Area

In the Gray Ranch area of southern Hidalgo County, the petroleum source and reservoir units of the El Paso and Montoya should be fair generally (Fig. 4), those of the Horquilla should be good in the reef margin and at least fair in the deep-marine basin (Fig. 5), those of the Epitaph and Concha should be fair generally and locally good where overlain unconformably by the Hell-to-Finish (Fig. 6), and those of the Mojado should be fair generally and locally good where the more porous sandstones are present (Fig. 7).

Stratigraphic traps are indicated in the Horquilla where reef-margin, porous dolostones change facies into tight shelf limestones and where deep-marine mudstones and limestones onlap the margin. They are inferred in the basin where the postulated submarine fan deposits of sandstone are buried by deep-marine limestones and mudstones. They are indicated in the Epitaph dolostones and Concha limestones where cavernous porosity is sealed above the unconformity by red mudstones of the Hell-to-Finish. They are indicated in the Mojado where shallow-marine or deltaic sandstone bodies are buried by dark mudstones or limestones.

Structural traps are indicated by the Laramide anticlines, such as the Winkler anticline drilled by the KCM No. 1 Forest Federal well (T.31S., R.18W.), and the Alamo-Hueco anticline drilled by the Humble No. 1 State BA well (T.32S., R.16W.). Others no doubt are present beneath the volcanic and valley-fill cover, and may be located by seismic, gravity, or other geophysical methods. Laramide thrusts, wrench faults, and possibly normal faults may also serve as traps.

Practically none of the stratigraphic traps have been drilled in Hidalgo County, but some of the structural traps have been drilled without a commercial discovery. To increase the probability of success, coincident stratigraphic and structural traps should be tested.

Considering the petroleum source rocks, reservoirs, and traps that no doubt were present in Early Tertiary time, the Gray Ranch area probably contained several significant oil and/or gas fields. However, the most fundamental question is: Have any such fields been preserved after the disruptive igneous and tectonic events of later Tertiary time? Some aspects of this problem are discussed below. (For a more complete discussion, see Thompson, 1976). But the question can be answered only by drilling exploration wells.

Large Tertiary volcanic cauldrons have been mapped by Elston and others (1979) in much of the Gray Ranch area. Associated igneous plutons locally have metamorphosed the adjacent Paleozoic and Lower Cretaceous rocks, and no oil or gas is expected to be preserved under such extreme conditions. Elevated temperatures and hydrothermal solutions associated with these intrusions probably caused oil and gas to migrate in the unmetamorphosed reservoirs away from the volcanic centers. During subsequent cooling, oil and gas probably remigrated updip along some reservoirs toward the volcanic centers and may be trapped around the metamorphosed zones.

Elston and others (1979) used the best evidence available to draw the cauldron boundaries, but they admit that the locations are approximate and may be moved with additional control. The boundaries drawn in surface outcrops of Tertiary volcanic rocks are the least likely to be changed. Those drawn in the Animas and Playas Valleys, where Quaternary alluvium is on the surface, may be changed appreciably with additional well control. However, the metamorphism of Paleozoic rocks in the ARCO No. 1 Fitzpatrick well tends to support the position of the boundary drawn in that part of the Animas Valley. Geophysical studies may also be helpful.

During the Basin and Range deformation of late Tertiary time (Pliocene), the Tertiary volcanics (Eocene to Miocene in age) and older rocks were uplifted or downdropped along major normal fault zones. Much of the present topographic relief between the mountain ranges and the valley floors may be attributed to this period of block faulting. However, displacements along the boundary faults may range from thousands of feet down to a few feet. Within the uplifted ranges, important cross faults also are seen, and joints are abundant. This widespread tensional fracturing in late Tertiary time may have had the most detrimental effect on the preservation of oil and gas in Paleozoic and Lower Cretaceous rocks. No doubt some fields were disrupted by the displacements and most probably were subject to leakage along fractures. In late Tertiary and Quaternary time, fresh water percolating down the fractures probably has flushed oil and gas out of some reservoirs.

In spite of these harmful igneous and tectonic effects, some oil and gas fields may be preserved in the uplifted mountain ranges. However, the chances for preservation are believed to be better in the down-dropped (graben) areas beneath the valleys, where faulting, fracturing, and flushing appear to have been less intense.

If feasible, before the Gray Ranch area is explored, at least two wildcat wells should be drilled in the eastern part of the Playas Valley to test the best reservoir objectives near the outcrops where they have been observed, and where the chances are best for preservation of oil and gas. One should be drilled in the southern part of T.30S., R.16W. (or T.30S., R.17W.) to test the porous dolostones in the reef margin of the upper Horquilla. The other should be drilled in the western part of T.32S., R.16W. (or T.33S., R.16W.) to test the porous sandstones of the Mojado. Both wells should be located on seismic highs or other geophysical anomalies, drilled with adequate rotary-mud systems to collect good cuttings, logged with hydrocarbon detectors and full suites of wire-line logs, cored and tested where reservoirs are found, and evaluated by experienced wellsite geologists and other analysts. Both wells should be drilled to Precambrian basement to test all objectives in the Paleozoic and Lower Cretaceous sections. Drilling depths may range from 10,000 to 20,000 ft. Such deep, first-class wildcats will be expensive, but they are needed to evaluate the petroleum resources of this area.

If the results are conclusively negative in these two wells, the entire southern part of Hidalgo County may be abandoned as an exploration target with the realistic assessment that at least the best objectives had been tested. However, the judgment that negative findings are conclusive will be difficult to make. Some operators may be discouraged if all the reservoirs are found to be flushed with fresh water, but some fields are known to have fresh-water drives. Because there are so many favorable factors, the probability that all objectives will be condemned is small.

If the results are positive, especially if a discovery of oil or gas is found in one or both wells, the exploration/development program should be extended to the western side of the Playas Valley, to the intermontane valley between the San Luis and Whitewater Mountains, to selected prospects in the Animas Mountains, and to the Animas Valley. These areas may be drilled before the two recommended wildcat locations, but the observations of good source rocks and reservoirs are farther away, the probability of oil and gas preservation is lower, and the job of assessment would be more difficult.

If the Gray Ranch area becomes a wildlife refuge, and oil and gas leasing is prohibited, the exploration program will be hindered or even halted. If oil and/or gas are discovered in the eastern Playas Valley (or really anywhere in the region), and the refuge is locked up, the indicated resources will remain undeveloped to the detriment of the industry, the economy, national defense, and the revenue coffers of government and private landholders. If the refuge is locked up before the key wells are drilled, operators may be discouraged by the large block of prohibited acreage, the possibility that the boundary may be enlarged in the future, and the possibility that their activities may be restricted even outside the boundary. In such a case, the oil and gas resources of Hidalgo County may never be evaluated.

In many areas, petroleum exploration and development have been conducted with no long-term damage to the environment, including wildlife, and in some cases have been beneficial. If the Gray Ranch does become a wildlife refuge, a rational leasing policy should be established to encourage exploration and development with adequate protection of the wildlife and other environmental concerns.

Geothermal, Carbon Dioxide and Other Mineral Resources

If the evidence of extensive igneous and tectonic effects in Tertiary time becomes overwhelming, the probability of petroleum occurrence will be decreased, but the probability of geothermal, carbon dioxide, and other mineral resources will be increased.

Geothermal prospects may be present in the Animas Mountains area where elevated geothermal gradients around volcanic cauldrons and associated plutons continue to heat water in reservoirs such as the Horquilla reef-margin dolostones, Horquilla deep-marine sandstones in submarine fans, Epitaph dolostones and Concha limestones with cavernous porosity, and porous Mojado sandstones. They may also be present in fractures within the mountains, along the boundary faults, or in reservoirs or fractures in the valleys. The Lightning Dock Known Geothermal Resource Area (KGRA) is present in the northern part of the Animas Valley (Elston and others, 1983).

Carbon dioxide gas may be found in the Paleozoic reservoirs if temperatures associated with the Tertiary igneous activity were high enough to decompose the carbonate rocks. Carbon dioxide may also have emanated directly from the volcanic centers into these reservoirs. Both types of origin have been suggested for some of the occurrences in northeastern New Mexico.

Metallic and nonmetallic deposits from hydrothermal fluids may also be found in the reservoir rocks indicated by petroleum geology. A major orebody several hundred feet thick, one mile wide, and 15 miles long may lie at a depth of only a few thousand feet where the Horquilla reef-margin dolostones cross the plutonic-volcanic complex in the central part of the Animas Mountains. Smaller, but still significant orebodies, may be found in cavernous Epitaph dolostones and Concha limestones around the Winkler anticline area. Other reservoirs in the Paleozoic or thick Lower Cretaceous sections may be too deeply buried for economic mineral development with present technology. However, if the proposed wildlife refuge is to be locked up in perpetuity, such prospects should be considered in a comprehensive evaluation of the mineral resources.

More specific discussions of metallic and industrial mineral deposits are given by Eveleth and Barker in the following sections.

## METALLIC MINERAL RESOURCES

by Robert W. Eveleth, Senior Mining Engineer, NMBMMR

The Gray Ranch area in southern Hidalgo County, New Mexico, has been prospected beginning at least as early as 1880. However, its remoteness as well as Indian troubles in the latter portion of the nineteenth century effectively precluded significant prospecting activity until after the turn of the century. Most recent activity has centered around the scattered manganese deposits which were brought into production as a result of the carload-lot program of the U.S. government during the 1950's, and the fluorspar deposits developed soon thereafter.

Known mineral deposits and occurrences are few; however, several structural features suggest the area may host yet undiscovered deposits. These include the Winkler Anticline on the northeast border of the ranch, the Animas Quartz Monzonite intrusive southwest of the Winkler Anticline and the Walnut Wells Monzonite porphyry intrusive just off the northern ranch boundary. Most of the known mineral deposits seem to be associated with these features. These include 1) a group of manganese deposits probably related to the Animas Quartz Monzonite and which lie about a mile off the northeast boundary; and 2) silver-lead deposits associated with the Winkler anticline/Walnut Wells intrusive complex (Fig. 8; Table 4).

### Manganese

None of the known manganese deposits associated with this intrusive are actually within the boundaries of the Gray Ranch. The deposits occur in fracture zones in the Oak Creek Tuff, a Tertiary volcanic unit (Zeller and Alper, 1965, pl. 1). The fracture zones, which vary in width from 2-10 feet, are filled with black manganiferous calcite. Oxidation of the calcite has produced several zones and irregular shoots of hard manganese oxides such as psilomelane, some of which may persist in depth for several tens of feet. A few of the deposits have produced, under the carload-lot program, a few dozen tons of sorted manganese ores grading up to 40%± Mn. Most of the material remaining appears to be too low in manganese content to be considered ore grade material (NMBM&MR file data).

The Oak Creek Tuff in which these deposits occur extends into the Gray Ranch area in section 17, T30S, R18W, and should be examined for possible manganese deposits. Such deposits, while not of current economic interest, could provide manganese resources in the future should foreign sources become unavailable.

Two other manganese deposits similar in character to those associated with the Animas Quartz Monzonite intrusive are known on the Gray Ranch. These are the Peace prospect (a/k/a Blue Jay)

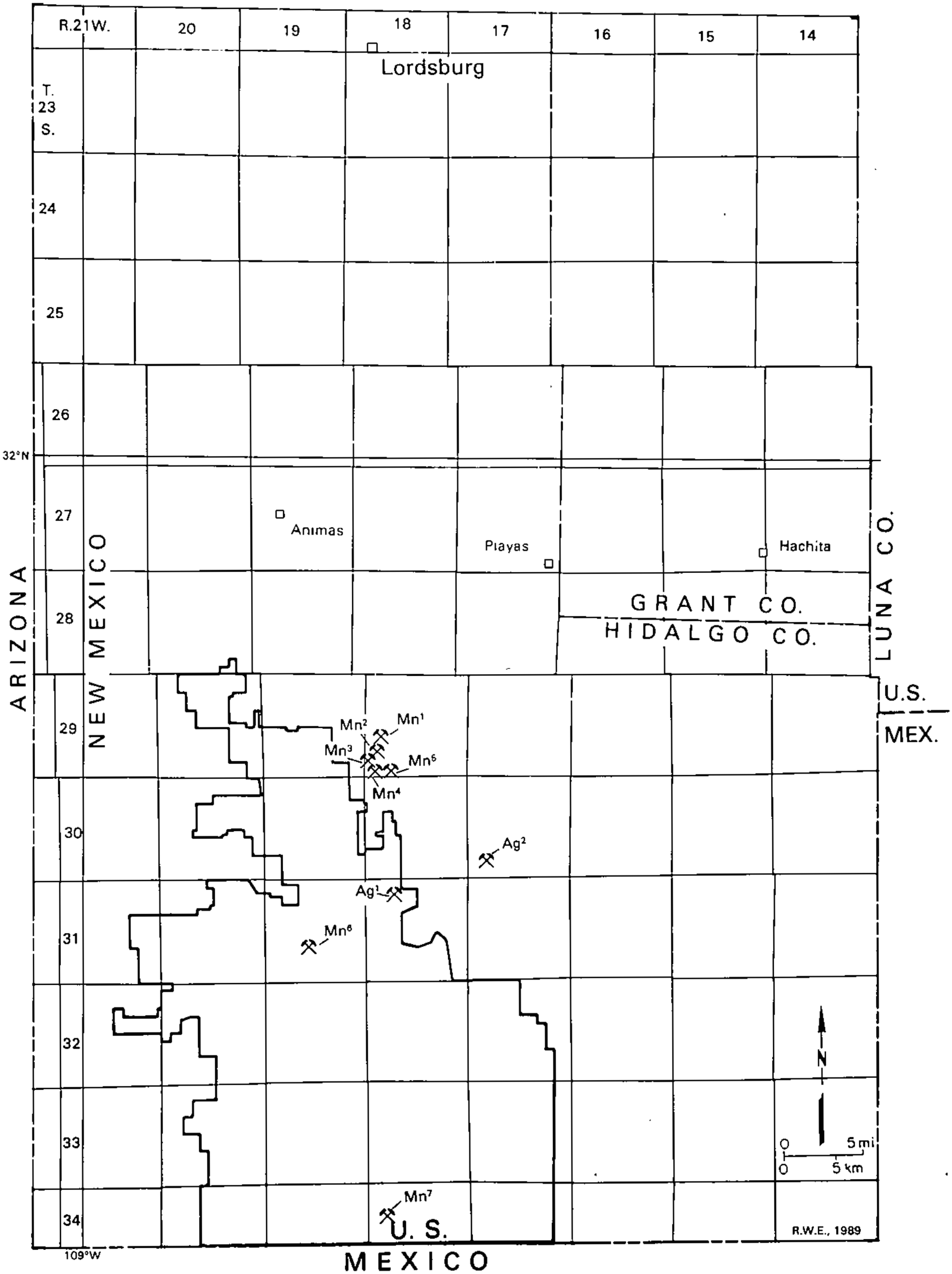


Figure 8. Manganese (Mn 1-7) and silver-lead (Ag 1-2) deposits in the Gray Ranch area (see Table 4).

Table 4: Metallic mines and prospects on or near the Gray Ranch, Hidalgo County, New Mexico (see Fig. 8).

| | Map # | Name | Alt. Name | Location | Ore Minerals | Gangue Minerals | Remarks |
|---|---|---|---|---|---|---|---|
| Silver-Lead deposits | $Ag_1$ | Gillespie | - | S1/2, sec 4<br>T31S, R18W | silver, native?<br>chlorargyrite?<br>argentite? | limonite | ore minerals mentioned by early accounts but not observed by recent investigators |
| | $Ag_2$ | Red Hill | - | SW1/4, sec 30<br>T30S, R17W | cerussite?<br>anglesite<br>galena<br>pyromorphite<br>smithsonite<br>sphalerite<br>wulfenite | quartz<br>hematite<br>limonite<br>psilomelane | largest, most productive mine in area; production of base and precious metals app. $100K |
| Manganese deposits | $Mn_1$ | Crooms | - | secs 19/20<br>T29S, R18W | psilomelane | calcite | |
| | $Mn_2$ | Lucky | - | NE1/4 sec 30<br>T29S, R18W | psilomelane<br>pyrolusite | calcite<br>quartz | |
| | $Mn_3$ | Black Streak | - | sec 30<br>T29S, R18W | psilomelane<br>pyrolusite | calcite<br>quartz | |
| | $Mn_4$ | Broaddus | Hoggett | secs 31/32<br>T29S, R18W | psilomelane<br>pyrolusite | quartz | sorted, high-grade ore averaged 0.5% $WO_3$ |
| | $Mn_5$ | Plains | - | SW1/4 sec 32<br>T29S, R18W | psilomelane<br>pyrolusite | calcite<br>quartz | |
| | $Mn_6$ | Peace | Black Hill/<br>Topaco | sec 29<br>T31S, R19W | psilomelane | barite<br>fluorite | sorted, high-grade ore averaged 1.03% $WO_3$ |
| | $Mn_7$ | Rusty Ruthlee | | secs 17/18<br>T34S, R18W | psilomelane<br>pyrolusite | calcite | |

in section 29, T31S, R19W, approximately 1 mi northwest of Animas Peak, and the Rusty Ruthlee prospect which straddles the line between sections 17 and 18, T34S, R17W, in the Whitewater Mountains. Small shipments were made to the government manganese depot in Deming during the 1950's but both properties have been inactive since. Both the Animas Mountains and the Whitewater Mountains should be examined in more detail for other types of mineral deposits.

## Silver-Lead

The few base and precious metal deposits in the area appear to be closely associated with the Winkler anticline/Walnut Wells Monzonite intrusive complex. The first recognized in the area was discovered in December 1880 by Ed Gillespie; the district carries his name today (Anonymous, 1881, p. 70). The Gillespie mine and other nearby deposits are developed along silicified fissures in the various limestone units ranging from Pennsylvanian (Horquilla) to Cretaceous (U-Bar) in age. The Gillespie appears to be the largest of these and was developed by an inclined shaft sunk to at least 100 ft (Elston, 1960, p. 418; McAnulty, 1978, p. 36). No records of production are known to be extant; however, a small amount of ore may have been stoped directly from the Gillespie shaft (Elston, 1960, p. 418). Other prospects in the Gillespie district are limited to a few shallow shafts and pits; no drifting seems to have been done in any of them. Early accounts mention native silver, chlorargyrite, and argentite as the ore minerals (Anonymous, 1881, p. 70) but recent observers were unable to verify their presence (Elston, ca 1960, p. 418; McAnulty, 1978, p. 36).

The most significant silver-lead deposit, known as the Red Hill Mine, lies about 3 1/2 mi off the northeast boundary of the Gray Ranch, roughly in line with the Gillespie Mine and the axis of the Winkler Anticline. The Red Hill deposit was developed along a strong fissure vein in the Oak Creek Tuff and has a recorded production of approximately $100,000 in lead and silver up to about 1950 (Elston, 1960, table 30, p. 411). The deposit is geologically unusual in that both hanging wall and footwall of the vein are in the Oak Creek Tuff. Evidence that the water table has fluctuated over geologic time is provided by the fact that oxidation is known to extend below the current water table (Elston, 1960, p. 413). Although this deposit is not on the Gray Ranch, the apparent trend in mineralization could be significant for the property. It is apparent that the hydrothermal solutions associated with the emplacement of the Walnut Wells Monzonite migrated for considerable distance, possibly along channels provided by the Winkler anticline. These solutions were sufficiently strong and persistent such that rocks like the Oak Creek Tuff, generally considered a poor host, nevertheless produced vein deposits such as that at the Red Hill Mine some 5-6 mi northeast of the intrusive center. This suggests that the underlying crystalline limestones and dolomites could well host a significant base and precious metal replacement deposit and would appear to be an excellent exploration target.

No known base and precious metal deposits are associated with the Animas Quartz Monzonite. Regardless, it could have produced such deposits at depth and its potential should be tested, particularly if replacement deposits associated with the Walnut Wells Monzonite are discovered.

## INDUSTRIAL MINERAL RESOURCES

by James M. Barker, Industrial Minerals Geologist, NMBMMR

Figure 9 shows the location of industrial mineral resources in the Gray Ranch area of southern Hidalgo County. They include:

Fluorspar

Limestone/Dolomite

Sand and Gravel

Stone

Nitrate

Perlite

Zeolite

### Fluorspar

The Winkler anticline, in the central part of the Animas Mountains, contains potentially commercial deposits of fluorspar (McAnulty, 1972, 1978, p. 61; Van Alstine, 1965, p. 260-261). The Winkler anticline is at the northeastern edge of the study area, with fluorspar mainly in Sec. 34, T30S R18W and Sec. 3, 4, 9, T31S R8W. Extensive low-grade deposits occur in concordant silicified limestone breccia zones up to 30 feet thick but averaging 20 feet. These deposits are in the Horquilla (Permian) and U-Bar (Cretaceous) Formations with the larger ones associated with the Horquilla. The Winkler anticline is intruded on the southwest by the Walnut Wells stock (quartz monzonite porphyry). Hydrothermal fluids from this stock carried the fluorite mineralization. The coarse crystalline high-grade fluorite of the Winkler anticline is amenable to beneficiation to either ceramic or acid grades by simple washing. Ore reserves are at least 150,000 tons of rock grading 25-35% $CaF_2$.

Fluorite occurs in the U-Bar Formation about four miles south of the Winkler anticline (McAnulty, 1972, 1978) at the Wilson prospect. This deposit, in SE1/4 Sec. 34, T31S, R18W, is a jasperoid outcrop bordering and along the U-Bar fault.

Additional deposits both downdip of known occurrences and on the margins of the Walnut Wells stock are likely (McAnulty, 1972).

### Limestone and Dolomite

Carbonate rocks of lower Paleozoic, upper Paleozoic, and Mesozoic age crop out in the northern and central parts of Animas Mountains. They may underlie the volcanic rocks at shallow

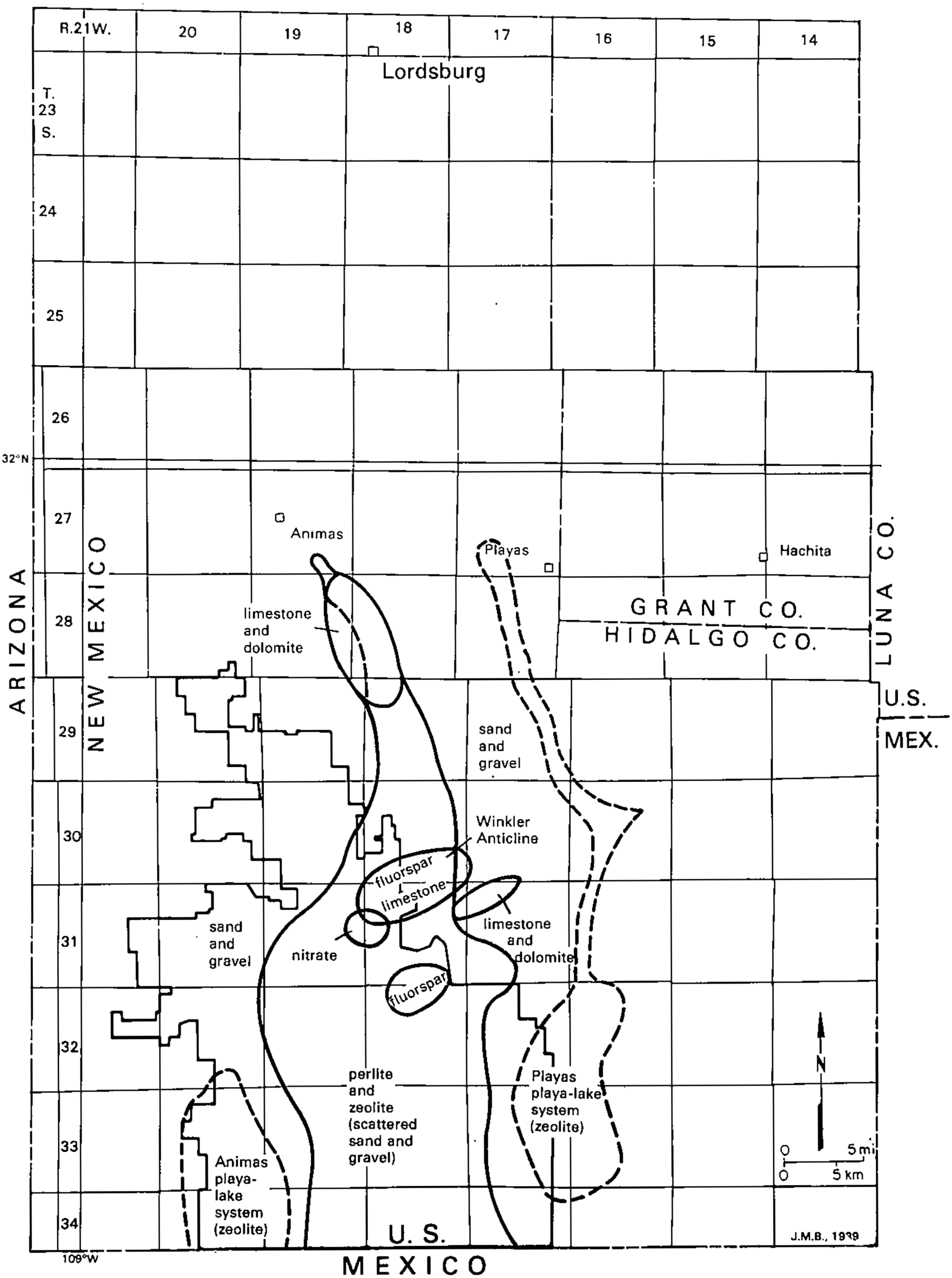


Figure 9. Industrial mineral resources of the Gray Ranch area.

depths in other parts of the mountains. The lower Paleozoic units are dolomite. The upper Paleozoic and Mesozoic units are limestone. Limestone and dolomite resources are summarized in Table 5. High calcium limestone is used as chemical feedstock or in stack gas cleanup; it may be used at the mining smelters in this region. Low calcium limestone is suitable for cement. Kottlowski (1962) showed high-calcium limestone resources on the north end of the study area (southeast of Animas) and in the Winkler anticline area (Fig. 9).

## Stone

Two basic uses for stone are as building stone or crushed stone. Many different rock units in the Animas Mountains could be used as crushed stone depending upon job requirements. Various rock units could also be used as building stone. Limestone and tuff can be easily fabricated into building stone. Igneous rocks can be cut and polished as required. The remote location of the Animas Mountains suggests that stone production is unlikely.

## Sand and Gravel

Pleistocene and Recent alluvium on the flanks of the Animas Mountains or in drainages within the mountains could be produced. Considerable resources exist in the valley fill in the Playas and Animas valleys (Carter, 1965).

## Nitrate

Nitrate has been mined from the Animas Mountains (Hayes, 1965). The Fitch claims (Mansfield and Boardman, 1932), in Sec. 12-13, T31S, R19W and Sec. 7-8, T31S, R18W, covered nitrate cropping out for about one mile. The deposit appears to be a surface concentrate from groundwater leaching of rock. The U.S.G.S. tested samples and found low soluble salt content with very little sodium or magnesium and little chloride or sulphate. The material was essentially a potassium nitrate and calcium nitrate mixture. Similar deposits may occur nearby. These deposits are or would be small and would support mining for only a short period if at all.

## Perlite and Zeolite

About 90% of the exposed bedrock in the Animas Mountains consists of igneous rocks or Tertiary volcanic rocks. Tertiary volcanic terranes elsewhere in southwestern New Mexico have deposits of perlite and zeolite so occurrences of these in the Animas Mountains cannot be dismissed without detailed field investigation. Zeolites are particularly likely to form where rhyolitic volcanic glass interacts with alkaline lacustrine fluids of the playa-lake systems of the Playas Valley on the eastern side of the Animas Mountains or the Animas Valley to the west (Hunt, 1978).

Table 5. Limestone and dolomite resources in the Gray Ranch area, Hidalgo County, New Mexico. Limestone quality is defined as high calcium ($\geq$95% $CaCO_3$) or low calcium (<95% $CaCO_3$) based on the most typical quality of limestone beds in the unit. Dolomite is not classified by quality.

| Group or Period<br>Formation (Age) | Probable<br>Quality | Remarks |
|---|---|---|
| Mesozoic | | |
| Ringbone (u. Cret.) | low calcium | contains few limestones |
| Mojado (l. Cret.) | low calcium | contains few limestones |
| U-Bar (l. Cret.) | high calcium | areally restricted |
| Naco Group | | massive, thick in part |
| Concha Ls. (u. Perm.) | low | |
| Scherrer (l. Perm.) | low | subsurface only?; very thin |
| Epitaph (l. Perm.) | low | subsurface only |
| Colina Ls. (l. Perm.) | high | some dolomite interbeds |
| Earp (l. Perm.) | high | contains few limestones |
| Horquilla (u. & l. Penn.) | high | cherty |
| Paradise (u. Miss.) | low | thin; few limestones |
| Escabrosa Group | | massive, thick in part |
| Hachita (u. Miss.) | high | |
| Keating (l. Miss.) | high | |
| Cambro-Ordovician | | |
| Montoya (Ord.) | dolomite | areally restricted, cherty |
| El Poso (Ord.) | dolomite | areally restricted, cherty |
| Bliss (Camb.) | dolomite | areally restricted, glauconitic, sandy |

Sources: Clemons and Mack, 1988; Soule, 1972; Kottlowski, 1962, 1965; Zeller, 1959, 1962; Zeller and Alper, 1965.

# CONCLUSIONS AND RECOMMENDATIONS

Significant mineral resources are indicated in the Gray Ranch area. Oil and gas resources are inferred by the petroleum source and reservoir rocks that have been projected from outside the area. Metallic mineral resources, including manganese, silver, and lead have been found within and near the ranch. Industrial mineral resources, including fluorspar, limestone and dolomite, sand and gravel, stone, nitrate, perlite, and zeolite, have been found within and outside of the ranch.

Final evaluations of these and other resources can be made only as a result of commercial exploration and development by industry operators. Such evaluations are needed for normal economic planning and national security emergencies.

These operators should be allowed access to the Gray Ranch area, but they may be asked to observe reasonable requirements in order to protect wildlife and other environmental concerns. Their past activities apparently have not had any serious impact in the Gray Ranch area.

We recommend that the State of New Mexico oppose the proposal that the U.S. Fish and Wildlife Service acquire the Gray Ranch and designate it as the Animas National Wildlife Refuge. We might be in favor if they would modify their policy of disallowing leasing of any mineral rights they own. We recommend that the State not donate its acreage to the refuge, because under the present USFWS policy the mineral resources would not be explored or developed. We also recommend that the State not consider trading for Federal acreage elsewhere in New Mexico until the mineral resources of the Gray Ranch area have been evaluated more thoroughly by industry operators.

REFERENCES


Anonymous, 1881, Gillespie District, New Mexico: Mining and Scientific Press, July 31, 1881, p. 70.

Carter, W. D., 1965, Sand and gravel; in Mineral and water resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 87, p. 353-361.

Clemons, R. E., and Mack, G. H., 1988, Geology of southwestern New Mexico: New Mexico Geological Society, Guidebook 39, p. 45-57.

Dane, C. H., and Bachman, G. O., 1965, Geologic map of New Mexico: U.S. Geological Survey, scale 1:500,000.

Drewes, Harald, 1986, Geology and structure sections of part of the northern Animas Mountains, Hidalgo County, New Mexico: U.S. Geological Survey, Miscellaneous Investigations Series Map I-1686, scale 1:24,000.

Elston, W. E., 1960, Mineral resources of Hidalgo County, New Mexico: unpublished manuscript, copy on file at New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, 448 p.

Elston, W. E., Deal, E. G., and Logsdon, M. J., 1983, Geology and geothermal waters of Lightning Dock region, Animas Valley and Pyramid Mountains, Hidalgo County, New Mexico: New Mexico Energy Research and Development Institute, report no. EMD 2-68-2102, 44 p.

Elston, W. E., Erb, E. E., and Deal, E. G., 1979, Tertiary geology of Hidalgo County, New Mexico, guide to metals, industrial minerals, petroleum, and geothermal resources: New Mexico Geology, v. 1, no. 1, p. 1-6.

Hayes, P. T., 1965, Nitrates and guano; in Mineral and Water resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 87, p. 372-373.

Hunt, C. B., 1978, Surficial geology of southwest New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 42, scale 1:500,000.

Kottlowski, F. E., 1962, Reconnaissance of commercial high-calcium limestones in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 60, 75 p.

Kottlowski, F. E., 1965, Limestone and dolomite; in Mineral and water resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 87, p. 345-353.

Mansfield, G. R., and Boardman, L., 1932, Nitrate deposits of the United States: U.S. Geological Survey, Bulletin 838, p. 42-

45.

McAnulty, W. N., Sr., 1972, Winkler anticline fluorspar, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Target Exploration Report E-3, 7 p.

McAnulty, W. N., Sr., 1978, Fluorspar in New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 34, 61 p.

New Mexico Bureau of Mines and Mineral Resources file data: unpublished proprietary manuscript reports of the U.S. Bureau of Mines and U.S. Geological Survey.

Soule, J. M., 1972, Structural geology of northern part of Animas Mountains, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 125, 15 p.

Thompson, Sam III, 1976, Tectonic and igneous effects on petroleum accumulations in southwestern New Mexico: New Mexico Geological Society, Special Publication no. 6, p. 122-126.

Thompson, Sam III, 1980, Pedregosa Basin's main exploration target is Pennsylvanian dolostone: Oil and Gas Journal, v. 78, no. 42, p. 202, 207, 210, 215.

Thompson, Sam III, 1981, Petroleum source rocks in exploration wells drilled to Paleozoic or Mesozoic units, Hidalgo and Grant Counties, New Mexico: New Mexico Energy Research and Development Institute, report no. EMD 2-66-3306, 126 p. (also New Mexico Bureau of Mines and Mineral Resources OF-153).

Thompson, Sam III, 1982, Oil and gas exploration wells in southwestern New Mexico; in Geologic studies of the Cordilleran thrust belt: Rocky Mountain Association of Geologists, Symposium, p. 521-536.

Thompson, Sam III, Behnken, F. H., Budding, A. J., Broadhead, R. F., Cernock, P. J., Bayliss, G. S., Ewing, R. C., Elston, W. E., and Erb, E. E., 1977, Geology, petroleum source rocks, and thermal metamorphism in KCM No. 1 Forest Federal well, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 152, 62 p.

Thompson, Sam III, and Jacka, A. D., 1981, Pennsylvanian stratigraphy, petrography, and petroleum geology of Big Hatchet Peak section, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 176, 125 p.

U.S. Bureau of Mines, 1977, Mineral Industry of New Mexico; in Mineral Yearbook (for the calendar year 1974), Vol. 2, Area Reports, Domestic: U.S. Department of the Interior, Washington, DC, 810 p.

Van Alstine, R. E., 1965, Fluorspar; in Mineral and water resources of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 87, p. 260-261.

Zeller, R. A., Jr., 1959, Reconnaissance geologic map of Playas fifteen-minute quadrangle: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 7, scale 1:62,500.

Zeller, R. A., Jr., 1962, Reconnaissance geologic map of southern Animas Mountains: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 17, scale 1:62,500.

Zeller, R. A., 1965, Stratigraphy of the Big Hatchet Mountains, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Memoir 16, 128 p.

Zeller, R. A., 1975, Structural geology of Big Hatchet Peak quadrangle, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Circular 146, 23 p.

Zeller, R. A., Jr., and Alper, A. M., 1965, Geology of the Walnut Wells quadrangle, Hidalgo County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 84, 105 p.

**APPENDIX**

State of New Mexico
OFFICE OF THE
Commissioner of Public Lands
Santa Fe

WILLIAM R. HUMPHRIES
COMMISSIONER

P.O. BOX 1148
SANTA FE, NEW MEXICO 87504-1148

June 9, 1989

Dr. Frank Kottlowski, Director
Bureau of Mines and Mineral Resources
Campus Station
New Mexico Tech
Socorro, NM 87801

Dear Dr. Kottlowski:

As the Gray Ranch issue develops due to the desire of Fish and Wildlife Service to acquire the private land within the Gray Ranch, I have maintained strong opposition to the federal purchase of the ranch. There are approximately one hundred thirty thousand acres of state minerals under surface that was sold by the Land Office and subsequently patented with the full right mineral development reserved by those patents. However, we learned a painful lesson in the 1982 Bitter Lakes, Salt Creek Wilderness issue. In that case there were state minerals under patented surface which Fish and Wildlife had acquired; Fish and Wildlife failed to recognize and honor our rights and the patent reservations. I believe Fish and Wildlife would oppose mineral development or make demands that would limit, or entirely preclude, mineral development if they acquire surface ownership.

My major concern is that the geologic considerations, and private interest (as demonstrated by the number of leases within the area), indicate that the area has undeniable potential for oil and gas development. In our analysis of the proposed acquisition, it appears that Fish and Wildlife either completely discounts or severely discounts any potential for mineral development, as a rebuttal to our objections.

Whatever potential there is for oil and gas development cannot be duplicated in another non-producing area in New Mexico. Thus, it's unlikely that BLM or Fish and Wildlife have within their inventory mineral lands of equal value and equal potential, that could make us whole by exchange. We would then become locked in an argument about the values of our minerals and the loss of revenue to the state. Fish and Wildlife will argue that very little would be owed to the state as compensation and will no doubt attempt condemnation. We would be arguing that the beneficiaries should receive a great deal of value for lost bonuses, rentals and royalties from an area that clearly indicates potential.

New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Information: 505/835-5420
Publications: 505/835-5410

June 19, 1989

Honorable William R. Humphries
Commissioner of New Mexico Public Lands
P.O. Box 1148
Santa Fe, NM 87504-1148

Dear Commissioner Humphries:

The New Mexico Bureau of Mines and Mineral Resources and its knowledgeable geologists and mining engineers are also greatly concerned about the Gray Ranch area in southwestern New Mexico. We are pleased to respond to your request to give you a report on the geologic potential, estimated relative values of the mineral sources in that area, and our scientific professional comments on the economic geology of that region. Sam Thompson, Sr. Petroleum Geologist, and Robert Eveleth, Sr. Mining Engineer, have been working with Ernie Szabo concerning the mineral resources of this area. We had hoped to obtain a confidential copy of the Tenneco report, but although we told the company we would not release any of its figures except in aggregate, they have refused our request. As I understand it, this report has been made available to the U. S. Fish and Wildlife Service. It is not easy to understand why the findings of the Tenneco geologists should be made available to the federal government and not to the state government.

Sam Thompson and Robert Eveleth, along with other staff members, are working on an evaluation of the mineral resources for the Gray Ranch area; hopefully we will be able to send that to you shortly. In addition to the possible oil and gas potential, some of the prospects contain precious metals, fluorspar, manganese, and other ores. In addition, some of the peripheral areas have possibilities for geothermal prospects.

We look forward to working with you and your staff in this issue of much economic importance to New Mexico.

Sincerely yours,

Frank E. Kottlowski

Frank E. Kottlowski
Director and State Geologist

FEK/jv

xc: James Robertson, Associate Director
Sam Thompson, Sr. Petroleum Geologist
Robert Eveleth, Sr. Mining Engineer

I would like to request that your bureau give us an opinion of geologic potential, estimated relative values and professional comments which you feel would enlighten and inform us. Additionally, if you see another area in New Mexico that has similar mineral qualities and potential, that we might receive in an exchange, I would like to know about that area also. If you can, please keep us informed regarding any Fish and Wildlife estimates of value that they discuss with you.

The Bureau of Mines and Natural Resources assistance in protecting very significant values for the state land trusts may be crucial. It is a sad comment to find ourselves in a situation where a federal agency is so willing to threaten the school trusts in such a manner. Unfortunately, it's not the first time or the last. Any enlightenment and help you could give us will be very important and greatly appreciated. Likewise, if you have any questions or suggestions or if we can be of any assistance, please don't hesitate to contact me.

Sincerely,

W. R. Humphries
Commissioner of Public Lands

WRH:mm

State of New Mexico
OFFICE OF THE
Commissioner of Public Lands
Santa Fe

WILLIAM R. HUMPHRIES
COMMISSIONER

P.O. BOX 1148
SANTA FE, NEW MEXICO 87504-1148

December 14, 1989

Sam Thompson
New Mexico Bureau of Mines
and Mineral Resources
Socorro, NM 87801

Dear Sam,

I want to thank you, Frank Kottlowski, Robert Eveleth and James Barker for your help on the evaluation and recommendations regarding the minerals associated with the Gray Ranch. I sincerely appreciate your effort and assistance in this very important matter. I will distribute copies of your report to members of our Congressional Delegation and Department of Interior as a matter of information.

I expect Senator Bingaman will introduce an authorization bill for the Animas National Wildlife Refuge in January or February and there will be subsequent hearings throughout 1990 regarding the acquisition of this property. Your report, along with our internal analysis and the future external contract evaluation of other mineral resources in the WSA's in southwestern New Mexico will help us establish values and the importance of these resources.

Again I thank you for your assistance and analysis and I appreciate your responsiveness in the interest of the New Mexico State Land Trusts. If I can ever be of any assistance don't hesitate to contact me.

Sincerely,

William R. Humphries
Commissioner of Public Lands

WRH/dm

Lo-Neste Peck
Copy Center

New Mexico Bureau of Mines & Mineral Resources
Socorro, NM 87801

A DIVISION OF
NEW MEXICO INSTITUTE OF MINING & TECHNOLOGY

Information: 505/835-5420
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Memorandum

TO: Frank E. Kottlowski, Director
FROM: Sam Thompson, III
DATE: December 7, 1989
SUBJECT: Open File Report No. OF-360

Attached is your copy of Bureau Open File-Report No. 360: "Mineral resources of the Gray Ranch area, Hidalgo County, New Mexico" by me, Bob Eveleth and Jim Barker. I regret the delay between the preliminary and final drafts, but much of it was due to the fact that several figures had to be re-drafted so that an accurate overlay of the Gray Ranch outline could be fitted to them.

We are sending three copies to Ernie Szabo. Two are for the State Land Office and one is to be forwarded to the U.S. Fish and Wildlife Service in Albuquerque if they so choose.

CC: Ernest Szabo, State Land Office, Santa Fe
Robert W. Eveleth, Co-Author
James M. Barker, Co-Author
Jiri Zidek, Bureau Editor