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# CENTRAL–WESTERN NEW MEXICO—AN EXPLORATION FRONTIER FOR OIL AND GAS

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**Abstract**—The vast region of central–western New Mexico cannot be discounted as a potentially petroliferous province until a substantial number of properly located wells is drilled. Extrapolating between outcrops and wells in nearby areas of New Mexico and Arizona suggests that more than 610 m of Cretaceous rocks and 1,220–1,530 m of Paleozoic sediments may be present beneath Tertiary rocks. Innovative seismic procedures and careful interpretation of the results may be imperative to the selection of locations that avoid thick Tertiary cover and structure influenced by intrusions.

The hydrocarbon potential of central–western New Mexico initially appears to be fairly low as only five wells out of a total of 42 drilled here had shows of oil and/or gas. However, all but two of these wells were drilled north of U.S. Highway 60 which bisects the region in an east–west direction and generally separates volcanic-covered terrain in the south from extensive outcrops of sedimentary rocks to the north. Although the volcanic rocks mask structures that might be present in underlying sedimentary strata, their presence does not condemn the oil and gas potential, as demonstrated by oil production beneath volcanics in the San Juan sag of south-central Colorado's San Luis Basin.

Source and reservoir beds for hydrocarbons are present in Pennsylvanian and Cretaceous strata, but the Pennsylvanian is absent from much of the area and the Cretaceous is exposed at the surface at many localities, with consequent likelihood of flushing of oil and gas by ground water. Lower Paleozoic source and reservoir rocks may be present in the subsurface in the southern part of the area. Cauldrons and associated shallow plutons in this area have probably destroyed hydrocarbons that might have been present near the volcanic centers, but thermal alteration is unlikely to have been deleterious a few thousand meters away from the centers. Several untested structures and stratigraphic pinchouts may provide potential hydrocarbon traps in this exploration frontier.

## INTRODUCTION

There is no production of hydrocarbons from central–western New Mexico. Drillers have completed 42 test wells in this region, five of which recorded shows of oil and/or gas. This report covers T8N to T9S and R4W to R21W, an area of approximately 27,700 km$^2$. Cenozoic volcanic and sedimentary rocks cover slightly more than half of the area (Fig. 1) and mask the underlying rocks that are of interest to hydrocarbon exploration. As a result, few wells have been drilled through the volcanics to test the underlying strata, especially south of T1N. Most of the wells have been drilled in the northwest and northeast parts of the area where Paleozoic and Mesozoic sedimentary rocks are exposed. These strata contain potential source and reservoir rocks for hydrocarbons; also, potential traps, mainly anticlines, are present in these rocks and several have been drilled. In the southern part of the area, it is likely that lower Paleozoic strata with good hydrocarbon source-bed and reservoir characteristics may be present in the subsurface beneath unconformably overlying Cenozoic rocks.

This report was prepared by using: completion cards; New Mexico Bureau of Mines & Mineral Resources Petroleum Exploration Maps 6 (Socorro County, compiled by Foster & Chavez 1985), 19 (Valencia County, compiled by Chavez 1985), 20 (Catron County, compiled by Bieberman & Chavez 1985a), and 26 (Cibola County, compiled by Bieberman & Chavez 1985b); geologic maps by Foster & Stipp (1961), Givens (1957), Jicha (1958), Tonking (1957), Weber & Willard (1959a, b), Willard (1957), Willard & Givens (1958), Willard & Stearns (1971), Willard & Weber (1958), and Willard et al. (1961); and reports by Foster (1964) and Kottlowski (1959, 1963).

## STRATIGRAPHY

The only exposure of basement rocks of Precambrian age in this vast region is a small outcrop of crystalline rocks in the eastern foothills of the San Mateo Mountains. Only 22 wells have penetrated the basement in this region. No strata of Cambrian, Ordovician, Silurian, Devonian, or Mississippian age are exposed and have not been reported in the test wells. However, regional isopach maps (Grant & Foster in press) suggest that some of these beds may be present beneath Cenozoic rocks in the southern part of the region. The nearest complete and well-described lower Paleozoic stratigraphic section (Shepard 1985) is near Hermosa in the eastern foothills of the Black Range in T12 and 13S, R8 and 9W, about 28 km south of the area considered in this report (Fig. 1). A generalized composite columnar section is shown in Fig. 2.

### Upper Cambrian and Lower Ordovician

This interval includes the Bliss and El Paso Formations. Paleozoic sedimentation in southwestern New Mexico began with deposition of the Bliss during Late Cambrian and Early Ordovician time with interbedded sandstone, siltstone, and minor dolomite. The sandstone is tightly cemented and all the rocks in the Bliss lack porosity except where fractured. No oil or gas shows have been reported for this unit in southwestern New Mexico. Near Hermosa this unit is 29 m thick (Shepard 1985).

The El Paso Formation of Early Ordovician age consists of limestone and dolomite gradationally overlying the Bliss or resting unconformably on Precambrian rocks. Intercrystalline to vuggy porosity is present in most dolomites, but in the Permian Basin in southeastern New Mexico most production from the El Paso is from fracture reservoirs. A few hydrocarbon shows have been reported from the El Paso in southwestern New Mexico. Greenwood et al. (1977) suggested that drill-stem tests be run in this unit because the hydrocarbons in the fracture reservoirs are commonly difficult to detect in cuttings and by log analysis. The El Paso is 107 m thick near Hermosa (Shepard 1985); the Bliss–El Paso interval thins northward and is probably absent in most of the subsurface in the area of this report (Fig. 3).

### Upper Ordovician

The Montoya Formation is unconformably on the El Paso strata or Precambrian rocks and consists of four units, described in ascending order. The Cable Canyon Sandstone is composed of quartz grains cemented by dolomite and is mostly too well cemented to be an effective reservoir. The Upham Dolomite has vuggy porosity and is a potential reservoir; a hydrocarbon show was reported in this unit in the Grimm et al. 1 Mobil well in sec. 32, T25S, R1W, southwest of Las Cruces, but it was not tested because of mechanical problems (Thompson &

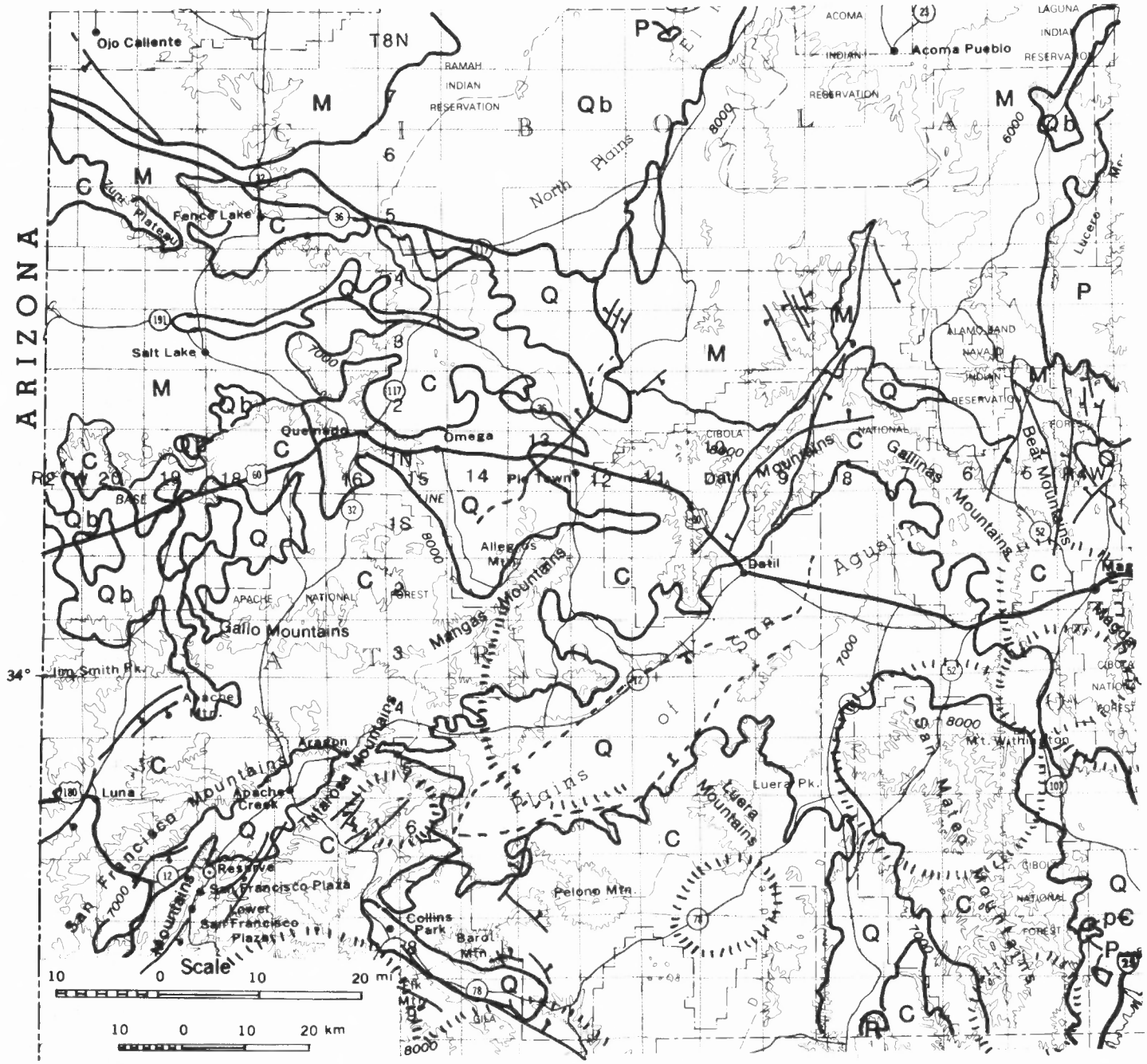



FIGURE 1—Generalized geologic map showing outcrops of Paleozoic (P) and Mesozoic (M) sedimentary rocks, Cenozoic rocks undivided (C), Quaternary basalt (Qb), Quaternary sediments (Q), and major tectonic features (from New Mexico Geological Society 1982). Locations of cauldrons (circular hachures) are from Elston (1978).

Bieberman 1975). The Aleman Member consists of interbedded dolomite and chert. The Cutter Member is composed of dense, light-gray dolomite. Shepard (1985) reported 57–66 m of the Montoya Formation near Hermosa; this unit thins northward and may be present in the subsurface in the southeastern part of the region of this report, but is absent farther north (Fig. 3).

### Silurian

The Lower to Middle Silurian Fusselman Dolomite is disconformable on the Montoya Formation and is unconformably overlain by Devonian shale. The Fusselman generally has good porosity. It is 9–15 m thick near Hermosa (Shepard 1985) and thins northward, probably pinching out near the southern margin of the area covered in this report (Fig. 3).

### Devonian

Upper Devonian strata resting unconformably on older rocks generally have been assigned to the Percha Shale, but Shepard (1985) divided this interval into the Oñate Formation and Percha Shale (in ascending order). The Oñate is described by Shepard (1985) as consisting of interbedded gray dolomitic siltstone and dolomite with 5–8 cm of black shale at the base. The overlying Percha consists of dark, marine shale and siltstone. These rocks are ideal source beds and provide a seal for hydrocarbons that might be present in underlying strata. The

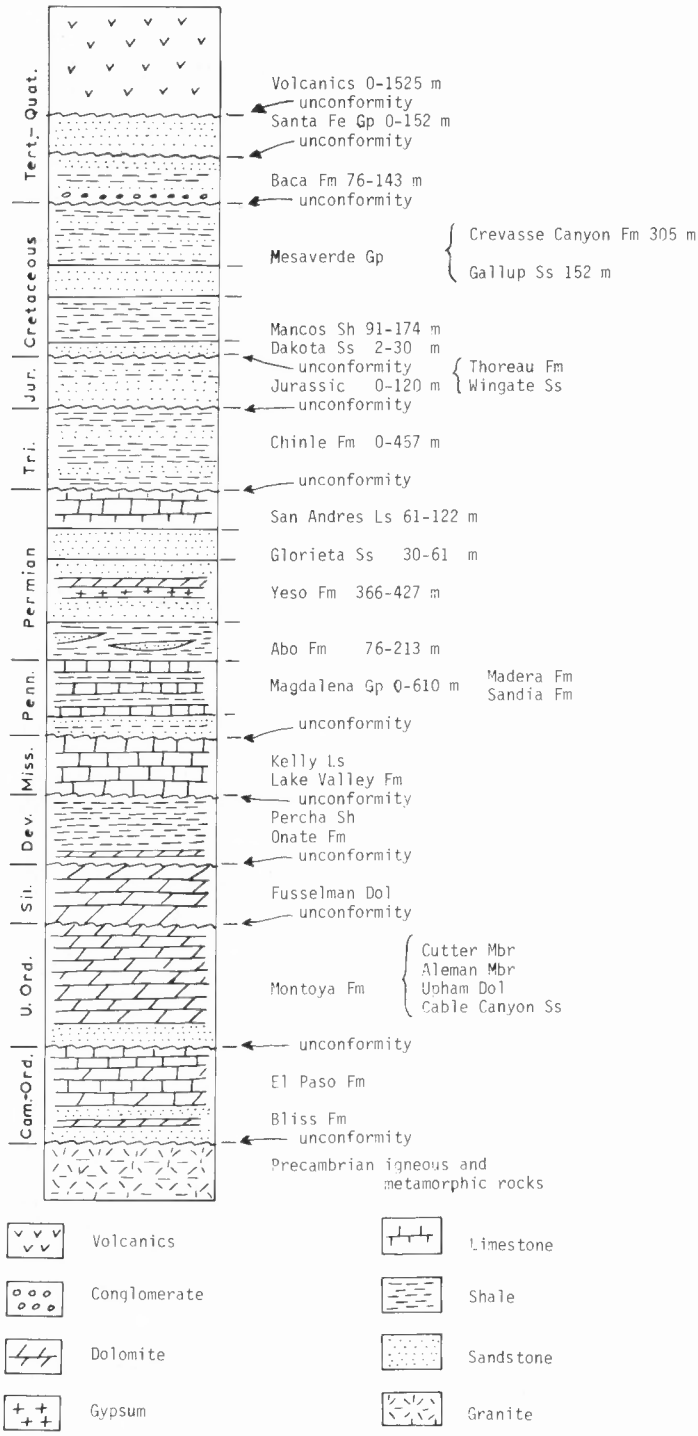



FIGURE 2—Generalized columnar section showing major units inferred to be present in central–western New Mexico.

Devonian is 64 m thick near Hermosa (Shepard 1985) and thins northward, with a truncated edge in the southern part of the area of this report (Fig. 3).

### Mississippian

The Lake Valley Formation and Kelly Limestone comprise the Mississippian System, in ascending order, near Hermosa (Shepard 1985). The Lake Valley consists of dark-gray argillaceous limestone and light-gray, crinoidal, cherty limestone; the overlying Kelly Limestone is also light gray, crinoidal, and locally cherty. The total thickness of these

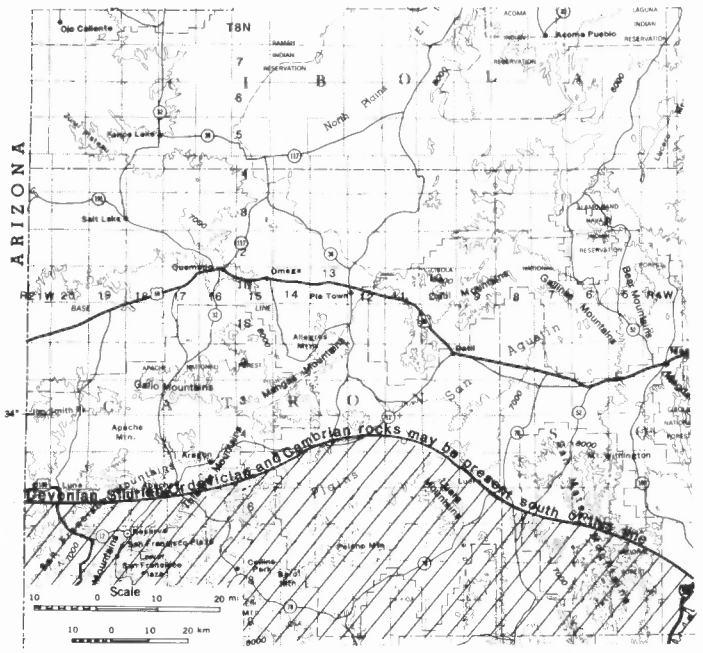



FIGURE 3—Map showing inferred location of pre-Mississippian Paleozoic rocks.

units is 64 m near Hermosa (Shepard 1985). The Mississippian may be as much as 50 m thick in the subsurface in the southern part of the region, but is truncated and absent to the north (Fig. 4). Mississippian beds rest unconformably on Devonian shale in the southeastern part of the area and on Precambrian rocks elsewhere.

### Pennsylvanian

Pennsylvanian beds are present in the eastern part of the region and are probably present in the subsurface in the southwestern corner of the area as well (Fig. 5). Elsewhere, the Pennsylvanian is absent and younger beds rest directly on Precambrian rocks. In the southeastern part of the area, Pennsylvanian sediments were deposited on the Precambrian and locally on the Mississippian.

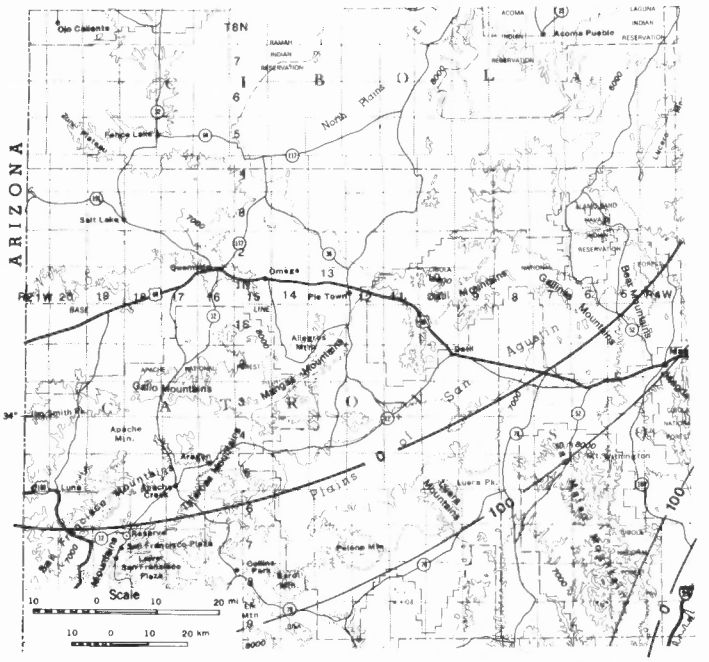



FIGURE 4—Isopach map of Mississippian rocks (Lake Valley Formation and Kelly Limestone). Contour interval 30.5 m.

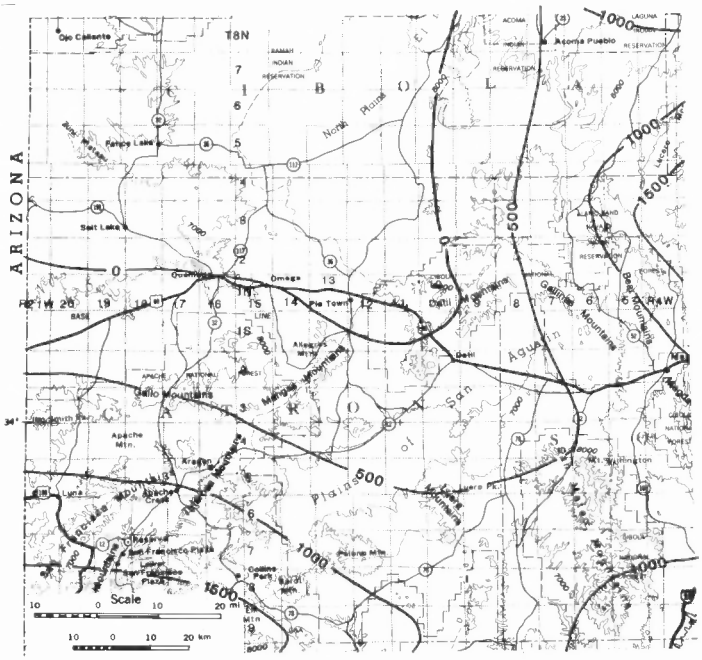



FIGURE 5—Isopach map of Pennsylvanian rocks (Sandia and Madera Formations of Magdalena Group). Contour interval 150.5 m.

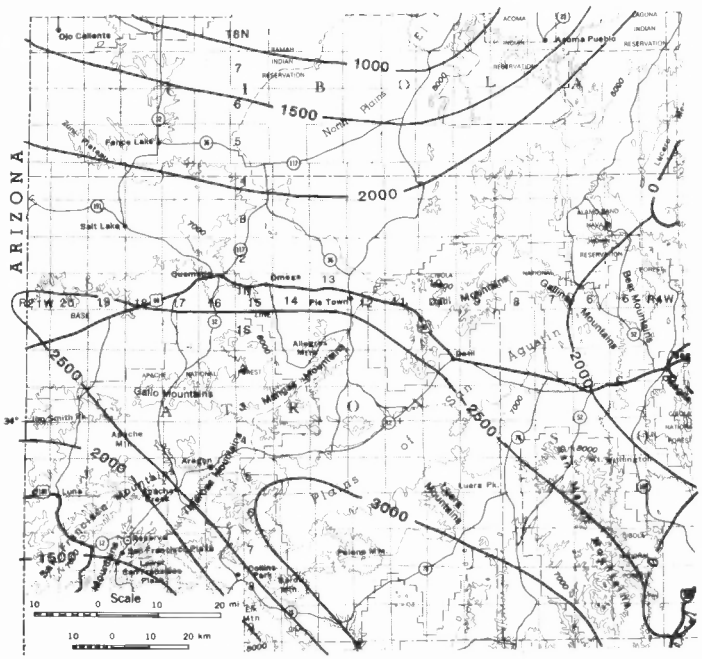



FIGURE 6—Isopach map of Permian rocks (Abo, Yeso, Glorieta, and San Andres Formations). Contour interval 150.5 m.

The Pennsylvanian strata are assigned to the Magdalena Group that is divided (in ascending order) into the Sandia Formation and the Madera Formation. Maximum thickness of the Magdalena on the eastern edge of this area is about 457 m. The Sandia Formation consists of sandstone and shale with subordinate interbedded limestone. The Madera consists mainly of marine limestone with interbedded shale and sandstone. Some of the dark shale and limestone beds could be source rocks for hydrocarbons, and the limestones and sandstones may be potential reservoir rocks. Original porosities are probably low in the dense limestones and in the strongly cemented sandstones; thus, fracturing is necessary to create permeability.

## Permian

Permian units are, in ascending order, the Abo, Yeso, Glorieta, and San Andres Formations, with a total thickness of about 900 m in the southern part of the area (Fig. 6).

The Abo Formation ranges from 76 to 213 m, thickening toward the east. It is composed of reddish sandstone and mudstone, largely lacking in source beds. Where the Abo rests directly on the Precambrian, source beds for hydrocarbons in the organic-rich shales and limestones of the older Pennsylvanian units are absent. However, in some cases oil migration could have occurred along unconformities into these areas even though the older source beds are locally absent.

The Yeso Formation overlies the Abo and consists of 366–427 m of orange–tan sandstone with a zone of gypsum, dolomite, shale, sandstone, and minor limestone in the middle part of the formation. Some of the sandstones are permeable; although adjacent hydrocarbon source rocks are lacking, longer distance migration of oil or gas may have occurred. Where the Pennsylvanian is present beneath the Permian rocks, there is a possibility of oil or gas being expulsed upward into sandstone reservoir rocks of the Yeso.

The Glorieta Sandstone rests on the Yeso and consists of ca 27–91 m of white sandstone with minor interbedded limestone. Porosity in this unit ranges widely, depending on the intensity of cementation. It may locally be a potential reservoir rock, particularly if it is fractured; however, there are few adjacent source beds.

Above the Glorieta is the San Andres Limestone that is composed of 61–122 m of dense, yellowish-gray to gray limestone and dolomitic limestone with minor sandstone interbeds. This unit could be a source rock and, where fractured, would be a potential reservoir for hydrocarbons.

## Triassic

The Chinle Formation comprises all of the Triassic in this region; it consists of reddish shale with subordinate sandstone and minor conglomerate and limestone, all of continental origin. The Chinle is about 610 m thick in the northern part, but thins southward to a zero edge near the central part of the area (Fig. 7). The Chinle rests unconformably on Permian strata. In view of the absence of source beds in the Chinle, it seems unlikely that it would have hydrocarbon potential.

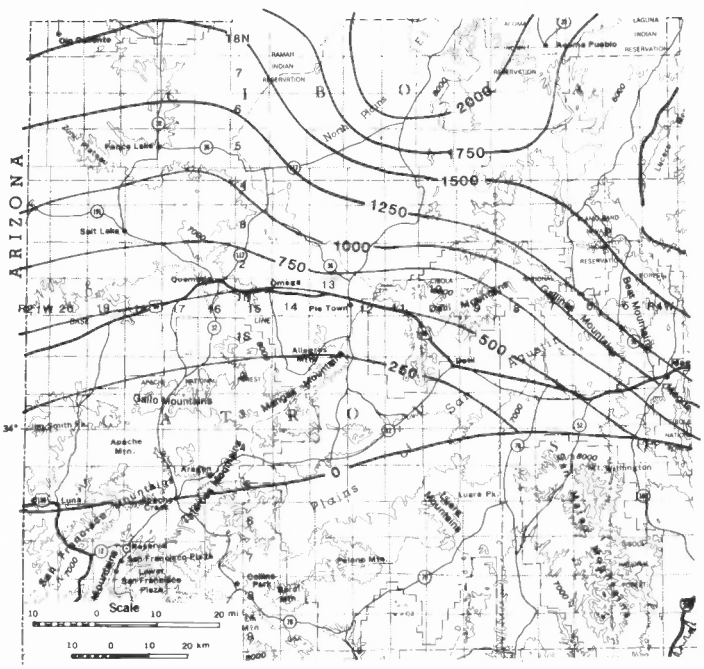



FIGURE 7—Isopach map of Triassic rocks (Chinle Formation). Contour interval 75.25 m.

### Jurassic

Jurassic strata consist of continental sandstones and shales that thin southward and are absent south of T5N (Fig. 8). There are no hydrocarbon source beds in this sequence and it is not likely that oil or gas would be found.

### Cretaceous

Cretaceous rocks, in ascending order, are the Dakota Sandstone, Mancos Shale, and Mesaverde Group. These units are widely exposed in the northern half of the area and may be present in the subsurface in the southern part as well (Fig. 9).

The Dakota Sandstone consists of 2–30 m of sandstone and interbedded gray to black shale. The Dakota rests unconformably on Jurassic and Triassic beds and is a potential reservoir rock with associated source rocks.

The Mancos Shale is composed of 90–168 m of dark, organic-rich, marine shale with subordinate interbedded sandstone. The Mancos is a major target for hydrocarbon exploration because of sandstone and fracture reservoirs and associated shale source rocks.

The Mesaverde Group intertongues with, and rests on, the Mancos and consists mainly of continental deposits of sandstone with subordinate shale and minor coal. The Mesaverde in this region has been divided into the Gallup Sandstone and Crevasse Canyon Formation (in ascending order). The Gallup has about 168 m of interbedded sandstone and dark-gray shale. This unit contains good reservoir rocks. The Crevasse Canyon Formation contains about 300 m of interbedded, gray, carbonaceous shale, sandstone, and minor coal. The sandstone intervals could be potential reservoir rocks, especially where adjacent coal beds could be sources of methane.

### Cenozoic sedimentary rocks

Tertiary sedimentary rocks consist mainly of the Paleogene Baca Formation which is red to gray sandstone, shale, and conglomerate 76–137 m thick. The Baca unconformably overlies Cretaceous beds, is truncated to the north by overlying volcanic rocks, and may thicken to the south beneath the overlying volcanics. In the eastern part of the area the Neogene Santa Fe Formation is present above the Baca Formation and consists of ca 100 m of tan, continental sandstone. It is unlikely that hydrocarbons will be found in any of the Tertiary rocks.

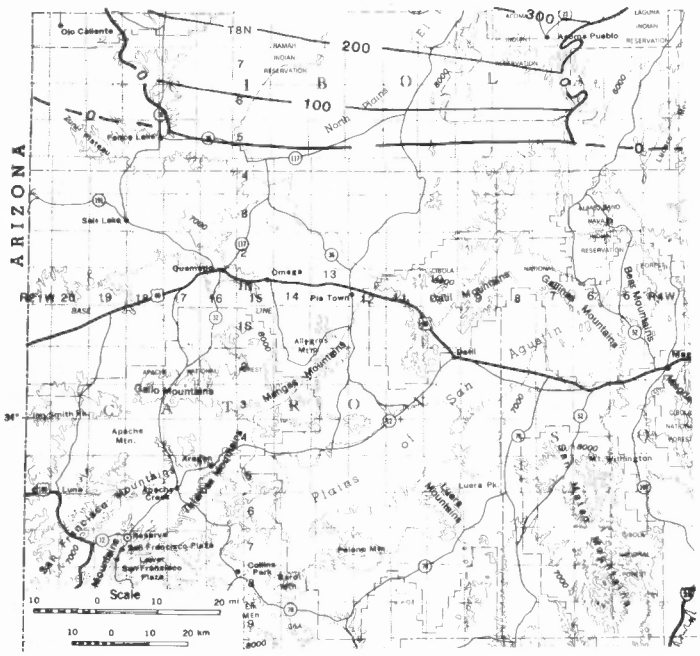



FIGURE 8—Isopach map of Jurassic rocks (Wingate Sandstone and Thoreau Formation). Contour interval 30.5 m.

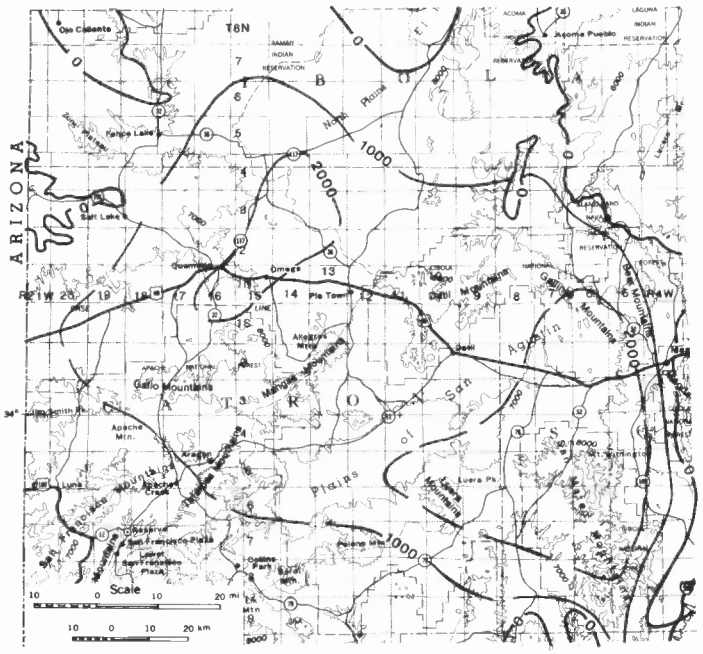



FIGURE 9—Isopach map of Cretaceous rocks (Dakota Sandstone, Mancos Shale, and Mesaverde Group). Contour interval 301 m.

### Cenozoic igneous rocks

Volcanic rocks are widespread and cover slightly more than one-half of the area. In the north the volcanics are probably no more than 30 m thick, but in the south they are much thicker, possibly 1,000 m near the southern boundary. The volcanic rocks are unconformable on the underlying units and tend to mask structures that may be present in the older rocks, and thereby make it difficult to use surface geology in exploration for hydrocarbon traps where the volcanics are extensive.

Many of the silicic volcanic rocks in the southern part of the area were erupted in the mid-Tertiary as ash-flow tuffs from known or inferred cauldrons (Fig. 1) that are thought to be underlain by shallow plutons (Elston 1978). Dikes and small stocks that are relatively minor in abundance are scattered in the northern part of the area.

## STRUCTURE

A structure contour map (Fig. 10) was drawn using the contact between Precambrian basement rocks and overlying Paleozoic strata as a datum. It shows major structures at that horizon; smaller folds observed at the surface are superimposed on the map. There are two major uplifts or structurally high areas bounding the region: the Zuni uplift on the north and the Lucero uplift on the east. Both of these high areas have Precambrian rocks exposed at high elevations in their cores. South and west of the Zuni uplift is the Mogollon slope, an area that dips gently to the south with a few broad structural highs that have low dips. A gravity-anomaly map (Fig. 11) and surface geology were used to infer basement structure in areas lacking drill-hole data.

In the southeastern part of the area, the San Agustin Basin is structurally low; this basin is at least partly bounded by faults and forms a graben. The Acoma Basin is not as deep and occurs in the northeastern part of the area. There are numerous high-angle faults in the southern part of the area that have created horsts, grabens, and tilted fault blocks.

Several doubly plunging anticlines have been mapped in the east-central part of the area. Two of these anticlines have intrusive igneous rocks exposed along their crests, suggesting that they either never had any oil or gas accumulations or that the hydrocarbons were destroyed. Three of the other anticlines have been drilled but had no shows. Five remaining anticlines have not been drilled.

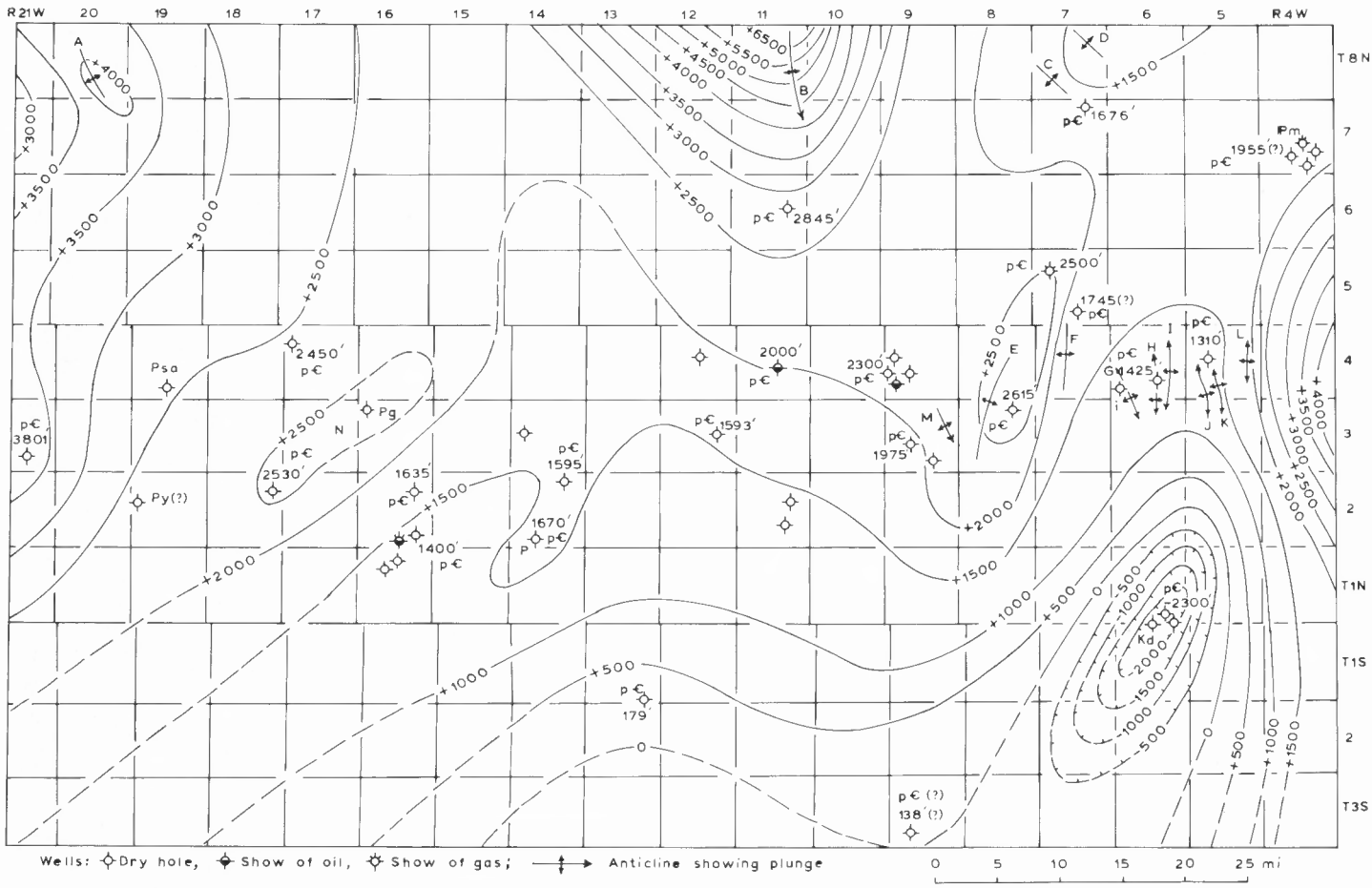



FIGURE 10—Structure contour map on the top of Precambrian rocks showing wells that have penetrated the Precambrian with elevations (in ft) of top of Precambrian. Formations at total depths, where known, are: p€ = Precambrian, ¶m = Madera Formation, Py = Yeso Formation, Pg = Glorieta Sandstone, Psa = San Andres Limestone, Kd = Dakota Sandstone, i = igneous rock.

## POTENTIAL OIL AND GAS TRAPS

The principal hydrocarbon source rocks of central–western New Mexico are the Pennsylvanian dark, organic-rich shales and limestones, and the Cretaceous dark, marine shale. Cretaceous coaly beds may also be a source of methane, and the San Andres Limestone (Permian) could be a minor source of oil. The most likely reservoir rocks are Cretaceous sandstones and Pennsylvanian sandstones and limestones. Permian sandstones and carbonates could also be reservoir rocks if Pennsylvanian source beds are present beneath them.

If lower Paleozoic rocks are present in the subsurface in the southern part of the area, they might provide source beds and reservoirs for hydrocarbons. The Devonian Oñate Formation and Percha Shale contain dark, marine shale that is an ideal source and seal for hydrocarbons in the underlying rocks. Intercrystalline porosity is commonly present in the Silurian Fusselman Dolomite and in the Upham Dolomite of the Upper Ordovician Montoya Formation, and fractures could provide porosity in the other carbonates (El Paso Formation, Aleman and Cutter Members, Lake Valley Formation, and Kelly Limestone). Recent studies of conodont color alteration in Paleozoic rocks of the Colorado Plateau in Arizona north of 32° 30′ latitude indicate thermal maturation adequate for oil generation (Wardlaw & Harris 1984).

Known or inferred cauldrons in the southern part of the area (Elston 1978) are probably underlain by shallow plutons that could have destroyed or driven out any hydrocarbons present near the volcanic centers. Studies by Thompson et al. (1977) in southwestern New Mexico indicate that thermal contact aureoles extend only short distances from intrusions, and at distances of ca 1,000 m the thermal alteration is in the mature range where oil may be preserved.

There are several kinds of potential traps in this region. Facies changes and intraformational unconformities in the Pennsylvanian may form stratigraphic traps. Although lack of subsurface control makes location imprecise, the zero edge of the Pennsylvanian may be a significant pinchout trap if coupled with favorable structure. Up-dip pinchouts of Cretaceous sandstones are probable traps for stratigraphic accumulations where depositional shoreline features can be identified or where thick suites of Cretaceous rocks are preserved in Laramide grabens or structural synclines beneath later Tertiary cover (Cather & Johnson 1984). The truncated edges of lower Paleozoic strata that might be present in the subsurface in the southern part of the area could provide potential hydrocarbon traps if favorably located structurally. Stratigraphic test wells and seismic data are needed to further refine such exploration targets. Anticlines are another kind of trap, with prospective targets in the Cretaceous, Permian, and Pennsylvanian. Most of the wells drilled to date have tested anticlines or other structurally high areas.

Five wells in this area have recorded shows of oil and/or gas (Tab. 1) from the Pennsylvanian, Permian, and Cretaceous. Unfortunately, there is no information concerning the kinds of oil shows (i.e. light, active oil or dead, residual stain), nor is there any record of pressures in the single drill-stem test reported. Seven anticlines or structural highs that appear to have closure have been drilled to date. Seven additional anticlines have not been tested; it is not known if all of these structures have closure, but the available maps suggest that three of them are closed. These structures are referred to by letters in Fig. 10; the following discussion considers each structure.

Anticline A (T8N, R20W) has Permian rocks exposed and these beds

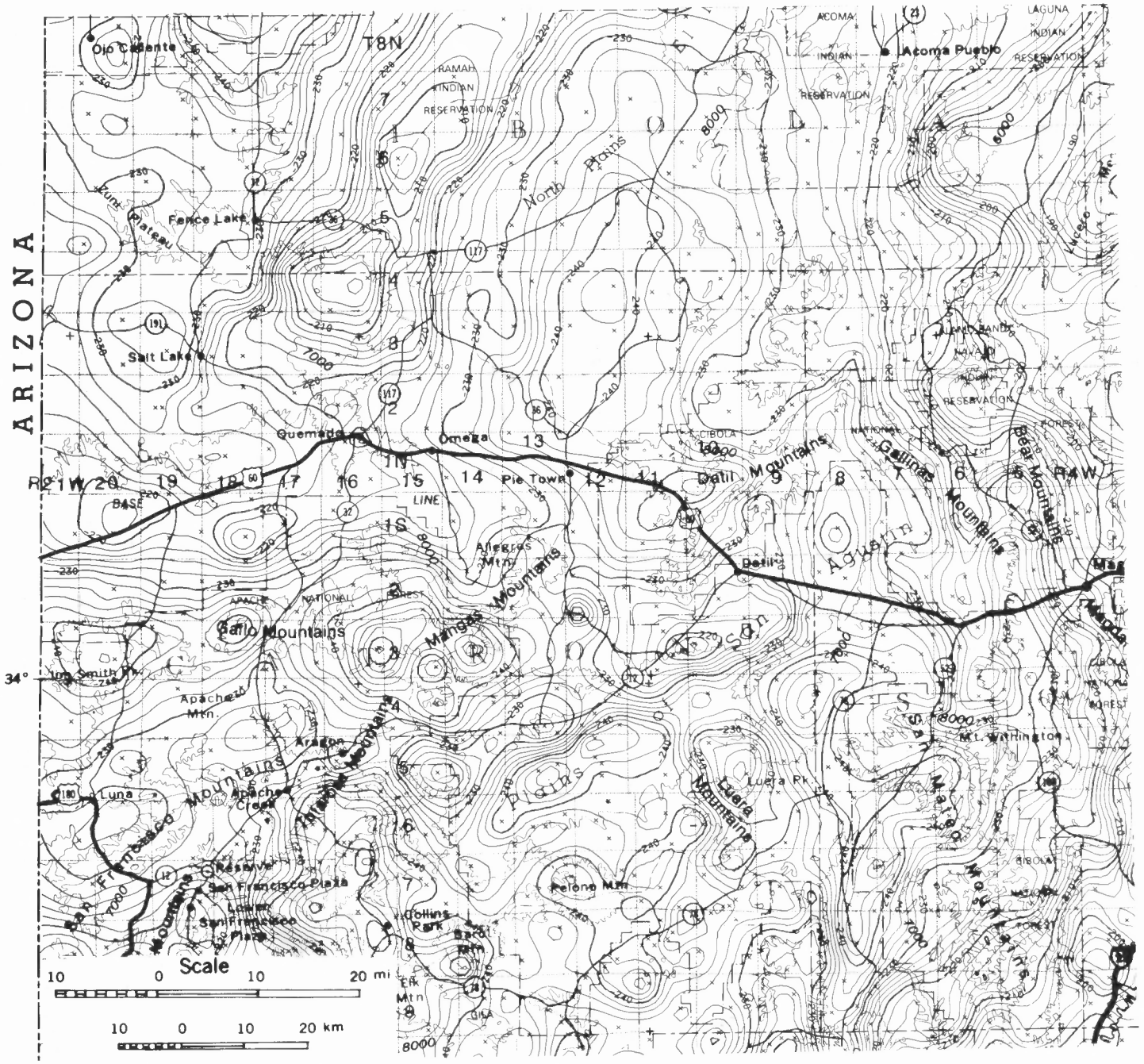



FIGURE 11—Bouguer gravity-anomaly map (from Keller & Cordell 1983). Same area as shown in Fig. 1. Contour interval is 2 milligals. Hachures indicate closed gravity lows and x is control point.

probably rest directly on the Precambrian. It is unlikely that this structure would contain hydrocarbons, but there is a possibility that $CO_2$ might be found, as it has been reported to the north. The available maps do not indicate closure for this anticline. Anticline B is the south-plunging nose of the Zuni uplift and has no closure. It is possible that an up-dip pinchout of the Pennsylvanian on this nose could provide a structural–stratigraphic play; however, the zero edge of the Pennsylvanian is not precisely located. Two small anticlines (C and D) in T8N, R7W appear to have no closure and a well on trend with C (in T7N, R7W) was dry. Triassic beds are exposed and Pennsylvanian rocks occur at depth.

Anticline F occurs in Cretaceous beds and appears to have no closure; it has not been drilled. Anticlines G and H have been drilled, resulting in dry holes. Anticline I is doubly plunging and is exposed in Triassic beds. This has not been drilled; in view of the presence of Pennsylvanian beds in the subsurface it is a prospective target. Anticline J has intrusive igneous rocks exposed at its crest and, therefore, is probably not prospective. Anticlines K and L are shown to be doubly plunging, with Triassic beds exposed and Pennsylvanian rocks probably present at depth. As these structures have not been drilled, they are prospective targets. Anticline M is a plunging structure without closure that occurs in Cretaceous strata and has not been drilled.

The structural high at locality N has been tested by two wells, both dry. It would be necessary to have seismic data to determine if the wells were on the top of the structure. Pennsylvanian beds are absent here. A structural high at locality P has been tested by one well. Volcanic rocks occur at the surface and seismic data are therefore necessary to evaluate the structure. Pennsylvanian strata are probably absent here.

TABLE 1—Oil and gas shows in central–western New Mexico.

| Well | Location (sec., T, R) | Total Depth (in feet) | Oil, gas shows |
|---|---|---|---|
| Fenner #1 Bailey | 35-2N-16W | 670' | Oil & gas, 483' Cretaceous? |
| Red Feather #2 | 30-4N-9W | 1330' | Oil at 1000', Dakota |
| Spanel & Heinze #1-9617 S.F. | 27-4N-11W | 5394' | Gas in Yeso, oil & gas in San Andres |
| Spanel & Heinze #1-9612 S.F. | 5-5N-7W | 4992' | Gas on DST 4537'-4637', Pennsylvanian? |
| Acme Development #1 S.F. | 27-7N-4W | 4965' | Gas shows at 3640'-3645' and 4540'-4545', Pennsylvanian? |

## ACKNOWLEDGMENTS

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