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OIL AND GAS EXPLORATION WELLS
IN SOUTHWESTERN NEW MEXICO

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and Mineral Resources

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ABSTRACT

In Hidalgo, Grant, Luna, and Doña Ana Counties of southwestern New Mexico, 64 oil and gas exploration wells have been drilled through 1980. In the 22 key wells drilled to Mesozoic, Paleozoic, or Precambrian rocks, shows of oil or gas have been reported in 11, but no commercial production has been established as yet. Several favorable source and reservoir units are indicated in the Paleozoic section, which is analogous to that of the productive Permian basin, and in the Mesozoic section, which is analogous to that of the western Gulf basin.

Lithostratigraphic and biostratigraphic studies of the subsurface sections in the key wells provide significant data for both local and regional interpretations. In the Humble No. 1 State BA, Ordovician conodonts were identified in the bottom of the well, negating a previous thrust interpretation. In the Grimm No. 1 Mobil 32, lower Tertiary palynomorphs were identified below the Lobo(?), providing a critical maximum age for that formation; Lower Cretaceous and Jurassic index fossils document a northward extension of the Chihuahua trough.

A regional isopach map of the Paleozoic shows thickening up to 15,000 ft in the Pedregosa basin area, thinning to less than 4,000 ft in the Burro-Moyotes uplift area, and thickening to over 8,000 ft in the Orogrande basin area. A map of the Mesozoic shows southward thickening of the Bisbee Group (Lower Cretaceous) to over 15,000 ft, northward onlap, and possible continuity of the upper part with the Sarten. Upper Cretaceous strata are less than 2,000 ft thick and exhibit southwestward onlap.

Laramide uplift and erosion stripped Mesozoic and older rocks from much of the Burro and other positive areas. Upon the Laramide unconformity, conglomerates and redbeds were deposited, followed by andesitic volcanic rocks; their decreasing ages to the northeast reflect the migration of the Cordilleran magmatic arc. Some Laramide thrusts may have formed by upward and outward movement from wrench zones. In the lower plate of a major thrust, thermal alteration of kerogens has exceeded the limit of oil preservation, and gas may not be preserved in older units.

INTRODUCTION

Oil and gas exploration wells drilled to Paleozoic or Precambrian rocks in the Pedregosa basin area of southeastern Arizona, southwestern New Mexico, and northern Mexico were discussed by Thompson and others (1978). The present investigation focuses on the wells in southwestern New Mexico and it: (1) includes those drilled to Mesozoic, Paleozoic, or Precambrian rocks; (2) provides an update of formation tops and other basic well information; and (3) presents isopach maps of Paleozoic and Mesozoic strata. Those strata contain the significant petroleum source and reservoir rocks of the region.

Figure 1 shows the locations, names, total depths, and oldest formations penetrated by exploration wells drilled to documented Mesozoic or older rocks in southwestern New Mexico prior to 1982. The map area covers about 156 miles from west to east and about 100 miles north to

south, including all of Hidalgo and Luna Counties and the southern parts of Grant, Sierra, and Doña Ana Counties in New Mexico. The northern part of Chihuahua, Mexico and the western part of El Paso County, Texas also are included in the map rectangle.

Table 1 is a generalized correlation chart of stratigraphic units in southwestern New Mexico. Separate columns of formation names are listed for the Pedregosa basin (after Zeller, 1965 and 1970), Burro uplift (after Jicha, 1954), and the Orogrande basin (after Kottlowski and others, 1956). These basins are areas of subsidence where Pennsylvanian rocks are 2000 ft thick or more (Kottlowski, 1960a). Only wells which reached units beneath the Laramide unconformity are discussed in this paper. Main rock types and depositional environments are grossly generalized. Petroleum source and reservoir evaluations are based on current work in the Hidalgo County area (Thompson,

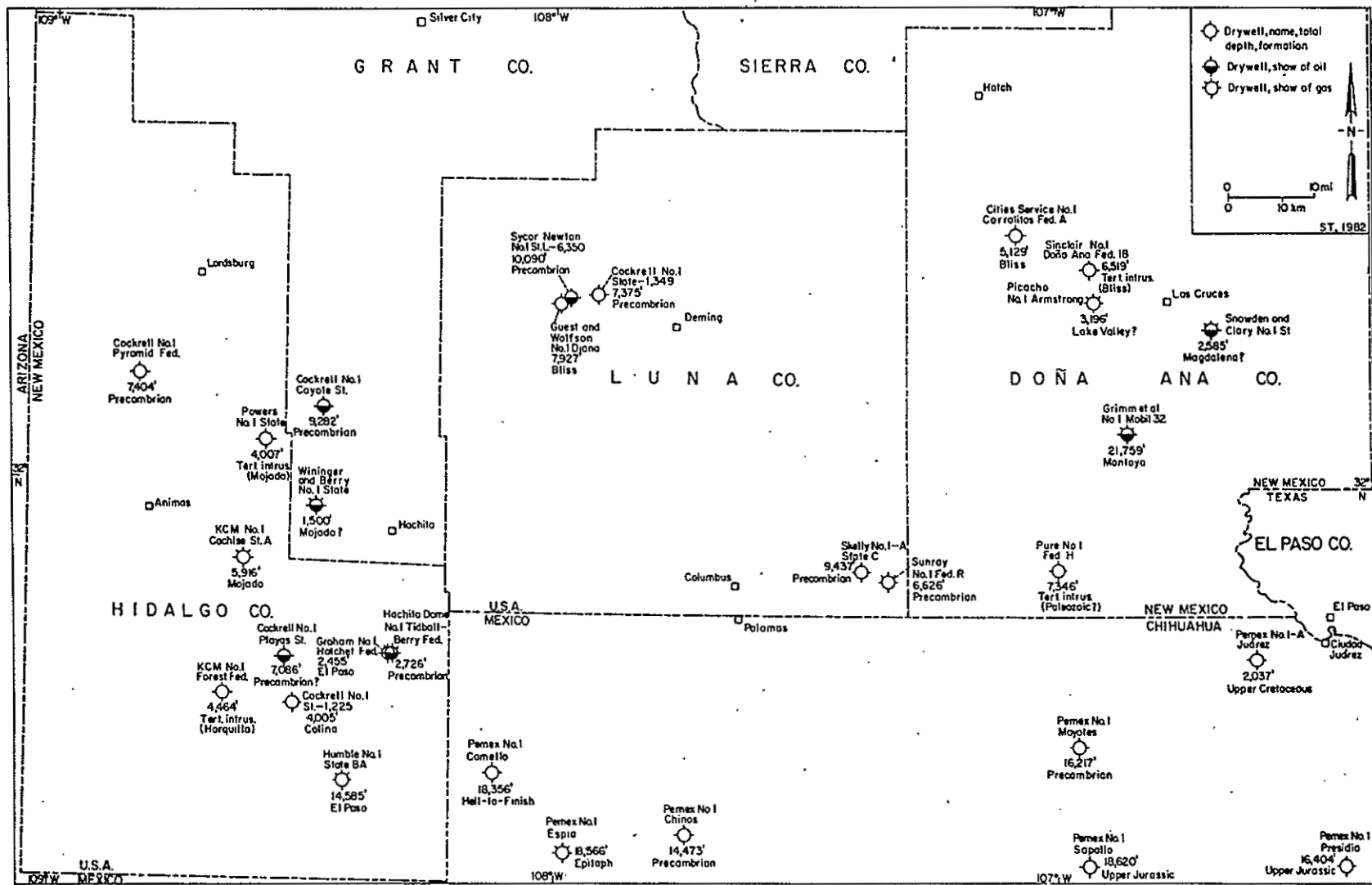


Figure 1. Map of oil and gas exploration wells drilled to Mesozoic, Paleozoic, or Precambrian rocks in southwestern New Mexico. Given at each location are the name, total depth in feet, and the stratigraphic unit at the bottom of the well.

Chronostratigraphic units	Pedregosa basin		Burro uplift	Orogrande basin	Main rock type	Depositional environment	Petroleum evaluation	
	Hidalgo-Grant Counties		Luna County	Doña Ana County			source	reservoir
Quaternary	-----bolson, fluvial, and other deposits-----				sand	nonmarine	none	poor
Quaternary-Upper Tertiary	Gila		Gila	Santa Fe	conglomerate	nonmarine	none	fair
Middle Tertiary	-----volcanic and local intrusive rocks-----				rhyolite, etc.	nonmarine	none	none
Lower Tertiary-	Hidalgo		Rubio Peak	Palm Park	andesite, etc.	nonmarine	none	none
Uppermost Cretaceous	Ringbone		Lobo	Love Ranch	cgl., redbeds	nonmarine	none	poor
	absent		absent	unnamed	sandst., mudst.	nonmarine	poor	poor
-----Laramide unconformity-----								
Upper Cretaceous	absent		upper Colorado	absent	sandst., mudst.	nonmarine	poor	poor
	absent		lower Colorado	Mancos	mudstone	shallow marine	good	very poor
Lower Cretaceous	Bis- bee	absent	Beartooth	Dakota	sandstone	deltaic	poor	fair
		Mojado	Sarten	Sarten	sandst., mudst.	deltaic	poor, fair	fair, poor
		U-Bar	absent	absent	limestone	shallow marine	fair	fair
		Hell-to-Finish	absent	absent	cgl., redbeds	nonmarine	none	very poor
Jurassic	absent		absent	unnamed	sandst., mudst.	marine	poor, fair	fair, poor
Triassic	absent		absent	absent	--	--	--	--
-----basal Mesozoic unconformity-----								
Permian	Guadalupian	Concha	absent	San Andres	limest., dolost.	shallow marine	fair	poor, fair
		Scherrer	absent	Glorieta	sandstone	shallow marine	very poor	poor
	Leonardian	Epitaph	absent	Yeso (Hueco?)	dolostone	shallow marine	fair-good	fair
		Colina	absent		limestone	shallow marine	fair	very poor
	Wolfcampian	Earp	Abo	Abo-Hueco	redbeds-limest.	non.-shall.mar.	poor-fair	poor-fair
Pennsylvanian	Virgilian	upper Horquilla	absent	Bursum	limest. limest.	shallow	fair	fair
		limestone-shelf	absent	Panther Seep	dolost. sandst.	to	to	to
	Missourian	dolostone-margin		Magda- lena	dolost. limest.	deep	good	good
	Desmoinesian	mudstone-basin	Magdalena	Lead Camp	mudst.	marine		
	Morrowan	lower Horquilla	absent		limestone	shallow marine	fair	poor
Mississippian	Chesterian	Paradise	absent	Helms	limest., mudst.	shallow marine	fair-good	poor
Devonian	Meramecian, etc.	Escabrosa	Lake Valley	Lake Valley-Rancheria	limest., chert	shall.-deep mar.	fair	poor
		Percha	Percha	Percha	dark mudstone	shallow marine	poor-fair	poor
Silurian	Fusselman	Fusselman	Fusselman	Fusselman	dolostone	shallow marine	poor	fair-good
Upper Ordovician	Montoya	Montoya	Montoya	Montoya	dolost., sandst.	shallow marine	fair, poor	fair, poor
Middle Ordovician	absent	Simpson	absent	absent	mudst., sandst.	shallow marine	fair	poor
Lower Ordovician	El Paso	El Paso	El Paso	El Paso	limest., dolost.	shallow marine	fair	poor, fair
Lowermost Ordovician-	Bliss	Bliss	Bliss	Bliss	sandstone	shallow marine	poor	poor
Upper Cambrian	absent	absent	absent	absent	--	--	--	--
Middle and Lower Cambrian	-----basal Paleozoic unconformity-----							
Precambrian	-----basement complex-----				granite, met.	nonmarine	none	none

Table 1. Stratigraphic units of southwestern New Mexico (modified from Thompson and others, 1978, Table 1).

1981) that is being extended to other parts of the region.

Lying within the Basin and Range province, this area is one of the active frontiers of petroleum exploration. Because of the stratigraphic similarities of the Paleozoic section with that of the Permian basin, and of the Lower Cretaceous section with that of the western Gulf basin, this area has a high potential (Greenwood and others, 1977). Projections of the Cordilleran fold and thrust belt have encouraged structural exploration (Corbitt and Woodward, 1973; Drewes, 1978); however, several contrasts are noted in comparison with the productive overthrust belt of Wyoming and Utah (Woodward, 1980; Thompson, 1980; Woodward and DuChene, 1981). Tectonic and igneous complexities, including Tertiary volcanism, local metamorphism, and extensive Basin and Range faulting, add to the risks of frontier exploration (Thompson, 1976, 1980).

EXPLORATION WELLS

Table 2 presents the basic data on the 22 wells drilled to pre-Laramide stratigraphic units in Hidalgo, Grant, Luna, and Doña Ana Counties, New Mexico (Fig. 1). These data generally were taken or derived from scout tickets, cuttings, logs, and other information available in the New Mexico Library of Subsurface Data, supervised by R.A. Bieberman at the New Mexico Bureau of Mines and Mineral Resources. Locations, names, and completion dates were taken directly from the scout tickets or reports by operators. Locations are given by township, range, section, and footage from north/south and east/west lines of the section. Elevations of the kelly bushing (KB), derrick floor (DF), surface-casing flange (SC), or ground level (GL) are of the points from which depths were measured in the individual wells.

Formation tops were derived from a synthesis of previous reports, spot checks of lithostratigraphic boundaries using cuttings and logs, and available biostratigraphic control. Generally used publications included Kottowski and others (1956, 1969), Thompson and Bieberman (1975), Thompson and others (1978), and Thompson (1981); specific references will be discussed under the counties. Where available, descriptions and logs prepared by the Permian Basin Sample Laboratory and reports by the Paleontological Laboratory (both of Midland, Texas) were useful. R.W. Foster (formerly with New Mexico Bureau of Mines and Mineral Resources) described cuttings and determined formation tops on several wells in the region. Although the tops reported on Table 2 are considered to be the best that can be presented with current knowledge, they are subject to revision as more detailed studies are made of individual wells.

Total depths generally are those measured by wire-line logs. The formation at total depth is indicated for each well; if a well bottomed in Tertiary intrusive rock, the host formation is indicated in parentheses. Shows of oil and gas reported in wells drilled prior to 1958 may not be reliable; those listed for wells drilled that year or later are considered reliable, and many have been documented by hydrocarbon logs. Results from geochemical analyses are not included. Although no commercial quantities of oil or gas have been found to date, the shows encourage further exploration.

In the following sections, wells in southwestern New Mexico are discussed under the counties. Information on wells drilled in northern Chihuahua, Mexico was provided by J.C. Tovar R. of Petroleos Mexicanos in Thompson and others (1978); no wells have been drilled in that area since that time (Justo Mesa D., personal communications, 1982). In the part of El Paso County, Texas, shown on the map (Fig. 1), none of the exploration wells have reached definite Mesozoic or older rocks according to Cooley (1958) and Harbour (1972, p. 78-80). For information on wells drilled in adjacent parts of western Texas, see Pearson and Underwood (1975), Uphoff (1978), and Pearson (1980). Information on wells drilled in southeastern Arizona was provided by J.N. Conley in Thompson and others (1978); since that time, two deep tests have been drilled by the Phillips Petroleum Co.

HIDALGO COUNTY

A total of 28 petroleum-exploration wells have been drilled in Hidalgo County. Of these, 9 have been drilled to pre-Laramide units. All 9 key wells are discussed in a recent report documenting petroleum-source units in the Hidalgo County area (Thompson, 1981). Data for Table 2 were taken from that reference.

The Cockrell No. 1 Pyramid Federal well was drilled in the Animas Valley on the west side of the Pyramid Mountains. Below the unconformity at the base of the Tertiary volcanic rocks is a Paleozoic section from Escabrosa (Mississippian) to Bliss (Cambrian-Ordovician). Each Paleozoic unit was intruded by Tertiary diorites. Elston and others (1979) show this area as lying near one of their volcanic cauldrons.

In the northern part of the Playas Valley, the Powers well was drilled near the Coyote Hills. C.H. Thorman prepared an unpublished sample description and determined that this well penetrated Mojado (Lower Cretaceous) intruded by Tertiary granodiorites (Thorman, 1977). R.F. Broadhead prepared an unpublished sample description on the KCM No. 1 Cochise State A which was drilled in the Playas Valley on the east side of the Animas Mountains. Kerogens in the Mojado have been subjected to a high degree of thermal alteration, and the section in this well is believed to have been buried beneath the major thrust whose present erosional limit is exposed in the northern Animas Mountains (Thompson, 1981, p. 41).

In the Hachita Valley, the Hachita Dome Inc. No. 1 Tidball-Berry Federal well encountered shallow Precambrian on the upper plate of the major thrust mapped in the Sierra Rica (Zeller, 1965, and 1975). The Graham well was drilled recently only 1,500 ft northwest of the Hachita Dome well; tops were determined by Fred Dumas (Permian Basin Sample Laboratory). Near this area, the Beal No. 1 Beal Federal well (29S-15W-28) reportedly drilled valley fill from the surface to 310 ft and Permian rocks from that depth to 414 ft; however, no cuttings or logs are available to verify the Permian designation.

In the southern part of the Playas Valley, the Cockrell No. 1 Playas State drilled through 2,480 ft of valley fill, encountered a Paleozoic section from Horquilla (Pennsylvanian-Permian) to Bliss, and may have bottomed in Precambrian. The Cockrell No. 1 State-1, 225 drilled through

Location	Well name	Completion date	Elevation	Formation tops (Ti = Tertiary intrusive rock)	Total depth	Oil, gas shows
HIDALGO COUNTY:						
24S-19W-31 1,980'N; 660'E	Cockrell No. 1 Pyramid Fed.	9-30-69	4,244' KB	Surface-Quaternary; 385'-Gila?; 1,890'-Tertiary volcanic rocks (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
26S-17W-4 330'S; 1,980'E	Powers No. 1 State	12-3-72	4,377' KB	Surface-Quaternary; above 920'-Tertiary (or Cretaceous) volcanic rocks; 1,190'-Mojado; 3,930'-Tertiary intrusive rocks	4,007' Tert. intrus. (Mojado)	None
28S-17W-18 1,980'N; 1,980'E	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'
30S-15W-12 1,655'S; 2,012'W	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'
30S-15W-12 1,980'S; 660'W	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
30S-17W-14 600'N; 1,980'E	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'
31S-17W-12 1,980'N; 660'E	Cockrell No. 1 State-1,225	11-24-70	4,480' KB	Surface-Quaternary; 150'-Gila; 2,465'-Tertiary volcanic (and sedimentary?) rocks; 2,595'-Epitaph; 3,770'-Colina	4,005' Colina	None
31S-18W-3 1,494'N; 1,753'E	KCM No. 1 Forest Fed.	1-22-75	5,156' KB	Surface-Earp (Ti); 255'-Horquilla (Ti); 2,225'-metamorphosed Horquilla and Tertiary intrusive rocks.	4,464' Tert. intrus. (Horquilla)	None
32S-16W-25 990'N; 1,980'E	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'
GRANT COUNTY:						
25S-16W-14 700'S; 700'W	Cockrell No. 1 Coyote State	8-24-69	4,354' KB	Surface-Quaternary; above 360'-Tertiary (or Cretaceous) volcanic rocks; 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'
27S-16W-16 1,600'S; 850'E	Winger 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'

Table 2. Basic data on exploration wells drilled to Mesozoic, Paleozoic, or Precambrian rocks in southwestern New Mexico (see text for sources of information).

Location	Well Name	Completion date	Elevation	Formation tops (Ti = Tertiary intrusive rock)	Total depth	Oil, gas shows
LUNA COUNTY:						
23S-10W-7 1,500'N; 700'W	Cockrell No. 1 State-1,349	11-6-69	4,534' KB	Surface-Quaternary; 230'-Tertiary volcanic and sedimentary rocks; 1,310'-Lobo; 6,550'-El Paso; 7,030'-Bliss; 7,240'-Precambrian	7,375' Precambrian	None
23S-11W-10 660'S; 330'W	Sycor Newton No. 1 St. L-6,350	10-22-74	4,556' KB	Surface-Quaternary; 200'-Tertiary volcanic and sedimentary rocks?; above 2,000'-Lobo; 6,530'-Montoya; 7,160'-El Paso; 7,630'-Bliss; 7,775'-Precambrian	10,090' Precambrian	Oil: 6,670'- 6,720'; 7,612'- 7,632'
23S-11W-16 1,980'N; 1,980'W	Guest and Wolfson No. 1 Diana	3-21-73	4,548' KB	Surface-Quaternary; 90'-Tertiary volcanic and sedimentary rocks; 2,680'-Lobo; 6,590'-El Paso; 7,835'-Bliss;	7,927' Bliss	None
28S-5W-19 560'S; 1,980'E	Skelly No. 1-A State C	1-13-64	4,029' KB	Surface-Quaternary; 700'-Tertiary volcanic and sedimentary rocks; 3,900'-Lobo?; 5,130'-Tertiary-Cretaceous volcanic rocks; 8,388'-Montoya; 8,622'-El Paso; 8,786'-fault, Precambrian	9,437' Precambrian	None
28S-5W-27 1,980'N; 1,980'W	Sunray Mid-Cont. No. 1 Federal R	3-24-62	4,097' KB	Surface-Quaternary; 550'-Tertiary volcanic rocks; 2,886'-Fusselman (Ti); 3,536'-Montoya; 4,354'-Simpson; 4,730'-El Paso (Ti); 6,396'-Bliss (Ti); 6,569'-Precambrian	6,626' Precambrian	Gas: 5,582'- 5,619'
DOÑA ANA COUNTY:						
22S-1W-27 660'N; 660'W	Sinclair No. 1 Doña Ana Fed. 18	4-7-62	4,684' GL	Surface-Quaternary; 60'-Santa Fe; 280'-Tertiary volcanic rocks; 2,846'-fault, Magdalena (Ti); 3,654'-Lake Valley; 3,922'-Percha (Ti); 4,304'-Fusselman; 4,580'-Montoya; 4,970'-El Paso (Ti); 6,330'-Bliss (Ti)	6,519' Tert. intrus. (Bliss)	None
22S-2W-6 1,980'N; 1,980'W	Cities Service No. 1 Corralitos Fed. A	7-24-71	4,786' KB	Surface-Tertiary volcanic and sedimentary rocks; 1,055'-upper Hueco; 1,734'-Abo; 2,094'-lower Hueco; 2,222'-Magdalena; 2,986'-Lake Valley; 3,260'-Percha; 3,580'-Fusselman; 3,890'-Montoya; 4,240'-El Paso; 5,060'-Bliss	5,129' Bliss	None
23S-1W-15 660'N; 1,980'E	Picacho No. 1 Armstrong	5-15-41	4,480' GL	Surface-Quaternary; 200'-Santa Fe; 265'-Tertiary volcanic rocks; 1,670'-Tertiary red mudstones (Lobo?); 1,806'-Tertiary tuffaceous sandstones and gray mudstones; 2,340'-Hueco; 2,760'-Magdalena?; 3,100'-Lake Valley?	3,196' Lake Valley?	Gas: 2,435'; 2,620'
23S-2E-36 106'N; 41'W	Snowden and Clary No. 1 State	11-1-49	4,240' GL	Surface-Santa Fe; 526'-Hueco; 2,475'-Magdalena?	2,585' Magdalena?	Gas and dead oil: 553'-573'; oil: 573';1,025' -1,035';1,161'; oil and gas: 1,492'-1,518'; 2,540'-2,560'

Location	Well Name	Completion date	Elevation	Formation tops (Ti = Tertiary intrusive rock)	Total depth	Oil, gas shows
DOÑA ANA COUNTY (cont)						
25S-1E-32 1,315N; 1,315'W	Grimm et al No. 1 Mobil 32	10-12-73	4,220' GL	Surface-Quaternary; above 310'-Santa Fe; 1,940'-Tertiary volcanic rocks; 5,880'- Lobo?; 12,100'-Lower Tertiary (Paleocene- Eocene) sedimentary rocks; 13,300'-Sarten; 14,100'-Jurassic sedimentary rocks (Ti); 15,550'-Hueco (Ti); 19,080'-Magdalena (Ti); 20,560'-Rancheria?; 20,710'-Percha; 20,880'- Fusselman; 21,560'-Montoya	21,759' Montoya	Gas and oil: 12,340'- 12,600'; gas; 19,015'- 19,240'; 20,620'- 20,690'; oil; 21,600'- 21,710'
28S-2W-24 1,060'N; 2,297'E	Pure No. 1 Federal H	2-8-62	4,404' SC	Surface: Lower Cretaceous sedimentary rocks (Ti); 625'-Permian? to Mississippian? sedi- mentary rocks (Ti); 3,850'-Percha; 4,060'- Fusselman; 4,405'-reverse fault?, Permian? to Mississippian? sedimentary rocks; 6,240'- marble?; 6,815'-Tertiary intrusive rock	7,346' Tert. intrus. (Paleoz.?)	None

2,595 ft of valley fill and Tertiary volcanic rocks and encountered the Epitaph-Colina (Permian).

On the Winkler anticline in the central Animas Mountains, the KCM No. 1 Forest Federal well drilled relatively unaltered Earp (Permian) and upper Horquilla down to 2,225 ft. Below that depth, the well penetrated metamorphosed Horquilla and a Tertiary intrusive complex of quartz monzonites. This location falls between two volcanic cauldrons (Thompson and others, 1977; Elston and others, 1979).

The Humble Oil & Refining Co. (Exxon) No. 1 State BA was drilled on the Alamo-Hueco anticline along the east side of the Playas Valley. It penetrated the lower part of the Lower Cretaceous section and a nearly complete Paleozoic section down to the total depth of 14,585 ft. With the excellent set of cuttings and logs, the formation tops could be determined accurately. Several lithologic and log markers were used to document a repeated section of Epitaph below a reverse fault at 3,310 ft. Less evident was a reverse fault at 14,120 ft where Escabrosa (Mississippian) was believed to lie below El Paso (Ordovician) (Thompson in Zeller, 1965, p. 116). During the present investigation, small samples were selected above and below 14,120 ft to get biostratigraphic determinations. A.C. Selby of ARCO Exploration Co. submitted the samples to the research department where T.R. Carr identified Ordovician conodonts and D.E. Potter identified graptolites both above and below 14,120 ft. This evidence indicates that the section from 13,214 ft to total depth is in the El Paso and that the previous interpretation of a reverse fault at 14,120 ft is erroneous. Appreciation is expressed to ARCO and the individuals involved for clearance to publish this significant information.

GRANT COUNTY

A total of 7 petroleum-exploration wells have been drilled in Grant County (one was located north of the map area of Fig. 1). Of these, only two have been drilled to pre-Laramide units. They also were included in the recent report on petroleum-source units (Thompson, 1981).

The Cockrell No. 1 Coyote State was drilled in the northern part of the Hachita Valley. Valley fill and Tertiary volcanic rocks were penetrated down to 1,790 ft. Below the unconformity at that depth, a complete section of the Bisbee Group (Lower Cretaceous) was penetrated down to 7,240 ft. Below the unconformity at that depth, only lower Paleozoic strata are preserved. A slight show of oil was found in Mojado sandstones by the mudlogger; however, on two drill-stem tests only fresh water (chloride contents 150 and 120 ppm) was recovered, indicating flushing by meteoric water from the Burro uplift area to the north.

Only a driller's log is available on the Winger and Berry well. Previous reports of Mississippian rocks at the surface and Ordovician rocks at the total depth of only 1,500 ft are considered erroneous. Near that location in the Little Hatchet Mountains the Ringbone Formation (uppermost Cretaceous) crops out. The reported shows of oil and gas are probably in the Mojado.

LUNA COUNTY

Of the 17 wells drilled in Luna County, five definitely have reached pre-Laramide units, and one recent well may have. Others which have been drilled to 2,000 ft or more in the northern and eastern part of the county appear to have reached red beds of the Lobo Formation (uppermost Cretaceous to lowermost Tertiary), which overlies the Laramide unconformity.

All five of the key wells were checked in an earlier study (Thompson and others, 1978). In the present investigation, formation tops were rechecked with available cuttings and logs and some revisions were made. Further revisions may be necessary after each well is studied in detail and biostratigraphic control is added.

In the Mimbres Valley area northwest of Deming, the Cockrell, Sycor Newton, and Guest and Wolfson wells encountered lower Paleozoic strata beneath the Laramide unconformity. Individual units should be documented with conodonts or other index fossils. Nevertheless, the lithostratigraphic evidence confirms the fact that younger Paleozoic and Mesozoic strata have been eroded off this subsurface portion of the Burro uplift. Above the unconformity, the Lobo is about 4,000-5,000 ft thick and may be filling a narrow Laramide trough trending northwest-southeast (parallel to the San Vicente Arroyo). The Lobo is only 500 ft thick in the Florida Mountains southeast of Deming (R.E. Clemons, personal communication, 1982).

Near Deming, two recent wells were drilled by the Seville Trident Corp. Their No. 1 City of Deming (24S-8W-6) was drilled in 1981 to a total depth of 4,225 ft and probably did not reach pre-Laramide units. Their No. 1 McSherry (24S-8W-4) was drilled in 1981-1982 to a total depth of 12,495 ft and probably went into Precambrian. Because these wells were drilled tight, no cuttings or logs were available for use in the present investigation. Shows of gas have been tested in both wells.

North of Camel Mountain, in the southeastern part of the county, the other two key wells also encountered lower Paleozoic strata beneath the unconformity on that portion of the Burro uplift. Cuttings in the Skelly well are of poor quality; however, a normal fault with at least 1,675 ft of stratigraphic throw appears to have been crossed at the El Paso/Precambrian contact. The total throw may be nearly 4,000 ft because the top of the El Paso is 3,960 ft higher in the Sunray well (3 mi to the southeast). A red-bed section between 3,900-5,130 ft in the Skelly well is correlated tentatively with the Lobo Formation. It overlies an andesitic-volcanic section which may be as old as uppermost Cretaceous. Normally, the Lobo and its correlatives underlie a Cretaceous or Tertiary volcanic section.

DOÑA ANA COUNTY

The 14 wells drilled in Doña Ana County were discussed by Thompson and Bieberman (1975). That work was based on reported information. Other references on these wells include: Kottlowski and others (1956, 1969), Kottlowski (1973), Foster (1978a, and 1978b), and Uphoff (1978). In the present investigation, formation tops were checked with available cuttings and logs on the 6 key wells drilled to pre-Laramide units.

South of the Robledo Mountains, the Sinclair No. 1 Doña Ana Federal 18 drilled valley fill and Tertiary volcanic rocks down to 2,846 ft. At that depth, a fault contact with the underlying Magdalena (Pennsylvanian) was inferred by Kottlowski and others (1969, p. 192); however, it may be an unconformity on the Robledo uplift. A nearly complete section of Paleozoic strata was penetrated down to the Bliss (Cambrian-Ordovician), but several units were intruded by Tertiary diorites.

On the east side of the Mason Draw anticline, the Cities Service No. 1 Corralitos Federal (Government) A drilled Tertiary volcanic and sedimentary rocks down to 1,055 ft. Below the inferred unconformity at that depth, the interval down to 1,250 ft consists of greenish gray mudstones and tan cherts (concretions?) which may be as young as Upper Cretaceous. The dolostone/limestone section from 1,250-1,734 ft resembles the Epitaph/Colina of Hidalgo County and may be a Yeso equivalent. However, the interval between 1,055-1,734 ft is designated upper Hueco following the stratigraphic column for the Robledo Mountains shown by Kottlowski (1960b). Beneath the Abo and lower Hueco, a Paleozoic section similar to that in the Sinclair well was penetrated, but no Tertiary intrusive rocks were encountered. Several porosity zones were detected in the Paleozoic carbonates. Low-chloride waters recovered on drill-stem tests were considered previously to be products of flushing by meteoric water (Thompson and Bieberman, 1975, p. 171). However, large negative deflections on the spontaneous-potential curve indicate that the formation waters are salty (even at depths as shallow as 3,000 ft), and the small volumes of water recovered on the tests are now interpreted as filtrates from the drilling mud.

The Picacho No. 1 Armstrong was drilled 3 mi southwest of Picacho Mountain, a prominent Tertiary intrusion west of Las Cruces. Previously, the interval from 1,670-2,340 ft was placed in the Love Ranch Formation (Thompson and Bieberman, 1975, p. 173 and Uphoff, 1978, p. 62). As a result of the present study of the cuttings, the red mudstones from 1,670-1,806 ft were correlated tentatively with the Lobo (= Love Ranch), and the tuffaceous sandstones and mudstones from 1,806-2,340 ft were designated as an unnamed unit of probable Tertiary age. Cuttings are of poor quality below 2,340 ft, and they are lacking below 2,688 ft. Formation tops of the Hueco, Magdalena, and Lake Valley were determined tentatively from descriptions on the sample log by Geological Service (Permian Basin Sample Laboratory).

The Snowden and Clary No. 1 State was drilled one mile south of Tortugas Mountain, an isolated exposure of Hueco(?) - Bursum (Permian) limestones (King and Kelley, 1980). Subsurface information is meager and cuttings are available only from 1,420-1,865 ft. Tops of the Hueco and Magdalena (including Bursum) were determined tentatively from the descriptions by Kottlowski and others (1956, p. 82).

The J.F. Grimm, N.B. Hunt, G.R. Brown, and Am Arctic Ltd. No. 1 Mobil 32 was drilled in the Mesilla Bolson on the La Mesa surface. This well set a depth record for the region of 21,759 ft; it penetrated thick sections of Cenozoic, Mesozoic, and Paleozoic strata. An extensive operator's

report by J.F. Grimm was published in Thompson and Bieberman (1975, p. 173-174). A thorough study of this well was made by Uphoff (1978). For the present investigation, the sample log by Fred Dumas (Permian Basin Sample Laboratory) provided the basic lithostratigraphic control, and the generally good cuttings were used to spot check formation tops. Unfortunately, the wire-line logs have not been released yet.

Biostratigraphic determinations in the Grimm well were obtained recently from A.S. Murer and R.A. Wetherhead of Mobil Producing Texas & New Mexico, Inc. Tertiary, Cretaceous, and Jurassic determinations with palynomorphs were made by J.E. Gerhard and those with foraminifers and other microfossils were made by D.J. Gauger, both of Mobil Field Research Laboratory. Permian and Pennsylvanian determinations with fusulinids were made by R.V. Hollingsworth of the Paleontological Laboratory. Appreciation is expressed to Mobil and the individuals involved for permission to publish this important information.

The interval between 5,880-12,100 ft in the Grimm well contains reddish brown mudstones, sandstones, and conglomerates; it is correlated tentatively with the Lobo. The interval between 12,100-13,000 ft contains brownish gray mudstones, sandstones, and carbonaceous material with palynomorphs dated as Late Paleocene to Early Eocene. This age determination provides the first evidence that the Lobo (= Love Ranch) may be no older than Early Tertiary in the Doña Ana County area.

The interval between 13,300-14,100 ft contains sandstones and gray to black mudstones; it is designated as Sarten (Lower Cretaceous). Palynomorphs, foraminifers, and ostracods indicate an Albian to Cenomanian age. An unnamed Jurassic section is designated between 14,100-15,550 ft; it contains black mudstones, dark limestones, and sandstones in the upper part. Palynomorphs indicate an Oxfordian-Callovian age between 14,100-14,250 ft, and arenaceous foraminifers indicate a Jurassic age between 14,120-14,450 ft and at 15,130 ft. The dark aspect of these rocks, and the lack of a distinct lithostratigraphic break across the subtle unconformity (where the lowermost Cretaceous and uppermost Jurassic are missing), suggest that they were deposited in a deep-marine environment within the Chihuahua trough.

A tentative top of the Hueco is placed at 15,550 ft, but it may be as high as 15,270 ft at the top of the crinoidal limestones. Wolfcampian fusulinids were determined between 15,680-19,080 ft. Magdalena (Pennsylvanian) is designated between 19,080-20,560 ft and consists of limestone, chert, sandstone, and mudstone. Missourian (Canyon), Desmoinesian, and Derryan (Atokan) fusulinids were determined between 19,120-20,510 ft. Tops of older Paleozoic units were based solely on lithostratigraphy. The well bottomed in Montoya (Ordovician) dolostones. Several shows of oil and gas were described by the mudlogger. Seven drill-stem tests were attempted, but none was completed.

The Pure No. 1 Federal H was drilled on the northeast side of the East Potrillo Mountains. Previous interpretations are discussed by Kottlowski and others (1969, p. 190-192) and by Thompson and Bieberman (1975, p. 174). In the

present investigation, cuttings and logs were used to determine the stratigraphic boundaries, but these results are preliminary. Because much of the well was drilled with air, the cuttings generally are too small for definitive lithostratigraphic analysis. Some of the larger chips could be the results of sloughing and may not be representative of the drilled intervals. A few core chips are available.

The Pure well appears to have been spudded in the oldest Lower Cretaceous unit mapped by Bowers (1960). He also mapped Hueco(?) limestones along the Basin and Range boundary fault. The interval from 625-3,850 ft appears to contain limestones, dolostones, cherts, and mudstones; it is designated as Permian? to Mississippian? undifferentiated. Fortunately, casing was set at 3,831 ft, and the cuttings down to 4,400 ft are relatively good. Dark, highly radioactive mudstones between 3,850-4,060 ft are inferred to be Percha, and the light, coarsely crystalline dolostones between 4,060-4,405 ft are inferred to be Fusselman. Both determinations should be checked with biostratigraphic evidence.

A reverse fault is inferred at 4,405 ft where circulation was lost in a possible fractured zone, and where the dipmeter shows an abrupt reversal from southeast above to northwest below. Cuttings again are poor below 4,600 ft, but the dominant carbonate section appears to be a repetition of the Permian? to Mississippian? undifferentiated unit. The abundance of clear calcite crystals beginning at 6,240 ft indicates that the lower part of the sedimentary section has been marbleized in contact with the Tertiary intrusive diorite below 6,815 ft.

A slight show of gas in the drilling mud was recorded between 4,380-4,400 ft. A drill-stem test from 4,354-4,412 ft recovered 3,480 ft of mud-cut water with a chloride content of 4,000 ppm. The spontaneous-potential curve shows a pronounced positive deflection through this interval, indicating invasion of meteoric water into the fault zone. This Pure well is another case illustrating the point that, in the Basin and Range province, uplifted areas tend to be flushed with fresh water.

REGIONAL ISOPACH MAPS

Kottlowski (1963) presented a series of regional isopach maps showing thicknesses of individual Paleozoic and Mesozoic units across southwestern and south-central New Mexico. Greenwood and others (1977) presented a similar series of maps covering southeastern Arizona, southern New Mexico, western Texas, and northern Mexico. Such overviews of stratigraphic units, especially if combined with delineations of depositional facies, are useful in regional projections of petroleum source and reservoir objectives.

In this short paper, only two isopach maps of southwestern New Mexico are presented — one each for the Paleozoic and Mesozoic. They provide the most basic step in analysis of the two most general stratigraphic units containing the significant petroleum source and reservoir objectives in the region. Exploration geologists may find them useful for gross estimates of: 1) burial history of source units, 2) distribution of source and reservoir units, and 3) drilling depths to test complete sections. They also

reflect generally the cumulative effects of tectonic uplift and subsidence.

Thicknesses of the *Paleozoic and Mesozoic* at the well locations in southwestern New Mexico were determined directly from the drilled intervals given in Table 2. True stratigraphic thicknesses of these gross units may be considerably less, especially where dips are appreciable. However, such corrections would be feasible in only those few wells where dipmeter surveys are available. Thicknesses of sills or other minor Tertiary intrusions generally were not discounted. Values shown at locations of Pemex wells in Chihuahua, Mexico were calculated from data in Thompson and others (1978, Table 4). Small areas of erosion sketched around wellsites are rough estimates in most cases and are shown to emphasize the fact that the unit is only locally thin or absent at that control point.

Thicknesses at surface sections were determined from publications and other sources listed under the Paleozoic and Mesozoic headings. Data range in quality from precise measurements to gross field estimates as reported by different workers. Most are totals of composite sections located in separate parts of a given mountain range. In some cases, such stacking of even precisely measured sections may result in a composite thickness that is not as representative of a single location as the uncorrected drilled interval in a well bore. Where a range of thicknesses was reported for a given unit, the maximum was chosen as long as it appeared reasonable in comparison with nearby control. Locations were placed at the top of the Paleozoic or Mesozoic sections to indicate where the reported thicknesses should be present in the subsurface. Some of the previously published sections contain errors of omission or duplication resulting from low-angle thrusts, which have been discovered in recent mapping (H. Drewes, personal commun., 1982).

The extent of local Quaternary erosion around the surface locations was not shown to avoid a cluttering effect on these small-scale maps, but it may be observed at the outcrops of Precambrian, Paleozoic, and Mesozoic rocks indicated on the geologic map of New Mexico by Dane and Bachman (1965). This map and others were used for regional control to determine key surface locations where the *Paleozoic or Mesozoic* are present or absent by non-deposition or erosion prior to Quaternary time.

Thickness data from other wells and surface sections immediately surrounding the map area were used to control the contour trends. The contour interval of 1,000 ft is considered small enough to show significant regional features and large enough to smooth over minor local variations.

PALEOZOIC

Figure 2 is a regional isopach map of Paleozoic strata in southwestern New Mexico. It confirms many of the regional thickness trends shown in the earlier version by Kottlowski (1963, Fig. 2). With the addition of several subsurface sections from more recently drilled wells, and of additional or better documented surface sections, the major features are more sharply delineated.

This isopach map includes all the units shown on Table 1

between the basal Paleozoic unconformity and the basal Mesozoic unconformity. At most places, both boundaries are considered to be accurately determined within 100 ft of section. In undisturbed sections, the only problems with the lower boundary are at locations where the basal Bliss sandstones are arkosic and differentiation with underlying Precambrian granite is difficult, especially in well cuttings. In the southeastern part of the map area, the upper boundary was determined with some difficulty within 200-300 ft of section because dark carbonates or mudstones of the Jurassic are superposed on similar rocks of the Permian.

Thicknesses shown at surface locations on this isopach map were determined from several sources. In Hidalgo County, they are Zeller (1965; measured 11,489 ft), Soule (1972; reported incomplete section of 3,465 ft), and Gillerman (1958; measured 5,643 ft). In Grant County, they are Cunningham (1974; measured 1,945 ft) and Pratt (1967; measured and estimated 3,269 ft). In Luna County, they are Jicha (1954; measured 2,274 ft), Kottlowski (1960a Pl. 13; measured incomplete section of 1,735 ft), Thorman and Drewes (1981, estimated 2,430 ft), and R.E. Clemons (current study; measured 1,565 ft and 3,720 ft). In southern Sierra County, the one is Jicha (1954; measured and estimated 1,824 ft). In Doña Ana County, they are Kelley and Silver (1952; measured 4,300 ft), Seager and others (1971; measured 425 ft), Kottlowski and others (1956; measured 7,130 ft), Kottlowski (1960b; measured and estimated 4,300 ft), and Seager (1973; measured incomplete section of 3,075 ft). In El Paso County, Texas, the one is Harbour (1972; measured 8,426 ft). In Chihuahua, Mexico, the one is Diaz and Navarro (1964; measured and estimated 10,675 ft). Estimated thicknesses are of nearly complete sections with additions from the nearest control.

Most of the formations in the Paleozoic are shallow-marine carbonate deposits. They generally were deposited over the entire region and are missing in most cases as a result of subsequent erosion. Unconformities within the Paleozoic are recognized at the bases of the Montoya, Percha, Horquilla-Magdalena, Earp-Abo-Hueco, and Scherrer-Glorieta. In this area, most exhibit low relief, and the hiatuses normally include only parts of the underlying units. However, at the basal unconformity of the Earp-Abo-Hueco, the entire Horquilla-Magdalena and older units locally have been eroded. Nevertheless, the depositional extent and preservation are documented by the fact that each key well drilled below the Mesozoic has encountered at least some part of the Paleozoic.

Where the Paleozoic thickness is greater than 5,000 ft, more complete Pennsylvanian-Permian sections are preserved. In the southern part of the map area, the Paleozoic attains a thickness of 15,000 ft, and the Pennsylvanian-Permian part is over 12,000 ft. Part of that thickening is attributed to the Pedregosa basin, a Pennsylvanian basin of subsidence (Kottlowski, 1960a). Similarly, in the eastern part of the map area, the Orogrande basin, another Pennsylvanian basin of subsidence, contributed to the thickening of the total Paleozoic to over 8,000 ft.

On the Moyotes ridge, uplift and erosion in mid-Wolfcampian time formed a boundary between these two

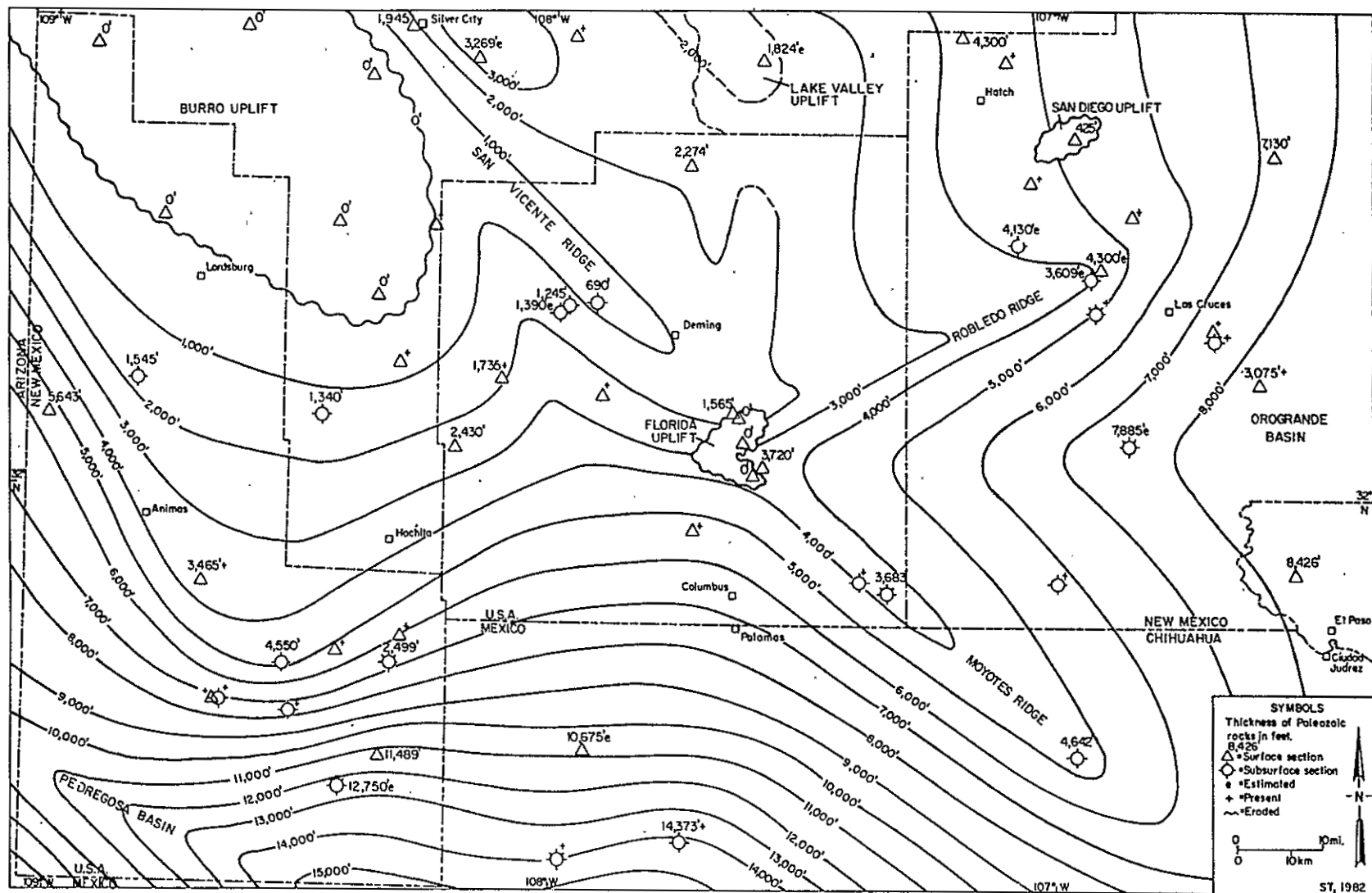


Figure 2. Paleozoic isopach map of southwestern New Mexico. The 1000-foot contour interval is considered small enough to show significant regional features and large enough to smooth over minor local variations and structural complexities.

Pennsylvanian basins. In the southeastern part of the Florida Mountains, Hueco rests unconformably on Lake Valley, and in the Pemex No. 1 Moyotes, Abo-Hueco rests unconformably on Precambrian. On the Burro uplift, in the northwestern part of the map area, the Paleozoic was completely eroded in Mesozoic time, as Beartooth (Cretaceous) rests unconformably on Precambrian (Elston, 1958). Laramide uplift and erosion, possibly along Precambrian shear zones, appears to be responsible for linear thinning of the Paleozoic on the San Vicente (to Moyotes) and Robledo ridges, as Lobo (or Love Ranch) rests unconformably on rocks as old as Lower Paleozoic. On the complex Florida uplift, at the intersection of the ridges, Lobo rests unconformably on Precambrian (R.E. Clemons, current study). On the San Diego uplift, Love Ranch rests unconformably on Lower Paleozoic rocks (Seager and others, 1971); it appears to be a local anomaly. On the Lake Valley uplift, Tertiary volcanic rocks rest unconformably on Lake Valley (Mississippian) (Jicha, 1954).

An isopach of the Bliss by Thompson and Potter (1981, Fig. 1) shows the paleotopography on top of the Precambrian. The most striking feature is the northeast-southwest trending crest of the ancestral continental divide extending across southwestern New Mexico (passing through the Hatch-Florida area). It also may follow a Precambrian shear zone. Because this feature is not evident on the total Paleozoic isopach, it apparently was not rejuvenated in post-Bliss time.

MESOZOIC

Figure 3 is a regional isopach map of Mesozoic strata in southwestern New Mexico. It includes all the units on Table 1 between the basal Mesozoic unconformity and the Laramide unconformity. It excludes some nonmarine sedimentary rocks and volcanic rocks of the uppermost Cretaceous.

Thicknesses shown at surface locations on this isopach map were determined from several references. In Hidalgo County, they are Zeller (1965; measured 9,969 ft), Zeller and Alper (1965; measured 7,619 ft), Gillerman (1958; measured and estimated 2,500 ft), and Elston (1960; measured 860 ft). In Grant County, they are Zeller (1970; measured and estimated 15,000 ft), Hewitt (1959; measured 1,160 ft), Edwards in Gillerman (1964, measured incomplete section of 273 ft), Cunningham (1974; measured 1,555 ft), and Pratt (1967; measured 1,755 ft). In Luna County, they are Jicha (1954, estimated 600 ft), and Kottlowski (1960a, Pl. 13; measured incomplete section of 800 ft). In Doña Ana County, they are Kottlowski and others (1956; measured 707 ft), Bowers (1960; measured incomplete section of 1,585 ft), and Lovejoy (1976; measured incomplete section of 1,361 ft). In Chihuahua, Mexico the one is Lovejoy and others (1980; measured incomplete section of 5,665 ft).

Note that Mesozoic rocks are shown as absent at the locality in the Tres Hermanas Mountains (northwest of Columbus). Kottlowski and Foster (1962) measured an incomplete section of 1,530 ft which they designated as Lower Cretaceous on the basis of a few poorly preserved pelecypods. At that stop on the 1981 field trip of the El Paso Geological Society, some of us observed that the dolo-

stones, limestones, and cherts resembled the Epitaph (Permian). A.C. Selby of ARCO Exploration Co. collected a sample and sent it to T.R. Carr who identified conodonts of Early Leonardian age. Appreciation is expressed to ARCO and the individuals involved for clearance to publish this important information.

Inferred depositional limits of the undifferentiated Jurassic, Bisbee Group (Lower Cretaceous), Sarten (Lower Cretaceous), and undifferentiated Upper Cretaceous are shown on the isopach. These limits provide explanations for some of the regional thickness patterns.

In the southeastern part of the map area, the depositional limit of the Jurassic lies within the Chihuahua trough of Navarro and Tovar (1975). In this trough, subsidence probably was more rapid than sedimentation, as the Jurassic black mudstones, dark limestones, and sandstones appear to have been deposited in a deep-marine environment. These basin-filling strata may onlap the bottom of the trough. The Jurassic ranges in thickness from 1,400 ft in the Grimm well to at least 4,800 ft in the Pemex No. 1 Sapallo, and possibly over 13,500 ft in the Pemex No. 1 Presidio.

The northern limit of the Bisbee Group trends nearly east-west across the middle of the map area. As described by Zeller (1965) in the Big Hatchet Mountains of Hidalgo County, the Bisbee is 9,969 ft thick and consists of three units: 1) Hell-to-Finish conglomerates and redbeds, 2) U-Bar limestones containing the distinctive orbitolinid foraminifers and rudist pelecypods in the upper part, and 3) Mojado sandstones and mudstones. These units generally are recognizable from the type area of the Bisbee Group in southeastern Arizona to western Texas where the succession corresponds approximately to the Trinity, Fredricksburg, and Washita of the Comanchean. A regional unconformity is evident at the base, but none has been documented within the Bisbee.

In the Hidalgo County area, the 10,000 ft or more in the Bisbee basin is projected from control in southeastern Arizona, as is the thin section on the Chiricahua ridge. The Little Hatchet basin may not contain the entire 15,000 ft estimated by Zeller (1965), but at least 10,000 ft are present. Regional thinning to the north appears to be mainly at the expense of the U-Bar, although the entire Bisbee appears to onlap an earlier Mesozoic highland.

In southern Doña Ana County and northern Chihuahua, different nomenclatures are applied to the Bisbee equivalents described by Bowers (1960) in the East Potrillo Mountains, by Lovejoy (1976) in the Cerro de Cristo Rey, and by Lovejoy and others (1980) in the Sierra de Juárez. This Lower Cretaceous section thickens to over 12,000 ft in the Pemex No. 1 Sapallo, after which the Sapallo basin is named.

The southern limit of the Sarten appears to trend northwest-southeast across the northern part of the map area (Fig. 3). At the type section in the Cooke's Range, the Sarten is about 300 ft thick and consists mostly of sandstone (Jicha, 1954, p. 26). It is late Albian to early Cenomanian in age (S.C. Hook, personal communication, 1982). The Sarten has been recognized also in the southern part of the San Andres Mountains (Kottlowski and others, 1956,

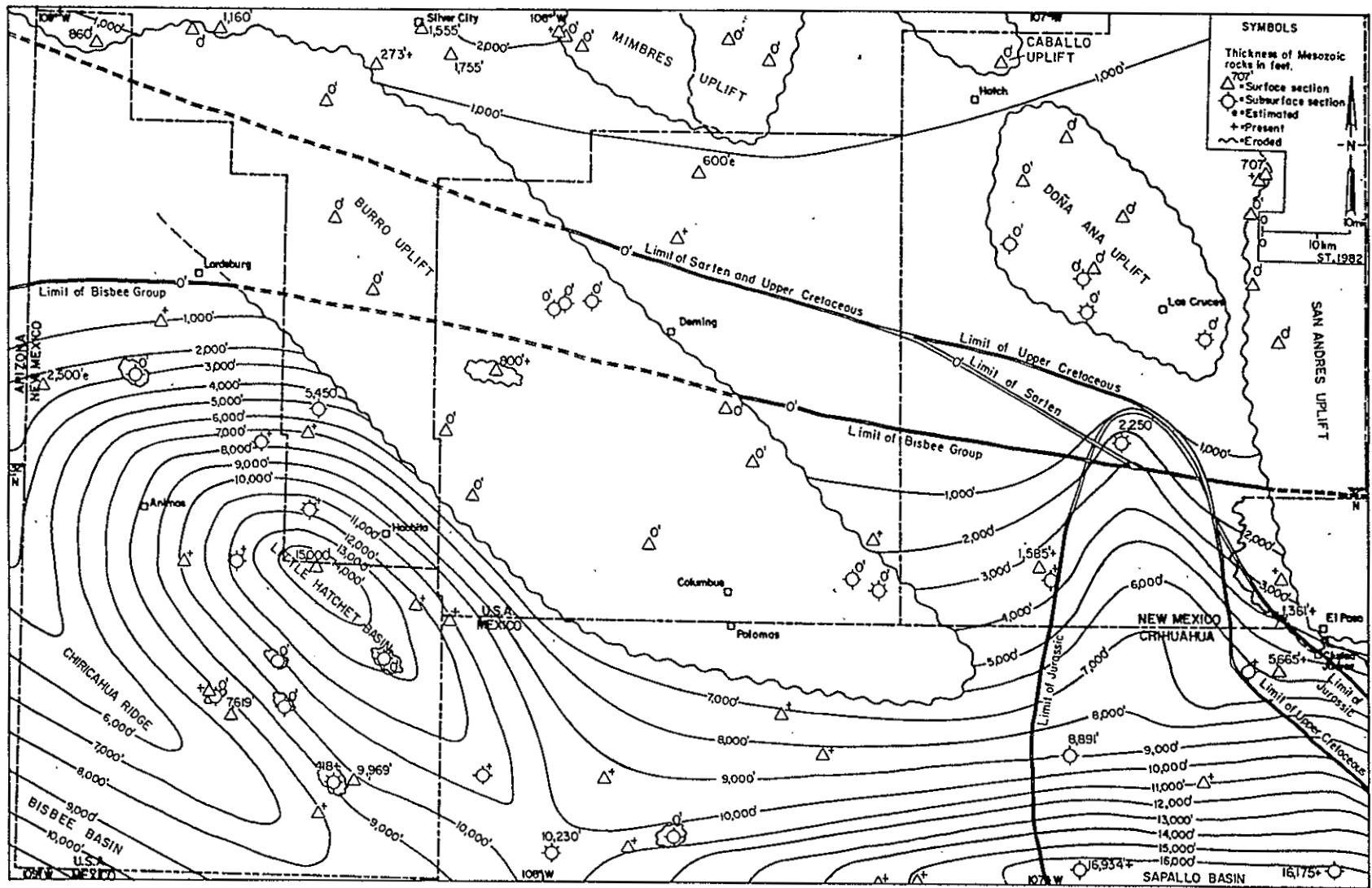


Figure 3. Mesozoic isopach map of southwestern New Mexico (includes the total thickness of units between the Laramide and basal Mesozoic unconformities).

p. 62-66; Seager, 1981, p. 33) and in the lower part of the Beartooth (unrestricted) in the Silver City area (Pratt, 1967, p. 42-44; S.C. Hook, personal communication, 1982).

The southern limit of the Sarten may represent onlap on the northern side of an earlier Mesozoic highland trending west-northwest to east-southeast through the Deming area. Alternatively, the Sarten may be a northern extension of the upper Mojado; they are similar in lithofacies and both contain the diagnostic foraminifer *Haplostiche texana* (Zeller, 1965, p. 68, and S.C. Hook, personal communication, 1982). As such, the Sarten would represent the last unit in a northward onlapping Lower Cretaceous succession of Hell-to-Finish, U-Bar, and lower Mojado. The northern limit of the Sarten lies around the northern boundary of the map area (Fig. 3). Its absence in the Deming area would then be explained as a result of subsequent erosion.

Recognition of Sarten in the Grimm well extends its previous usage to the south and lends support to the alternative interpretation of an upper Mojado extension. If later evidence confirms this relationship, the southern limit of the Sarten would not be a depositional limit but only an arbitrary cutoff between Sarten and Mojado (Bisbee Group).

The southern limit of undifferentiated Upper Cretaceous also trends generally northwest-southeast across the northern part of the map area (Fig. 3). Included are deltaic-marine, sandstone-mudstone units called Beartooth (restricted)-Colorado (Pratt, 1967, p. 42-44) or Dakota-Mancos (Kottlowksi and others, 1956, p. 66-68; Seager, 1981, p. 33-34); they are equivalent to the Woodbine-Eagle Ford of Texas (Hayes, 1970, Fig. 5). The upper part of the Colorado contains nonmarine sandstones and mudstones which probably are equivalent to the Mesaverde. The unconformity between the Sarten and Beartooth (or Dakota) occurs within the Cenomanian; other unconformities are documented within the Turonian part of the Colorado (Hook and Cobban, 1981; and S.C. Hook, personal communication, 1982). Together, the Sarten and the Upper Cretaceous units are less than 2,000 ft thick in the northern part of the map area.

The Upper Cretaceous limit curves southward as a result of absence in the Grimm well and presence in the Cerro de Cristo Rey and Sierra de Juárez. In those two surface sections, the Upper Cretaceous is called Boquillas Formation and consists of 360 ft of dark mudstones and thin limestones; it is Cenomanian to probably Turonian in age (Lovejoy, 1976, p. 20; Lovejoy and others, 1980, p. 27).

These Upper Cretaceous rocks are absent over a large area covering southwestern New Mexico, southeastern Arizona, and northern Mexico (Hayes, 1970, Fig. 5). The southern limit shown on Figure 3 may represent a depositional boundary with southwestward onlap onto a low-relief land area. Alternatively, this limit may represent an erosional boundary with the onlap boundary lying originally an unknown distance to the southwest; however, it is likely that such a distance was less than 100 mi, because at least one remnant section should have been preserved if the distance had been greater.

In any case, between the time of U-Bar deposition (Aptian-early Albian) and that of the Upper Cretaceous units

(late Cenomanian-Turonian), positions reversed from land on the north and sea on the south to land on the southwest and sea on the northeast. The uplift of the southwestern area probably was associated with the northeastward migration of the Cordilleran magmatic arc (Damon and others, 1981). During continued migration in Laramide time, the sea finally withdrew from the region.

Laramide uplift and erosion stripped Mesozoic and older rocks from much of the Burro and other uplifts shown on Figure 3. The remainder was eroded in Cenozoic time. Upon the Laramide unconformity, conglomerates and redbeds were deposited, followed by andesitic volcanic rocks. The Ringbone-Hidalgo succession in Hidalgo-Grant Counties is uppermost Cretaceous (Campanian-Maestrician) in age (Hayes, 1970, Fig. 5; Marvin and others, 1978, Table 1, sample A); the Lobo-Rubio Peak and Love Ranch-Palm Park successions in Luna-Doña Ana Counties are lower Tertiary (Paleocene-Eocene) in age (this paper, Grimm well; Seager and others, 1975, Table 1; and R.E. Clemons, personal communication, 1982). These relationships of decreasing age to the northeast also reflect the migration of the Cordilleran magmatic arc in Laramide time (Damon and others, 1981).

CONCLUSIONS AND RECOMMENDATIONS

Paleozoic and Mesozoic strata of southwestern New Mexico and adjoining areas contain several petroleum source and reservoir units. In Hidalgo-Grant Counties, the source units appear to have generated abundant gas and moderate amounts of oil (Thompson, 1981). The best reservoir objective in that area is the upper Horquilla (Pennsylvanian-Permian), which contains thick porous dolostones at the margin of the Alamo Hueco basin, a deep-marine basin lying within the Pedregosa basin (Thompson and Jacka, 1981). Documentation of source and reservoir units is continuing in that area and adjacent parts of southwestern New Mexico. Projection of these objectives into subsurface prospects is directly dependent upon the accuracy of the stratigraphic-sedimentologic framework.

Documentation of lithostratigraphic and biostratigraphic boundaries in the Paleozoic and Mesozoic has progressed well, but some surface sections and many subsurface sections need additional control before detailed isopach-facies maps of individual units can be made with a high level of confidence. Continuing studies of biostratigraphy, paleoecology, and microfacies by D.V. LeMone and his students, at the University of Texas at El Paso, are adding much of the needed control.

In the Paleozoic, the Cambrian-Ordovician-Silurian units were deposited over a broad shelf, so their regional facies problems are minimal. Some changes are evident in the Devonian, but the Mississippian shows major differentiation into shelf, margin, and basin facies which need accurate delineation. Similar major facies changes are evident in the upper Pennsylvanian-lower Permian; their regional delineation has important economic significance regarding projection of the porous dolostones in the margin facies. Additional documentation of the deep-marine deposits in the Pedregosa and Orogrande basins is needed; the southern terminations of these basins may form a

rift-rift-rift triple-junction relationship with the Marfa basin, similar to that shown by Elam (1982) for the Marfa-Delaware-Valverde basins in western Texas.

In the Mesozoic, the recently discovered Jurassic unit in the Grimm well prompts re-examination of other sections in the region which contain the Paleozoic-Mesozoic boundary to see if equivalent units are present elsewhere. The concept that the Jurassic is confined to deep-marine deposits in the Chihuahua trough should be examined critically. The Lower Cretaceous of the Little Hatchet Mountains (discussed by Zeller, 1970) needs to be measured and described in detail, but the problem is complicated by multiple thrusting. Northward onlap of the Bisbee Group should be documented with seismic sections. Especially important is the relationship between the upper Mojado and Sarten; were they separated by a barrier, or were they a continuous part of the northward onlap? Analyses of depositional environments and paleocurrents may help resolve this question. Similar studies may document the southwestward onlap of the Upper Cretaceous. Results of these studies will be useful to exploration by delineating unconformity traps along the onlapping edges of these sandstones. Stratigraphic-sedimentologic work on selected Cretaceous units is being done by H.S. Chafetz at the University of Houston, G.H. Mack at New Mexico State University, and their students.

Important aspects of Laramide history may be deciphered by investigation of: 1) Precambrian, Paleozoic, and Mesozoic trends; 2) the Laramide unconformity itself, and 3) the Lobo and correlative units overlying the unconformity. As shown on the Bliss isopach (Thompson and Potter, 1981, Fig. 1), the northeast-southwest trending crest of the ancestral continental divide formed on top of Precambrian basement is relatively continuous across southwestern New Mexico. This continuity constrains the amount of any subsequent lateral offset by tear or wrench faulting to a few tens of miles or less. Other depositional or erosional trends in Paleozoic and Mesozoic rocks also appear to be relatively continuous. Some workers have ignored such evidence in their tectonic interpretations involving offsets of many tens to hundreds of miles. On the regional isopach map prepared for this paper, no major lateral offsets are indicated, but some may be documented with more detailed study.

Subcrop and supercrop maps of the Laramide unconformity would show the extent of erosional truncation below and the depositional relief above that important surface. A narrow trough several thousand feet deep filled with conglomerates and redbeds of the Lobo appears to trend east-southeast from the three key wells west of Deming at least to the Grimm well. This trough may be a graben along the crest of a Laramide uplift, or it may mark the down (north) side of a major fault — reverse, normal, or mainly strike slip.

Laramide thrusting is evident at many localities in the region. Interpretations of regional overthrusts with hundreds of miles of displacement remain controversial. The alternative explanation of thrusts rising upward and outward from wrench zones should be considered (Thompson, 1980, p. 210). Moreover, the potential for preservation of

petroleum beneath either types of thrusts appears slim. In the KCM No. 1 Cochise State A, kerogens in the Mojado have reached a high degree of thermal alteration beyond the limits of oil preservation, and in older units even gas may not be preserved. This section probably was buried by the major thrust fault seen in the Hidalgo County area (Thompson, 1981, p. 41).

Studies of the Cenozoic rocks also are useful to petroleum exploration. An isopach map of all the units above the Laramide unconformity, in combination with those of the Mesozoic and Paleozoic, would give a complete summary of the burial history of the region and provide a means of estimating drilling depths to Precambrian basement. Locations of volcanic centers, ash-flow tuff cauldrons, and the thicknesses of outflow units in the Tertiary and Quaternary are important considerations. Volcanologists working in southwestern New Mexico include: 1) in the Hidalgo-Grant Counties area, W.E. Elston and students at the University of New Mexico; 2) in the Luna-Doña Ana Counties area, R.E. Clemons and W.R. Seager, at New Mexico State University, and 3) in the southern parts of Luna County, Doña Ana County, and adjacent Texas, J.M. Hoffer and students at the University of Texas at El Paso, who also are analyzing drill cuttings and cores of volcanic rocks in several wells. Structure-contour maps on tops of the Precambrian, Paleozoic, and Mesozoic would complement the set of isopach maps and provide basic data for a regional tectonic-stratigraphic synthesis. With continuing improvements over the entire spectrum from surface mapping to subsurface analysis, a comprehensive geologic framework can be developed for increased proficiency of petroleum exploration in southwestern New Mexico.

Within the next few years, several operators plan to drill additional exploration wells. For thorough evaluation of the prospects, adequate drilling programs should be planned to: 1) obtain good cuttings for lithostratigraphic (and biostratigraphic) analyses over the entire section drilled; 2) employ hydrocarbon loggers to watch for oil and gas shows around the clock; 3) collect canned cuttings for source-rock analyses; 4) cut cores of major source and reservoir units; 5) run drill-stem tests on any reservoir encountered, with or without a show of oil or gas, to measure subsurface pressures and provide samples of hydrocarbons or formation waters for analyses; and 6) run a full suite of first-class wire-line logs. Such a complete program is expensive, but considering the great sums of money currently being spent on leasing, geophysics, and the basic drilling costs themselves, the acquisition of essential subsurface data should be given adequate consideration within the total investment plan. Not only will such programs provide every chance for success on individual prospects, but also they collectively may determine whether or not southwestern New Mexico will become a productive petroleum province.

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