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PETROLEUM PROSPECTS IN SOUTHWESTERNMOST NEW MEXICO

By

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INTRODUCTION

Southwesternmost New Mexico involves Hidalgo County and parts of Luna County and Grant County. This region is accessible via Interstate Highway 10, U.S. Highways 70 and 80, via N.M. State Highway 81, and N.M. State Highway 338 from Lordsburg. State Highway 9 crosses the southern part of the county. East to west, via Hachita, State Highway 79 connects the Geronimo Trail from Rodeo with Antelope Wells on the east.

From west to cast, the main north-trending physiographic units are: Peloncillo Mountains, Animas Valley, Pyramid Range, Animas Mountains, Playas Valley, Big and Little Hatchet Mountains, Alamo Hueco Mountains, and the Hachita Valley. Lesser ranges include the Sierra Rica, Apache, Cedar, Victorio, Carrizalillo, Tres Hermanas, Florida, and Cooks Ranges.

Geologically the region lies on the north flank of the Sonoran geosyncline (pre-Pennsylvanian) south and southwest of the Burro-Florida tectonic alignment and on the northeast flank of the Pedregosa basin (Pennsylvanian and Permian), on the north flank of the Mexican geosyncline (early Cretaceous), and within the Cretaceous-Cenozoic intrusive-extrusive province of the southwestern United States and northern Mexico.

A part of the Mexican Highlands in the Basin and Range province, this region may also be considered by some to be a northern extension of the Mexican Mesa Central between the Sierra Madre Occidental and Oriental. Tectonically it falls into the Sonoran-Chihuahuan part of the Basin and Range system and is the locale of intersection of the north-trending Cordilleran Mountain system and the older west-trending Ouachitan-Sonoran tectogenic system. As such, its geologic history is interestingly complex as a future petroleum province.

The writer in indebted to Robert A. Zeller, Jr., for his critical study of this region and for months of cooperative commercial work; to Frank Kottlowski for hours of discussion, cooperation in supplying specific data, and his many excellent publications on the geology of New Mexico; to Lee Kilgore for releasing certain photogeologic data on parts of the region which my associates and I did not analyze via air photography; to John H. Matkin, formerly Vice President of Kern County Land Company, and Darrow Thompson, President of Thompson International Corporation for financial backing in the study of southwestern New Mexico since 1958 and for release of geologic information; to Ty Tannich of Lower Diamond A Ranch for his enjoyable humor and expert guidance during the weeks of early field work in the region; to Joseph Nelms for expert drafting; and certainly not least to Florence Mather Wengerd for typing of the manuscript and aid in compiling data from many sources.

An explanatory note: As an experiment in publication I have provided a detailed bibliography of articles published since 1950 with no specific references in the text; in addition, I have sought to provide detailed explanation of each figure in order to make it an entity without breaking the text with references to the figures.

REGIONAL EVENTS

For purposes of tabulation, southwesternmost New Mexico may be divided into three parts: North—between T. 26 S. and T. 28 S.; Central—between T. 29 S. and T. 31 S; South—between T. 32 S. and T. 34 S., inclusive. This simple division, however, crosses obliquely the tectonic northwest trends of the Florida shelf, the Alamo-Hueco shelf slope, and several subsidence axes of the Pedregosa basin.

This region was high shelf to basinal throughout those periods when marine strata were being deposited and stood low, but above sea level, for critical lengths of geologic time between marine invasions. The following tabulation of the regional events integrates the regional structure into a sequential pattern of sedimentational and igneous events. The table is designed to show regional movement and the resulting position of the region with relation to the sea during each geologic period. Many of the listed events are questionable, yet each event listed above the preceding events may have had an important effect on the results of previous regional movements.

Late Pennsylvanian and late Permian wrenching movements are surmised based on analogous abrupt scdimentational variations known to exist on the west side of the Paradox basin. More drilling is needed here to prove the concept that, although the Florida islands may indeed have been a sediment-controlling archipelago in early Pennsylvanian time, the Florida block may have moved up and southeastward along at least two major subparallel major wrench faults activated in Virgil time and rejuvenated in late Permian time.

The remainder of post-Permian time saw almost complete tectonic disintegration of the region with Laramide thrust faulting, folding, and some volcanism and granitic intrusion, succeeded by high-order mid-Tertiary normal faulting to form the Basin and Range structure interlarded with Cascadian intrusion and extrusion of rhyolitic and andesitic rocks. Mineralization of the region probably occurred during Cretaceous and Tertiary orogenic events.

Note that where Late Cretaceous marine sedimentary rocks are not present, we may conclude that rather sharp

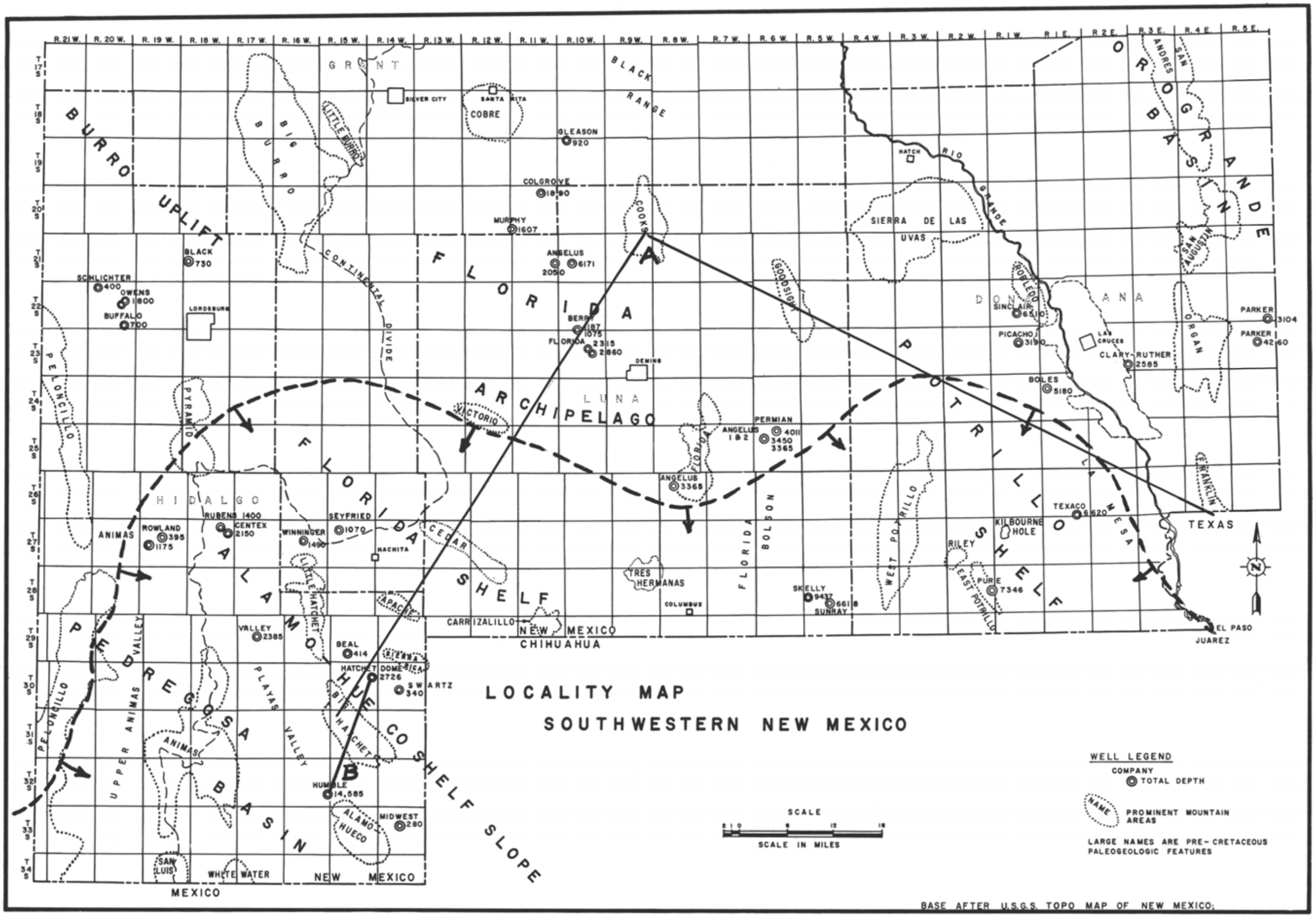


FIGURE 1.

Locality map—southwestern New Mexico—showing the traces of the Regional Cross Section A (Figure 2), and the Regional Cross Section B (Figure 4). The region of major stratigraphic oil potential is interpretive based on paleogeologic factors involving the north shelf of the Sonoran seaway extending from the Pedregosa sag (basin) on the west, around the southeast end of the Florida uplift, and across the Potrillo shelf (see Wengerd, 1969, p. 199-201) on the east. This article is concerned with the west half of this mega-shelf, particularly the Florida shelf, the Alamo-Hueco shelf slope, and the Pedregosa basin. The best oil potential in this area lies in Permian and Pennsylvanian strata with high gradients of facies gradation.

TABLE 1. REGIONAL EVENTS—SOUTHWESTERNMOST NEW MEXICO

GEOLOGIC TIME	NORTH	CENTRAL	SOUTH
Recent	Continued faulting & alluviation	Same as North	Same as North
Pleistocene	Vast alluviation of valleys, continued faulting, intense volcanism, regional uplift.	Vast alluviation, continued faulting, some volcanism, regional uplift.	Vast alluviation, continued faulting, traces of volcanism, regional uplift.
Tertiary	Block faulting, regional uplift, deep erosion, filling of grabens, much volcanism.	Same as North	Same as North
Late Cretaceous	North to northeast tilt, high shelf clastic and some carbonate deposition, widespread erosion after severe orogeny, volcanism.	Very high shelf to swamp & alluvial clastics, severe orogeny & widespread erosion.	Perhaps some alluvial deposits, but mainly great local orogeny succeeded by deep erosion.
Early Cretaceous	Widespread & deep erosion, continental deposits interfingering with high shelf carbonates & clastics from north; south tilt. Four depositional cycles, regional uplift with some non-marine deposition.	Mid-shelf to low shelf & basinal with widespread reef growth in 2 to 4 depositional cycles. General E-NE tilt, regional uplift but local continental basin subsidence; filling by clastics.	High to mid-shelf with widespread fringing reefs, deposition of thick non-marine & marine clastics interfingered. General uplift with NE tilt.
Jurassic Triassic	Regional uplift & widespread erosion.	Same as North	Same as North
Late Permian	Uplift and some wrench faulting.	Same as North	Uplift and erosion.
Early Permian	Continued high shelf carbonate, back reef, followed by red clastic invasions from NE & NW, & widespread erosion succeeded by high shelf seas with clastic deposition.	Mid-shelf to reefing on break-in-slope, invasion by red clastics as region lifted; SE tilt & invasion of mid-shelf carbonate-depositing seas.	Low shelf to shelf break-in-slope, tilt to SE as uplifted & some red continental clastics invaded seas. Subsidence to low shelf seas invading from SE.
Late Pennsylvanian	Northwest trending wrenching along NE & SW sides of Florida uplift.	Clastic shelf deposition SW of Florida uplift.	Low shelf to basinal deposition of carbonates and shale.
Pennsylvanian	Widespread erosion, S & SW tilt, high-shelf marine carbonate clastic deposition with numerous disconformities both marine & subaerial.	Some erosion; SW tilt, shifting shelf break-in-slope with reef growth in carbonate-depositing seas.	Some erosion, S to SW tilt, marine basinal to low shelf deposits of carbonates with thick basinal shales.
Mississippian	Highly irregular deep erosion, subsidence, SE then SW tilt, high shelf to midshelf to high shelf.	Moderate erosion, S tilt then SW tilt as seas encroached to deposit mid-shelf carbonates.	Slight erosion, SE tilt then SW tilt, with low shelf then high shelf marine carbonate deposition.
Devonian	Subsidence, invasion of mud-depositing high-shelf seas.	Subsidence, invasion of mud-depositing mid-shelf seas.	Subsidence, invasion of mud-depositing low-shelf seas.
Silurian	Uplift, deep erosion to peneplain, NE tilt.	Same as North	Same as North
Ordovician	Same as below, mid-shelf, uplift, erosion, subsidence to high shelf.	Same as North	Same as North
Cambrian	Subsidence, S tilt, brief marine invasion, high shelf.	Subsidence, SE tilt, brief marine invasion, high shelf.	Subsidence, E tilt, brief marine invasion, high shelf.
Precambrian	Orogeny-epeirogeny-peneplanation.	Same as North	Same as North

NOTE: Read "upward" in geologic time, but notations for each period should be read downward.

epeirogeny graded into the localized orogenic tectonism of the Laramide to form the strongest folds and thrust faults in the region.

All Tertiary and Quaternary sediments are closely related to block-faulting and igneous activity, and it is this geologic episode which probably destroyed some of the petroleum potential over more than 50 percent of the area of southwesternmost New Mexico.

STRUCTURAL AND IGNEOUS CONTROLS ON PETROLEUM EXPLORATION

Structure is one of the major limiting factors in possible petroleum occurrences in southwesternmost New Mexico. Laramide and late Paleozoic folding no doubt created anticlines which may have served as the most obvious structural traps; however, Laramide overthrust sheets may have masked such anticlines. Thus, an anticline which crops out may be cut off in the subsurface, or an overthrust sheet may conceal anticlines under it. Later high-angle faults cutting across anticlines may act as either channels or barriers to the dysmigrational escape or up-section transmigration of hydrocarbons. If such late normal faults served as channels, oil or gas may be found in any porous beds which overlie source beds, including Tertiary volcanic rocks. If the faults serve as barriers, they may seal the ends of anticlines and form combination anticline-fault structural traps.

Basin and Range deformation does not appear to reflect older structure and therefore should be used with considerable reservation as a guide to finding older deeper structures. Had broad gentle folds been formed during Basin and Range deformation, they would naturally have been impressed upon the older deeper rocks and structures, but the effect of such gentle folding upon intensely folded pre Laramide rocks is negligible. Thus, a gentle anticline in Tertiary rocks could be underlain in pre-Tertiary rocks by a hodgepodge of intense earlier structures including synclines, overthrusts, or overturned folds. Basin-and-Range type deformation is still active in the region, and there are places where valley fill has recently been raised slightly due to minor folding or movement along buried faults. Inasmuch as Basin-and-Range structure may not reflect earlier structure, such uparching of alluvium is considered by some geologists to be of little importance in reflecting Laramide and earlier structures.

Basin-and-Range block faulting has elevated the mountain blocks and depressed the valley blocks along generally north-south trends. Individual mountain blocks have been elevated by different amounts with respects to other mountain blocks which results in exposure of rocks of different ages in the different ranges. Also, within each mountain block some parts have been arched upward more than others resulting in exposures of older rocks. Depressed valley blocks undoubtedly have also been depressed by variable amounts. Laramide structures where exposed in mountain blocks are complex; hence the Laramide structures underlying the valleys may also be complex. Superimposed upon the Laramide structures are the Basin-and-Range structures, and these later high-angle normal faults further complicate the structures in older rocks.

It is pure surmise that there appears to have been little strike-slip movement on Basin and Range normal faults which separate the mountain and valley blocks. If no wrenching occurred, however, Laramide structures of the mountain blocks should pass into the valley blocks along the same trends. There is no reason to believe that thick sections of Tertiary volcanic rocks do not overlie important traps in the pre-Tertiary sedimentary rocks in some parts of the broad valleys. Inasmuch as elevation of the mountains and depression of the valleys seems to have started during formation of the Tertiary volcanic rocks, the volcanic rocks of the valleys should be interbedded with alluvium.

An estimation of the thickness of alluvial fill in a particular place may be made by observing such factors as whether the area is in a mountain or valley block, whether it is on the east or west side of a valley, and whether bedrock is exposed nearby or is found in nearby water wells. In Animas Valley, alluvial fill is probably moderately thick along the entire eastern side and thin along the western side. In Playas Valley, alluvial fills are thin along the western side and moderately thin on the northern and southern ends.

The valley fill probably thickens progressively toward the west sides of the Big Hatchet and Little Hatchet Mountains where the fill has its maximum thickness. The thickness of Tertiary volcanic rocks in the valleys may be estimated by identification of the volcanic formations where exposed in mountain blocks. The rocks range up to 8000 feet or more in thickness, but in many places erosion has removed the upper beds hence the present preserved thickness in the mountains may be much less than may be found by drilling in the valleys.

In petroleum exploration of any region, the deleterious effects of igneous rocks on potential oil or gas accumulations must be considered. Tertiary volcanic rocks which blanket much of the region and which probably covered the entire region at one time are mostly pyroclastic. The source of much of the volcanic rock was probably outside the region. However, granite intrusive masses in Granite Gap in the Little Hatchet Mountains and north of Gillespie Peak in the Animas Range were probably related to the Tertiary volcanics. Also, intrusive andesite southwest of Gillespie Peak and in parts of the Peloncillo Mountains is related to the Tertiary volcanics. Halos of metamorphism surrounding these areas eliminate them as potential petroleum areas. Elsewhere in the region where Tertiary volcanic rocks have been removed by erosion, the underlying older rocks are not metamorphosed, and they may contain commercial oil and gas, as indicated by shows encountered in tests drilled in Hidalgo County.

Andesite flows interbedded with lower Cretaceous rocks have not affected underlying rocks. In the areas of the vents from which these rocks flowed, small halos of metamorphism would be expected, but no such vents have been found. Throughout the region rare small dikes of basalt are found cutting older rocks, but metamorphism extends only a few inches from the contacts.

Across the central part of Hidalgo County there is a west-northwest-trending belt of presumably Laramide intrusive latite, monzonite, and quartz monzonite. Such intrusives are found in the north end of the Sierra Rica, in the Apache Hills, in the central part of the Little Hatchet Mountains, in the north-central part of the Animas Mountains, and north of Granite Gap in the Peloncillo Mountains. Metamorphic halos around these intrusives extend for a radius of up to one mile, and the heat from these masses may have driven the hydrocarbons from the sedimentary rocks over a much greater radius. Petroleum exploration along the trend of this belt would be unwise, although there may be areas within the belt between intrusives that were unaffected by thermal metamorphism.

EROSION SURFACES AND STRATA (altered after Wengerd, 1969, p. 203-204)

Several erosion surfaces in the stratigraphic column of southwesternmost New Mexico are the result of epeirogenic uplift to subaerial erosion after a cycle of carbonate deposition. There appears to be northward gradation of the Pennsylvanian carbonates into medium-grained quartzose and arkosic elastics on the Florida shelf and southward gradation into fine-grained bituminous limestone and dark gray shale on the Alamo-Hueco shelf slope. The porous shelf elastics probably exerted a control on the groundwater dissolution of carbonate facies of equivalent age while the area underwent episodic subaerial erosion. In addition many submarine disconformities exist which have not been detected, and these may have been responsible for intra-stratal solution which increased intercrystalline and intergranular porosity created upon or closely subsequent to deposition.

There are very few thick elastic lentils in the sections on the Alamo-Hueco shelf slope; hence, it may be inferred that this area and its provenance never stood much more than a few hundred feet above sea level until Late Cretaceous time. Ground water generally has dissolutionary effects only to and slightly below sea level and, inasmuch as

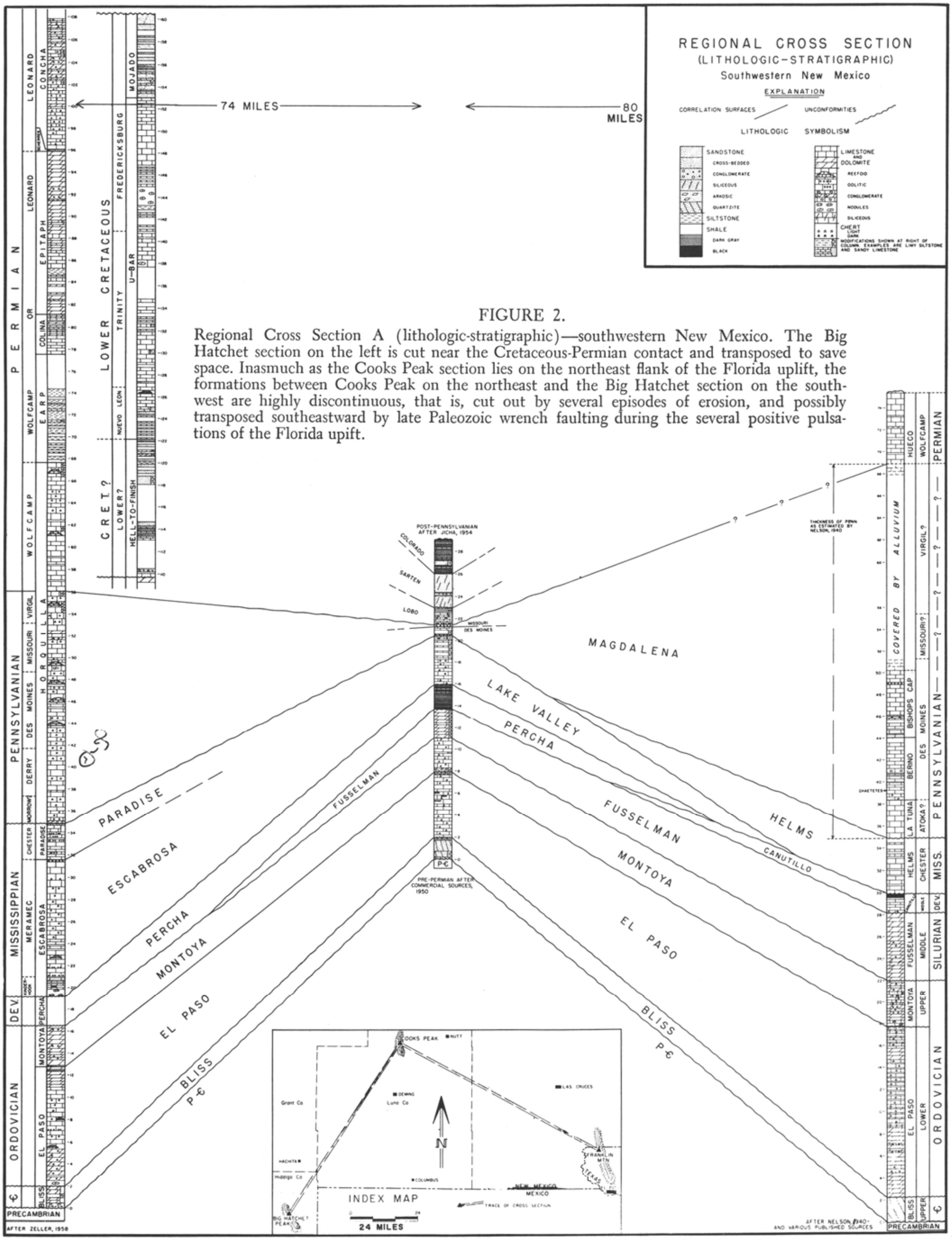


FIGURE 2.

Regional Cross Section A (lithologic-stratigraphic)—southwestern New Mexico. The Big Hatchet section on the left is cut near the Cretaceous-Permian contact and transposed to save space. Inasmuch as the Cooks Peak section lies on the northeast flank of the Florida uplift, the formations between Cooks Peak on the northeast and the Big Hatchet section on the southwest are highly discontinuous, that is, cut out by several episodes of erosion, and possibly transposed southeastward by late Paleozoic wrench faulting during the several positive pulsations of the Florida uplift.

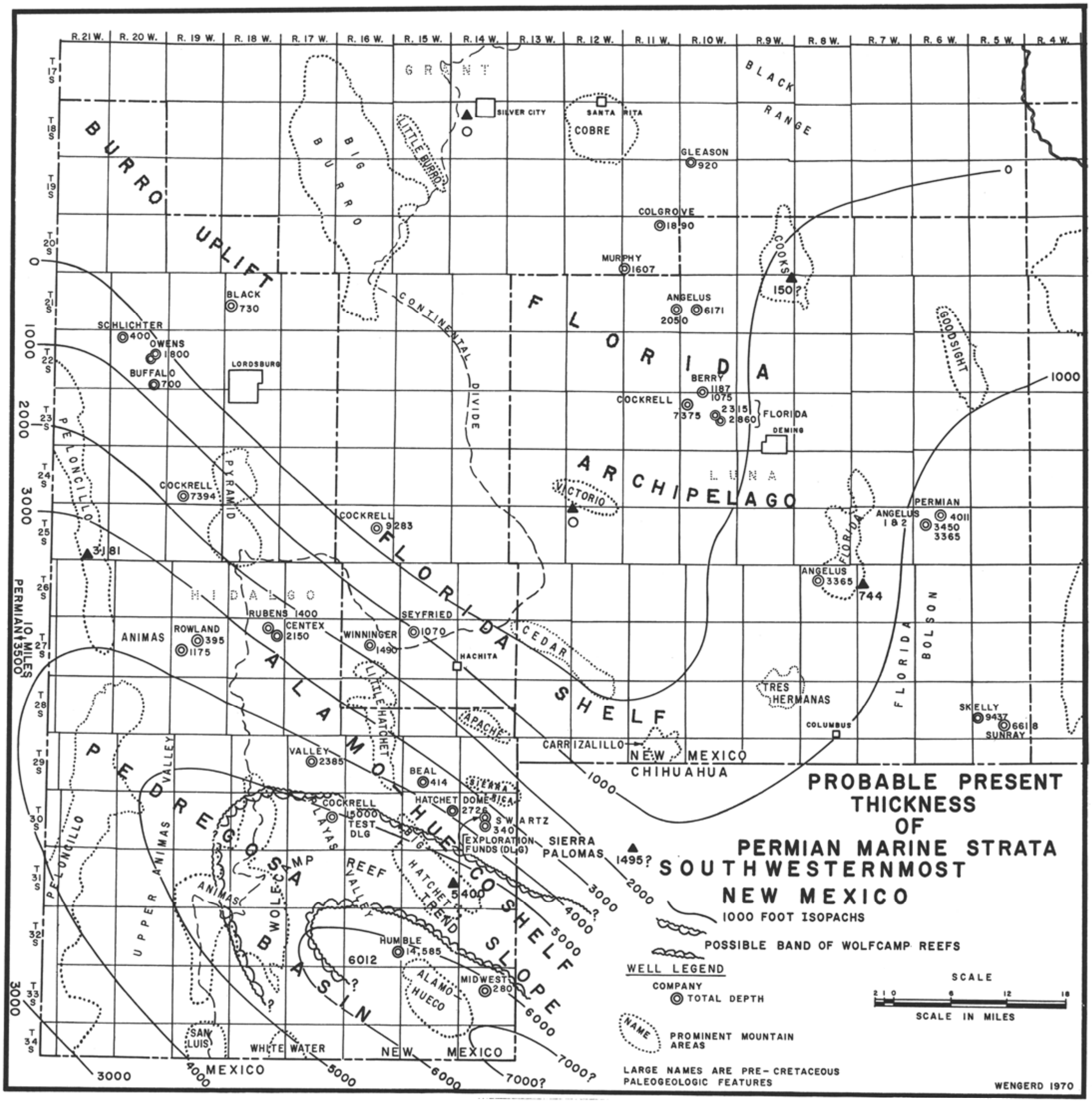


FIGURE 3.

Probable present thickness of Permian marine strata, southwesternmost New Mexico. Thickness variations in Permian strata are no doubt much more complicated than indicated on this map because Holocene, Quaternary, and Tertiary erosion, in response to block-faulting and uplift, has stripped Permian rocks from certain locales. In addition, nonmarine facies were deposited from westerly, northerly, and easterly sources to interfinger with marine Permian. Much of the record of such marine-nonmarine interfingering has been destroyed by Mesozoic uplift of the Burro positive, and a renewed Mesozoic uplift and erosion of the late Paleozoic Florida positive area which may originally have been an archipelagic sediment source during Pennsylvanian time. Until more deep wells are drilled, such as those by the undaunted and brave Cockrell Corporation, much of our interpretation of the complicated interplay of tectonic activity and sedimentation from Pennsylvanian to Cretaceous time must be surmise. Specifically, this map indicates concepts of the configuration of the Permian basin of deposition as developed by Zeller and the writer, showing also an interpretation of the late Horquilla reef trends as they might exist where Permian strata are present in the subsurface.

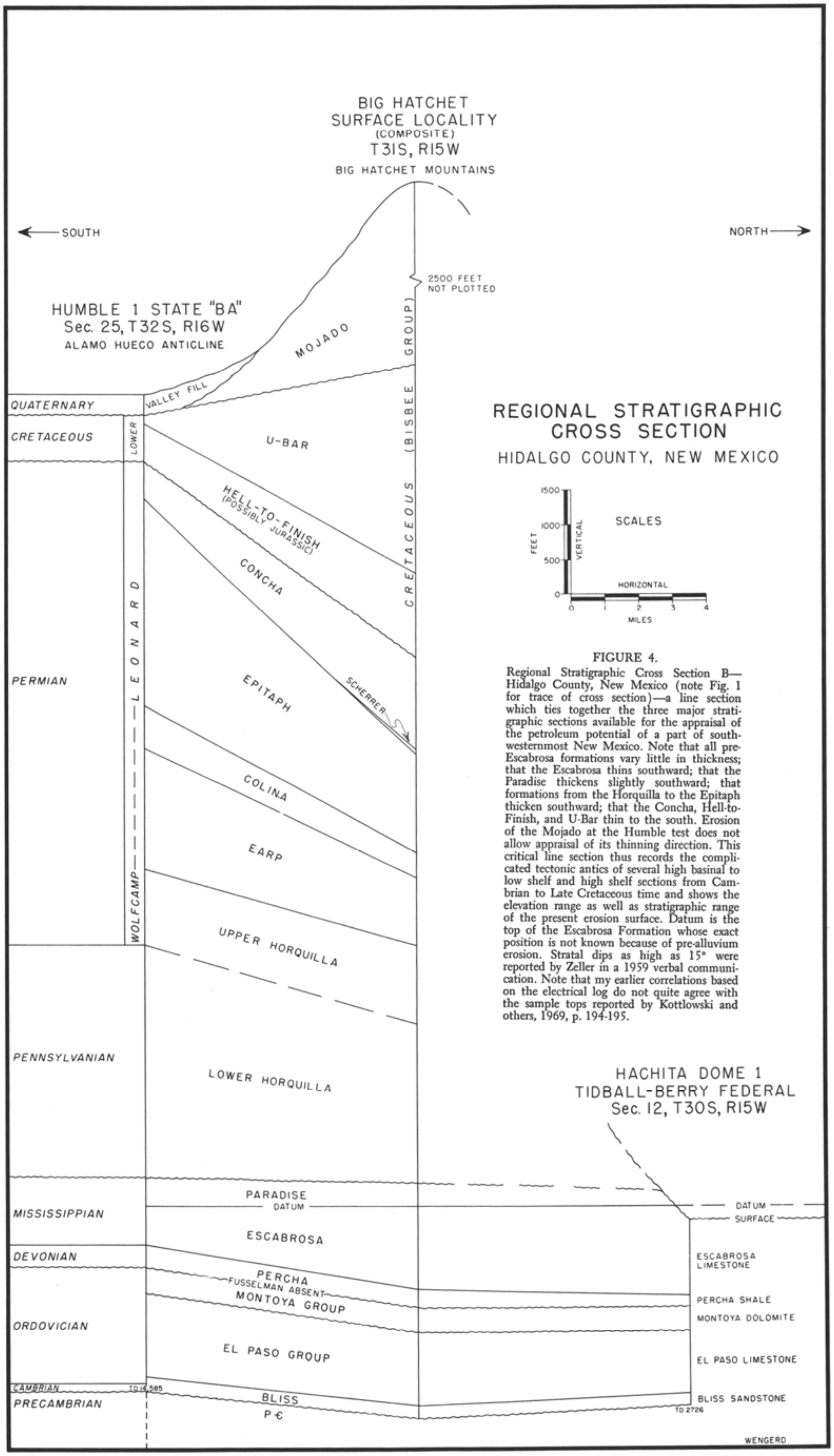


FIGURE 4.

Regional Stratigraphic Cross Section B—Hidalgo County, New Mexico (note Fig. 1 for trace of cross section)—a line section which ties together the three major stratigraphic sections available for the appraisal of the petroleum potential of a part of southwesternmost New Mexico. Note that all pre-Escabrosa formations vary little in thickness; that the Escabrosa thins southward; that the Paradise thickens slightly southward; that formations from the Horquilla to the Epitaph thicken southward; that the Concha, Hell-to-Finish, and U-Bar thin to the south. Erosion of the Mojado at the Humble test does not allow appraisal of its thinning direction. This critical line section thus records the complicated tectonic antics of several high basinal to low shelf and high shelf sections from Cambrian to Late Cretaceous time and shows the elevation range as well as stratigraphic range of the present erosion surface. Datum is the top of the Escabrosa Formation whose exact position is not known because of pre-alluvium erosion. Stratal dips as high as 15° were reported by Zeller in a 1959 verbal communication. Note that my earlier correlations based on the electrical log do not quite agree with the sample tops reported by Kottlowski and others, 1969, p. 194-195.

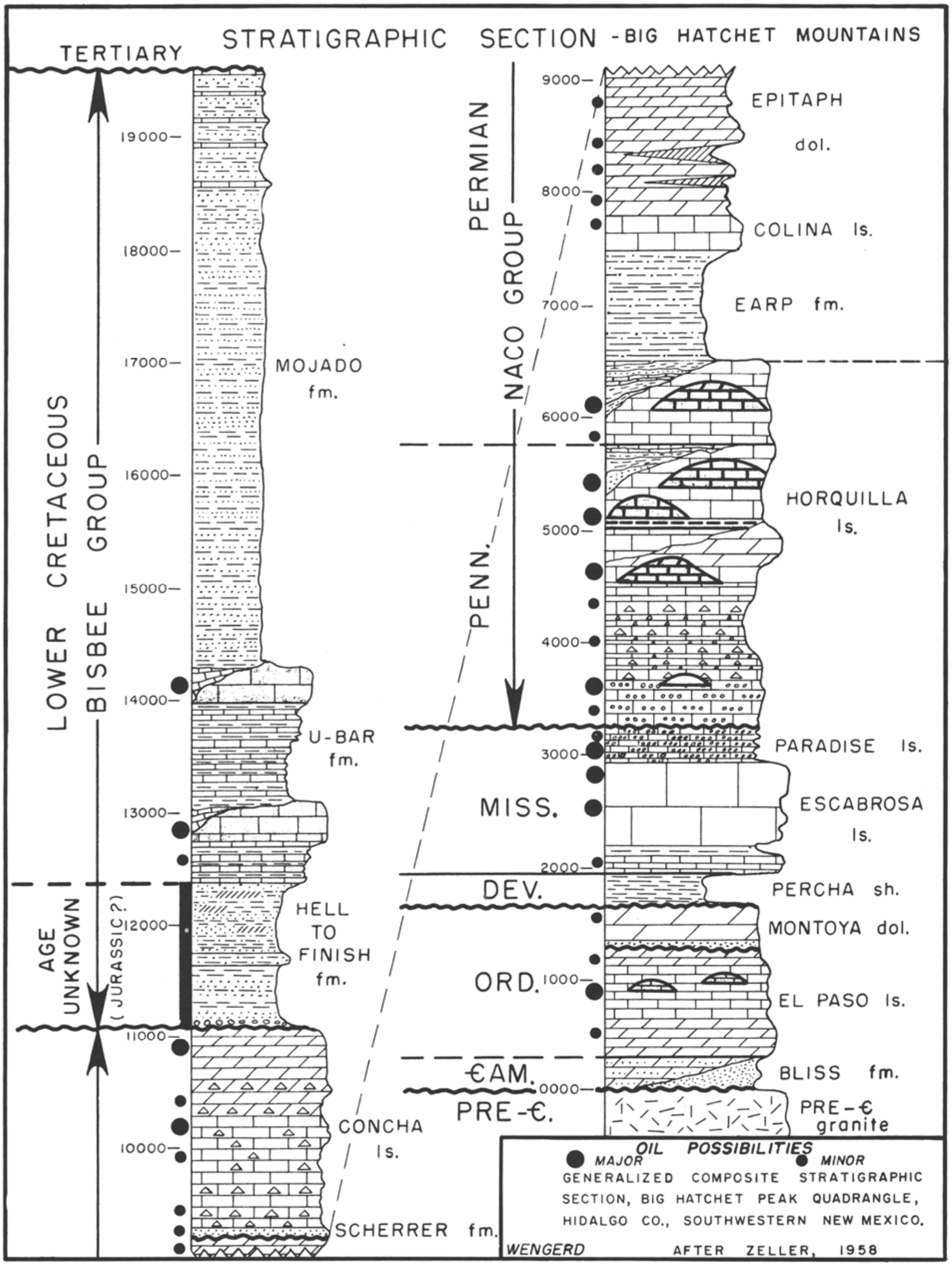


FIGURE 5.

Stratigraphic Section (composite)—Big Hatchet Mountains (*after* Zeller 1958, and later commercial work). This section shows those strata which may have major and minor oil possibilities in southwesternmost New Mexico. The Hell-to-Finish Formation is now considered to be of Cretaceous age. The thickness of reefs in the Horquilla is vertically exaggerated.

the regional relief was low, ground water related to an upper erosion surface affected strata below a subjacent disconformity in very few of the carbonate sequences. This probably was the situation until the post-Hueco uplift and wrenching of the Florida positive area and south tilting prior to Cretaceous marine invasion from the south. Almost certainly ground water affected all but the most tightly folded or most severe facies gradation traps during and subsequent to the Laramide orogeny. It is this destructive feature, combined with wide alluvial cover, volcanism, and intense block faulting, that makes the search for unbreached oil-filled traps so arduous in this section of the Basin and Range structural province.

Following is a tabulation of the widespread, known erosion surfaces, from youngest to oldest:

TABLE 2

BETWEEN FORMATIONS	LITHOLOGY BELOW	LITHOLOGY ABOVE
Mojado/U-Bar	limestone	continental clastics
Hell-to-Finish/Concha	dolomite	continental conglomerate and sandstone
Concha/Epitaph	dolomite	limestone*
Earp/Horquilla	limestone	red deltaic clastics
Horquilla/Paradise	oolitic limestone	oolitic limestone
Escabrosa/Percha	shale	limestone
Percha/Montoya	dolomite	marine shale
Montoya/El Paso**	dolomite	dolomite
Bliss/Precambrian	igneous and metamorphic	sandstone and dolomite

* in places the Scherrer quartzose sandstone basal Concha is present and may be a thin reservoir. ** in places the Cable Canyon quartzose sandstone is present as a thin potential reservoir at the base of the Montoya group.

There is a conspicuous absence of thick marine shale above all but the Percha-Montoya erosion surface. The Percha Shale represents a suitable source environment, and its environment may have been responsible for the generation of petroleum and its accumulation in the solution and intercrystalline openings of the Montoya Dolomite. The continental elastics of the Mojado, Hell-to-Finish, and Earp Formations, however, can hardly be considered to have been suitable as source environments. Thus one may conclude that petroleum generated in this region must be intraformational and of an almost in-situ origin related to thin marine shale or the carbonates themselves.

A specific formation-by-formation summary of fluid movements in relation to regional tilts is not possible for most areas in the Basin and Range country for the following reasons: (1) Too few deep oil tests have been drilled and few quality of water or pressure data are available in the region of southwesternmost New Mexico; (2) The orogenic activities, Laramide thrusting and intrusion, mid-Tertiary Basin and Range normal faulting, and intense Tertiary and Quaternary volcanism undoubtedly created some derangement of fluid systems in pre-Tertiary formations. Epeirogenic regional tilts related to subsidence of the Pedregosa basin combined with moderate compactional drives in fluids encased in carbonate sequences probably led to initial migration of oil and gas present in marine reservoirs. However, these earlier first-phase accumulations were probably altered in location by inter- and intrasystemic marine and fresh water incursion as disconformities were created. Tertiary, Pleistocene, and Recent fresh water movements facilitated by faulting probably untrapped some accumulations; hence, only in certain secreted tectonic units in the broad valleys may one find preserved remnant reservoir pressures or unflushed traps where petroleum is entrapped.

RESERVOIRS AND TRAPS

The formations embracing potentially productive reservoir beds in southwesternmost New Mexico are listed below: *(Adapted* from Table 1, p. 190, Kottlowski, Foster, and Wengerd, 1969) .

The reader must realize that much of the above is surmise, because of decided lack of sufficient subsurface information, and that the tabulation is based mainly on data from the outcrops in the Sierra Juarez (Palomas Range) of Mexico and in the Big Hatchet Mountains; further, most of the known potential reservoirs are carbonates and little can be said about the oil and gas-bearing possibilities of wedging shelf sandstones and other types of facies gradation traps.

TABLE 3

FORMATION	SYSTEMIC AGE	RESERVOIR LITHOLOGY	PROBABLE POROSITY	TYPES OF TRAP
U-Bar	Cretaceous	limestone	vuggy	bioherm, anticline
Concha	Permian	dolomite, sandstone, limestone	intercrystalline solution	anticline, facies gradation
Epitaph	Permian	dolomite	intercrystalline solution	anticline
Colina	Permian	limestone	intercrystalline	anticline
Upper Horquilla	Permian	limestone	vuggy	bioherm, anticline
Lower Horquilla	Pennsylvanian	limestone, dolomite, oolitic limestone	vuggy, interoolite	same, facies gradation
Paradise	Mississippian	oolitic limestone	interoolite, solution	anticline, facies gradation
Escabrosa	Mississippian	limestone	intercrystalline, solution	anticline
Montoya	Ordovician	dolomite, sandstone	intercrystalline, solution	anticline
El Paso	Ordovician	limestone, dolomite	intercrystalline, solution	anticline, bioherm

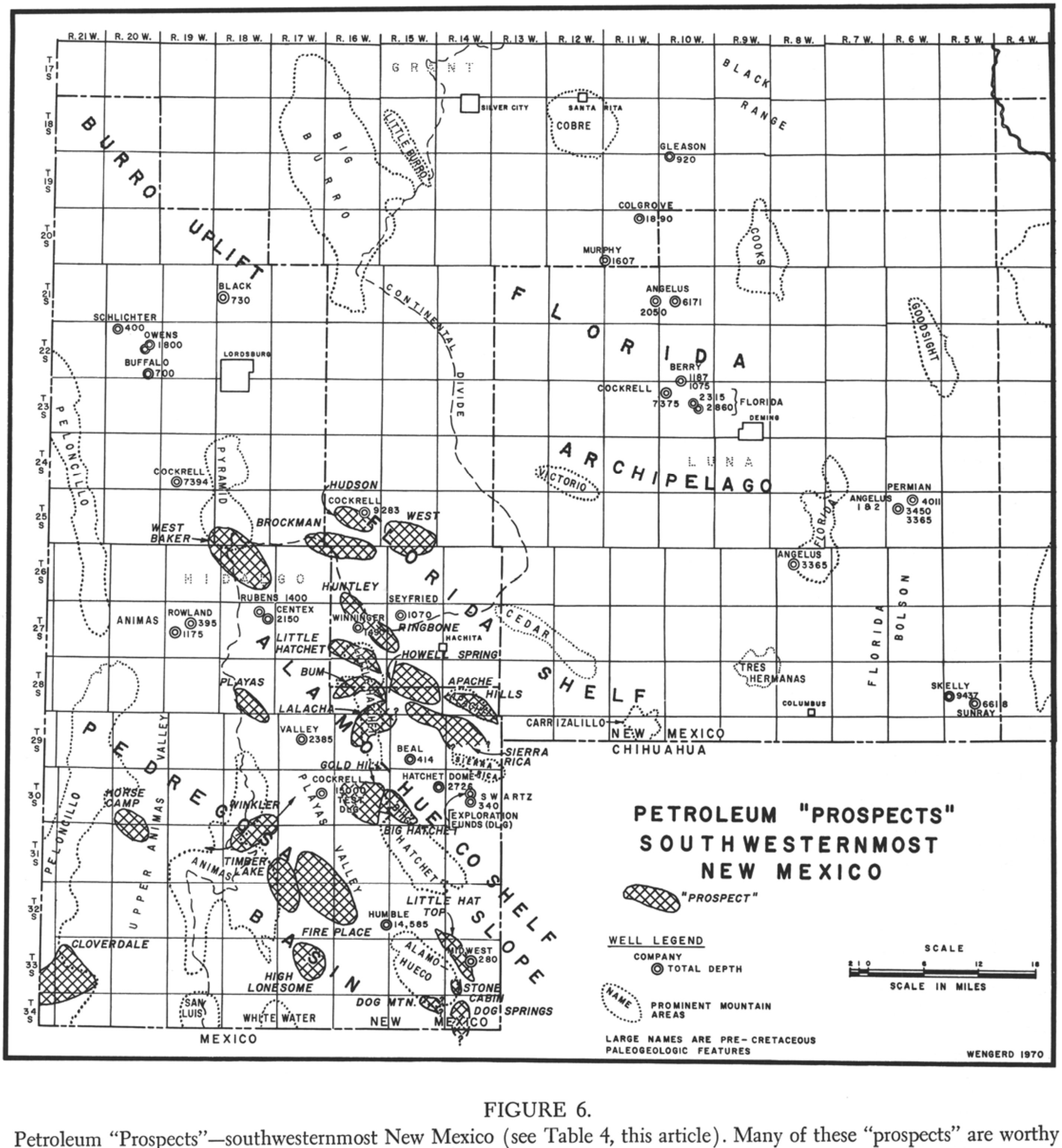


FIGURE 6.

Petroleum "Prospects"—southwesternmost New Mexico (see Table 4, this article). Many of these "prospects" are worthy of careful photogeologic, field, and geophysical analyses.

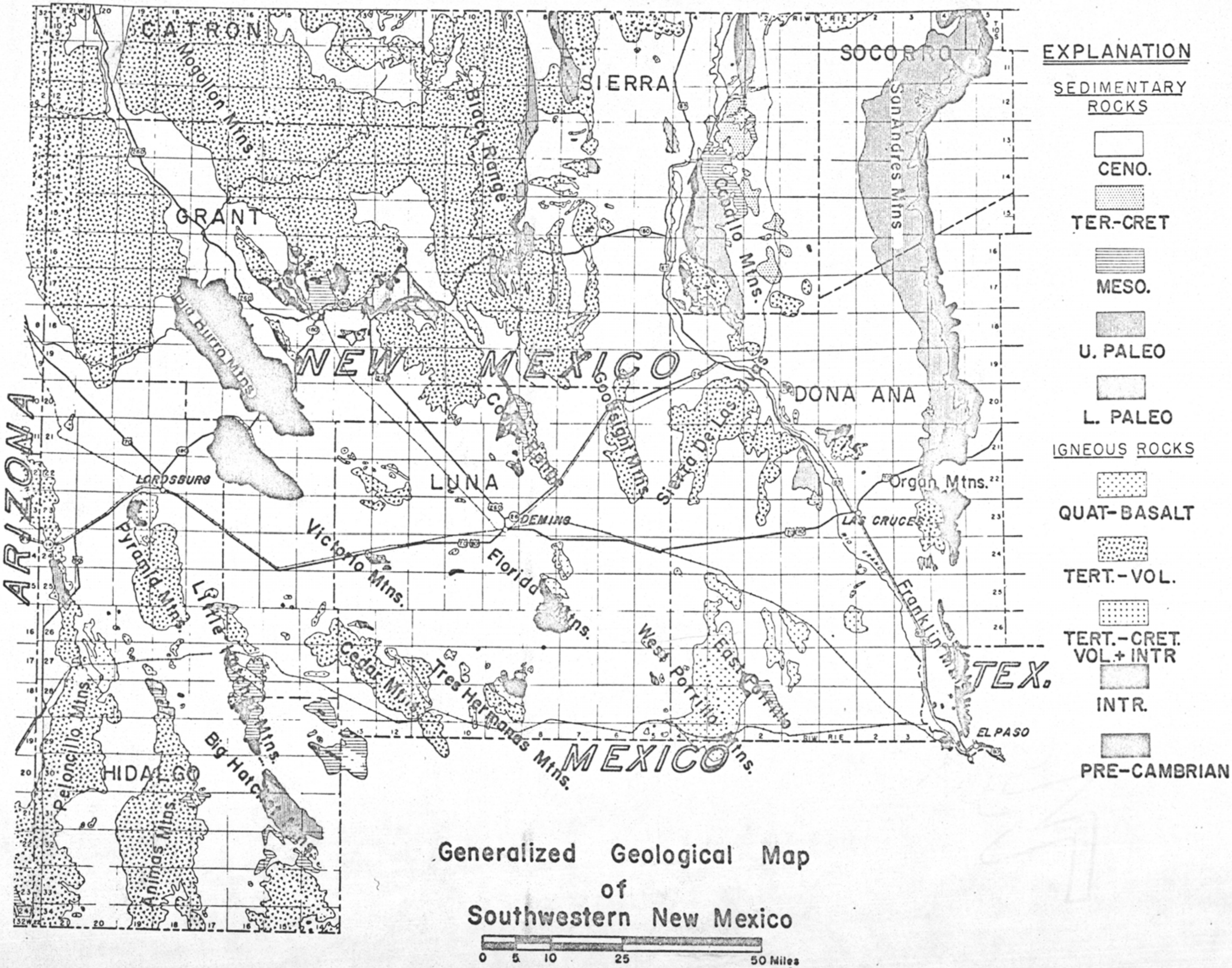
GENERALIZED STRATIGRAPHIC SECTION

SONORAN BASIN IN SOUTHWESTERN NEW MEXICO

R.E. MURPHY
JULY, 1959

SYSTEM	SERIES	FORMATION	LITH.	THICK.	DESCRIPTION
QUATERNARY & TERTIARY		*ALLUVIUM, VOLCANIC & INTRUSIVE IGNEOUS ROCKS*		*4000'*	BASIN & RANGE BLOCK FAULTING NORTH-SOUTH AXES *Bolson gravels, talus & rhyolite & basalt volcanic flows, dikes & plugs.* *Volcanic clastics, andesite, subaquious and subereal deposition.*
CRETACEOUS	LOWER	*MAJADO*		*4500'*	INTENSE FOLDING; HIGH & LOW ANGLE FAULTING NORTHWEST ~ SOUTHEAST AXES WITH THRUSTING REPORTED *Gray limestone at top, thin & shaley.* *Gray sandstone, also buff & reddish, hard, clean quartzitic silica cement, graywacke also present, grey-brown & well cemented, brown shale stringers.* *Limestone at base greenish-gray to reddish.*
		U-BAR		*1500'*	*Gray limestone, light, fx to mx, massive & reefy, w/some thin bedded limestone and dark gray shales.*
		HELL TO FINISH		*1600'*	*Buff sands also reddish & yellow, fg to mg, SA-SR, siltstones & shales are common.* *Basal conglomerate w/rounded limestone cobbles.*
PERMIAN	GUADALUPIAN	NACO GROUP: *CONCHO*		*1300'*	BROAD GENTLE FOLDING *Gray limestone, massive to medium bedded w/abundant chert, irregular, grayish-pink nodules & lenses, very fossiliferous.*
	LEONARDIAN	NACO GROUP: *SCHERRER*		*100'*	*Tan sandstone & siltstone w/reds & browns, fg & hard.*
		NACO GROUP: *EPITAPH*		*1500'*	*Gray dolomite, light & dark, fx to mx, medium to thin bedded w/local gyp & grey to reddish grey vfg quartz sandstone & siltstone.*
		NACO GROUP: *COLINA*		*350'*	*Gray limestone, dark to black, vfx to fx, medium bedded very fossiliferous.*
	WOLFCAMPIAN	NACO GROUP: *EARP*		*1000'*	*Gray dolomite, light to dark w/limestone stringers vfx to mx, w/abundant fusilinids in upper ⅓ of formation.* *Shales, red siltstones and sands, fg to cg, w/occasional pebble conglomerate.*
PERMIAN / PENNSYLVANIAN	WOLFCAMPIAN; VIRGILIAN; MISSOURIAN; DESMOINESIAN; DERRYAN; MORROWAN	NACO GROUP: *HORQUILLA*		*3500'*	*Gray limestone, dark to black, thin to thick bedded, reefoid in upper ⅓, fusilinids abundant except in lower part, cherty, w/pinkish gray & black chert nodules & interbeds common. Local unconformities w/coarse basal clastics other places disconformable w/gradational contact.*
MISSISSIPPIAN	CHESTERIAN	*PARADISE*		*350'*	BROAD UPLIFT WITH UNCONFORMITY *Gray limestone, dark occasionally brown, coarse xln & oölitic w/calcareous sand and shale streaks, very fossiliferous w/crinoids, brachs & corals.*
	MERAMÉCIAN; OSAGIAN; KINDERHOOKIAN	*ESCABROSA*		*1300'*	*Gray limestone, light, fx to mx, occasionally coarse in upper part, massive bedded, abundant crinoids, brachs & corals.* *Middle limestone, black to gray & cherty.* *Thin bedded limestone at base w/thin shale streaks.*
DEVONIAN	UPPER	*PERCHA*		*250'*	*Shale, black, also brown or greenish w/limestone nodules.*
SILURIAN	NIAGARAN	*FUSSELMAN*		*0'-300'*	GENTLE UPLIFT WITH DISCONFORMITY *Silurian absent to the west by non-deposition.*
ORDOVICIAN	CINCINNATIAN	*MONTOYA*		*350'*	*Gray dolomite, light, massive and cherty.*
	CANADIAN	*EL PASO*		*1100'*	*Dark dolomite, bluish & green, vfx-mx, w/black to gray chert & occasional thin sand streaks & sandy at base.* *Gray dolomite, light, vfx to mx, upper part thin bedded & cherty.* *Gray dolomite, dark, in lower part*
CAMBRIAN	CROIXIAN; ALBERTIAN	*BLISS*		*200'*	*Sand, reddish brown to white & quartzose with silica matrix & oölitic, hematite common.*
PRE CAMBRIAN					

Compiled from U.S. Geological Survey
and N.M Bureau of Mines Publications.



Generalized Geological Map of Southwestern New Mexico

WILDCAT TESTS

To avoid undue repetition, the reader is referred to the article entitled "Key Oil Tests and Stratigraphic Sections in Southwest New Mexico" by Kottlowski, Foster, and Wengerd, in the 1969 N. M. G. S. Guidebook of the Twentieth Field Conference, The *Border* Region, p. 186-196. Specific data based on examination of well cuttings for critical deep tests in the region are published in that article.

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The three very important tests drilled "tight" by the Cockrell Corporation (T. 23 S., R. 10 W.; T. 24 S., R. 19 W.; T. 25 S., R. 16 W.) are reported to have bottomed in Precambrian rocks, with all three showing questionably short sections of Paleozoic strata. A fourth Cockrell test in sec. 14, T. 30 S., R. 17 W., being drilled as of May, 1970, will be most important for the six reasons here listed as a test of:

1. the northwest extension of the Winkler anticlinal trend, out of the central Animas Mountains into the Playas valley;
2. possible Horquilla reef trends extending northwestward from known reefs in the Big Hatchet Mountains;
3. the depth of valley fill;
4. the location of an anticlinal nose plunging northwestward out of the Big Hatchet Mountains;
5. facies translocation by early and/or late wrench faulting recognizable by comparisons with measured sections in the Big Hatchet Mountains and in the Humble test in sec. 25, T. 32 S., R. 16 W.;
6. existence of a metamorphic aureole around the igneous intrusion exposed in Granite Gap lying several miles to the east.

PETROLEUM PROSPECTS

Despite the complications of Cretaceous-Tertiary-Quaternary-Recent events, there are interesting areas which may be petroleum prospects in southwesternmost New Mexico. These prospects names are, for ease of reference, based on nearby natural or man-made features. It is recognized that perhaps only a few of these anomalous areas deserve the name of "petroleum prospect," and only these few might warrant further geologic exploration and analyses by geophysical means or by the drill.

A map included with this article shows areas which are anomalous in the sense that they look like petroleum prospects. Note that many prospects may exist, particularly in southern Luna County, which in almost 12 years of work have not yet been noticed; but this map, in the writer's opinion, fairly depicts the prospects which can be localized by the means we have used. These locales of structural anomaly may be divided into four main groups:

A. those which show anomalous elevations of 20 to 50 feet in the Valley fill, such as High Lonesome in the southern Playas Valley;

B. mountain anticlines or structures such as Winkler in the Animas Mountains;

C. lowland anticline or structures off the ends or flanks of mountains, such as Ringbone on the north end of the Little Hatchet Mountains, and the structures related to the Alamo Hueco Mountains in southeastern Hidalgo County;

D. projection of mountain structures across major Basin and Range normal faults, such as Gold Hill prospect.

The great lack of subsurface data, and an inadequate "scatter" of outcrop data for all formations, does not allow construction of prognoses, prediction of depths to granite, drilling costs, specific discussion of closure, or trap type, or more than a cursory listing of these prospects. Table 4 is a tabulation which can only be a meager guide to what these prospects may mean.

A perusal of this list of "prospects" does not engender great confidence in the exploration geologist because of meager data, but if this writer were told that six wells could be budgeted without further detailed exploration, he would choose Winkler, Brockman, Ringbone, Howell Spring, Gold Hill, and Fireplace. A company in its right mind would not follow such a program without first using every pre-drilling exploratory tool, but in the interest of pure science and in attempts to get reliable stratigraphic information which may lead to discoveries of major oil fields in the Basin and Range province, deep drilling is absolutely necessary.

WINKLER ANTICLINE-AN INLIER IN THE VOLCANICS

The Winkler anticline is a classic example of how specific restudy of a potential petroleum prospect adds to the knowledge of regional tectonic sequences.

Robert A. Zeller and the writer studied this anticline during the early summer of 1959. Reasonable doubt by the writer as to the thrust-origin of this structure led Zeller to remap the prospect, and his summary was accompanied by his letter dated July 8, 1959. Following is a partial quotation from that letter:

"I am enclosing a brief supplement to the . . . map .. . I suggest you extend the anticline which lies south of Gillespie Mountain in the Animas Range, northeastward and southwestward from its exposed area. How far it is extended is an open question; also, remove the klippen."

Zeller's summary report, edited and rearranged, follows:

"Subsequent field work in the Animas Mountains by the writer since preparation of the report has revealed two major changes in the former interpretation of the geologic history of the region, both of which have important bearing on petroleum discovery in the region, and the work has shed some light on a specific anticline as a possible petroleum reservoir. These new concepts have resulted from work on the anticline which lies southwest of Winkler Ranch in the low pass south of Gillespie Mountain, principally in secs. 2, 3, 4, 9, and 10, T. 31 S., R .18 W. Henceforth, this structure is called Winkler anticline.

On the original map and report, this anticline was indicated in Cretaceous rocks and was shown as having klippen of Pennsylvanian-Permian rocks resting upon its axial area. It is now known that these exposures of Paleozoic rocks are the exposed core of the Winkler anticline and are not remnants of a thrust sheet. Thus, the structure, where exposed, has considerable closure. The northeast trend of the fold,

TABLE 4

PROSPECT	TYPE*	LOCATION	TRAP	TREND	LENGTH-WIDTH (MILES)		SURFACE ROCKS
Hudson	(A)	T25S, R16W	?	NW	4	2	Alluvium
West	(A)	T25-26S, R15W	?	W	6	3	Pennsylvanian, volcanics, alluvium
Brockman	(C)	T25-26S, R16-17W	Anticlines**	W	7	2	Cretaceous
West Baker	(C)	T25-26S, R18-19W	Anticline(?)**	NW	8	4	Volcanics
Huntley	(C)	T26-27S, R16W	Nose	NW	3	2	Volcanics, Alluvium
Ringbone	(C)	T27S, R15-16W	Anticline	NW	5	2	Cretaceous, volcanics, alluvium
Little Hatchet	(B)	T27-28S, R16W	Anticlines	NW	6	2	Cretaceous, volcanics, alluvium
Howell Spring	(A) (D)	T28S, R15W	Fault	NW	6	4	Alluvium
Bum	(B)	T28S, R16W	Anticline**	W arc	5	2	Cretaceous, volcanics
Apache Hills	(B)	T28-29S, R14W	Fault	NW	5	2	Volcanics
Playas	(B)	T28-29S, R18W	Anticline	NW	5	2	Pennsylvanian, Permian, volcanics
Sierra Rica	(B) (D)	T28-29S, R14-15W	Nose	NW	10(?)	4	Pennsylvanian, Permian, volcanics, alluvium
Lalacha	(B)	T28-29S, R16W	Anticlines and nose	NE	6	3	Cretaceous, volcanics, alluvium
Big Hatchet	(B)	T30S, R15-16W	Faults and anticlines	WNW	4	2	Cambrian to Permian
Gold Hill	(D)	T30S, R16W	?**	NW	5	4	Alluvium
Winkler	(B)	T30-31S, R18W	Anticline	NE	6	2	Permian, Cretaceous volcanics, alluvium
Horse Camp	(A) (C)	T30-31S, R20W	?	NW	5	3	Volcanics, alluvium
Fireplace	(A) (D)	T31-32S, R16-17W	Nose?	NW	10	4	Alluvium
Timberlake	(C)	T31-32S, R17-18W	Fault	NNW	6	3	Volcanics, alluvium
High Lonesome	(A)	T33S, R17W	?	N(?)	4	3	Alluvium
Cloverdale	(B)	T33-34S, R21-22W	Nose(?)	NE(?)	6(?)	4	Volcanics
Dog Springs	(C)	T34S, R14W	Anticline	N	6(?)	2	Cretaceous, volcanics, alluvium
Dog Mtn.	(C)	T34S, R15W	Nose**	WNW	2	1	Volcanics
Stone Cabin	(C)	T33S, R14W	Nose**	S	2	1	Volcanics
Little Hat Top	(C)	T32-33S, R14-15W	Anticline**	NW	7	2	Cretaceous, volcanics, alluvium

* see previous discussion of types as to regional location (mountains or valleys, etc.)
** Faulted

which is anomalous in this area where predominant structures trend northwest to nearly north, is thought to represent a Precambrian structural feature which has been rejuvenated. It seems probable that the fold extends southwestward under the cover of Tertiary volcanic rocks and northeastward under valley fill. Because of the amplitude of the fold, it probably extends for some distance, although it may be offset by high-angle or normal faults. The extensions of this structure may represent favorable structural targets for petroleum exploration.

This anticline started its strong post-Precambrian growth after Permian deposition and before lower Cretaceous sediments were deposited. Therefore, it proves the presence of a strong period of orogeny prior to early Cretaceous time. Such an orogeny has been recognized in southeastern Arizona but not in southwestern New Mexico, but, since its discovery in the area of the Winkler anticline, it may be assumed that much of southwestern New Mexico was also influenced by the orogeny. This concept opens new possibilities for the discovery of anticlines under the Cretaceous rocks.

Growth of the Winkler anticline continued after deposition of the Tertiary volcanic rocks. This is shown by the bedding attitudes of the adjacent Tertiary volcanic rocks which dip away from the anticline in all directions. This is of great importance because one has reason to suspect that arching in the Tertiary volcanic cover may reflect the presence of anticlines in underlying Cretaceous and Paleozoic rocks. Since the growth of the Winkler anticline continued until such late geologic time, perhaps it may have continued into Recent time. This assumption would give reason to suspect that anomalous high areas in valley fill may reflect older structures beneath.

These recent discoveries open new realms of thought in petroleum exploration in the region; however, these concepts should be used in combination with other concepts and information to delineate favorable structures." (end of summary).

It may surprise the reader to know that Winkler anticline has never been drilled. This anticline appears to lie near the base of the Alamo-Hueco shelf slope of the Pedregosa basin. Although Mississippian, Pennsylvanian, and Permian strata may be similar to those drilled by the Humble test in T. 32 S., R. 16 W., there is every probability that this anticline developed early, and was moderately active as a spur fold penecontemporancous to sedimentation on the shelf slope of the subsiding Pedregosa basin during Pennsylvanian and Permian carbonate deposition. If such is the case, the Winkler anticline is a prime prospect for a deep Precambrian test.

CONCLUSIONS

The possibilities of commercial oil and natural gas occurring in southwesternmost New Mexico are good as are indicated by the very thick sections of Paleozoic and Cretaceous sedimentary rocks, the shows of oil and gas in the tests drilled to date, and by the several favorable structures known to exist. However, the location of these potentially commercial quantities of oil and gas is a difficult problem. Exploration is severely limited by the factors of igneous intrusions and structure, despite the excellent stratigraphic setting.

Igneous areas to be avoided lie near the intrusives southwest and north of Gillespie Peak in the central Animas Range, the Granite Gap in the Little Hatchet Mountains, and in most of the northern half of Hidalgo County. Also, the area of the intrusive belt extending from the northern end of the Sierra Rica and the Apache Hills west-northwestward through the central and northern parts of the Little Hatchet Mountains, and northern spur of the Animas Mountains, and the central and northern parts of the Peloncillo Mountains should be avoided or explored with caution. This belt includes that part of Hachita Valley which lies between Hachita Valley and Twelve Mile Well, that northern locale of the Playas Valley which includes the central part of Playas Lake.

Study of the strata suggests that the most favorable areas of greater porosity are those underlain by early Wolfcamp (upper Horquilla) reefs equivalent to the Hueco section. Paleogeographic maps of early Wolfcamp strata suggest that the general trend of these reefs is probably southeast and northwest from Big Hatchet Peak; however, there are very few data to indicate the actual trends of these reefs, and it is equally possible that the Permian reefs have an arcuate trend between the Animas Mountains and Big Hatchet Peak. In either case, about the southern one-fourth of Hidalgo County appears to be stratigraphically most favorable.

The discovery of favorable structural traps is the most difficult problem. With the exception of the Big and Little Hatchet Mountains and the vicinity of the northern end of the Coyote Hills, most of Hidalgo County is mantled by alluvium and Tertiary volcanic rocks. Throughout those parts of the county which lie west of Playas Valley, the only method of locating Laramide structural traps is through geophysical methods; however, there may not be any co-spatial relationship among Basin and Range, Laramide, and older structures; hence a study of joint patterns, exposed folds in volcanic rocks, or topographically or structurally high areas in the alluvium covered areas may not be an ancillary and significant tool in locating buried structure.

In parts of the Playas and Hachita Valleys, parts or whole structural traps might be located generally by projecting Laramide anticlinal axes from exposures in the flanking ranges into the valleys. Of course, the success of this procedure depends upon the assumption that there was insignificant lateral movement along early northwest-trending wrench faults and along the much later normal faults flanking the ranges. The validity of the assumption probably may be tested by gravity surveys of the valleys. Also, the specific choice of drilling locations in those parts of the valleys underlain by Laramide anticlines might best be based upon gravity data.

In seeking the best potential locations for oil or gas accumulations, the following generalized steps are important:

1. Avoid areas of large-scale igneous intrusion and where broad reaches are covered with thick pyroclastic and effusive rocks.

2. Limit exploration to areas where the strata are most favorable. Pre-Cretaceous strata exhibit relatively predictable lithofacics gradations throughout the region. However, the presence or absence of reefs in the lower Cretaceous section is entirely unpredictable inasmuch as these early Cretaceous marine sags were small, shifted laterally in time, and appeared and disappeared abruptly in various areas at various times. The most predictable stratigraphic variable appears to be the trend of early Wolfcamp reefs, but present data are so sparse that only a general notion may be formulated on this trend. Nevertheless, since reefs in any of the Paleozoic strata show promise of greater porosity than adjacent correlative strata, exploration should be conducted along trends parallel to and along the Alamo Hueco shelf slope.

3. Choose a simple Laramide structural trap with closure with a consideration that such an anticline, without low-angle-thrust complications, may be a rejuvenated late Paleozoic fold.

Exploration in the region is difficult at best due to the various igneous, stratigraphic, and structural limitations, but it is further complicated by the thick deposits of Tertiary volcanic rocks and valley fill which blanket so much of the region. Two general methods of locating Laramide structures are possible. First, Laramide anticlines exposed in mountains, and discoverable by field work and photogeologic mapping, may be projected into valleys along the same trends. Second, geophysical methods should be employed to find covered Laramide structures. Magnetic surveys over areas underlain by volcanic rocks or alluvium derived from volcanics and pre-volcanic rocks may not be successful because of the highly variable contents of magnetite and depths to "basement." Seismic surveys have been tried in the region, but apparently the results are questionable. Gravity surveys, if properly interpreted and combined with an understanding of the geology of the region, seem to offer the most promising geophysical means for locating covered structures.

SUGGESTED READING

Armstrong, A. K., 1962, Stratigraphy and paleontology of the Mississippian System in southwestern New Mexico and adjacent southeastern Arizona: N. Mex. Bureau Mines & Min. Res. Mem. 8, 99p.

Callaghan, E., 1953, Basin and range structure in southwestern New Mexico: Guidebook of Southwestern New Mexico, Fourth Field Conf., N. M. Geol. Soc., p. 116-117.

Diaz, T., and A. Navarro G., 1964, Lithology and stratigraphic correlation of the upper Paleozoic in the region of Palomas, Chihuahua: 1964 Field Trip Guidebook, Geology of Mina Plomosas-Placer de Guadalupe Area, Chihuahua, Mexico, West Texas Geological Society, Publication 64-50, p. 65-84.

Elston, W. E., 1957, Geology and mineral resources of Dwyer quadrangle, Grant, Luna, and Sierra Counties, New Mexico: N. Mex. Bureau Mines & Min. Res. Bull. 38, 86 p.

Elston, W. E., 1958, Burro uplift, northeastern limit of sedimentary basin of southwestern New Mexico and southeastern Arizona: Amer. Assoc. Petrol. Geol. Bull., v.42, p. 2513-2517.

Flower, R., 1958, Cambrian-Mississippian beds of southern New Mexico: Guidebook of the Hatchet Mountains and the Cooks Range-Florida Mountain areas, Grant, Hidalgo, Luna Counties, southwestern New Mexico, Eleventh Field Conf., Roswell Geol. Soc., p. 79-87.

Gillerman, E., 1958, Geology of the central Peloncillo Mountains, Hidalgo County, New Mexico, and Cochise County, Arizona: N. Mex. Bureau Mines & Min. Res. Bull. 56, 152 p.

Griswold, G. B. 1961, Mineral deposits of Luna County, New Mexico: N. Mex. Bureau Mines & Min. Res. Bull. 72, 157 p.

Jicha, H. L., 1954, Geology and mineral resuorces of the Lake Valley quadrangle, Grant, Luna, and Sierra Counties, New Mexico: N. Mex. Bureau Mines & Min. Res. Bull. 37, 93 p.

Kottlowski, F. E., 1958, Pennsylvanian and Permian rocks near the late Paleozoic Florida Mountains: Guidebook of the Hatchet Mountains and the Cooks Range-Florida Mountain areas, Grant, Hidalgo, and Luna Counties, New Mexico, Eleventh Field Conf., Roswell Geol. Soc., p. 79-87.

Kottlowski, F. E., 1959, Real wildcat country, Pennsylvanian of southwest New Mexico: Oil and Gas Journal, v. 57, no. 16, p. 148-151 (April 13) .

Kottlowski, F. E., 1960, Summary of Pennsylvanian sections in southwestern New Mexico and southeastern Arizona: N. Mex. Bureau Mines & Min. Res. Bull. 66, 187 p.

Kottlowski, F. E., 1962, Paleozoic Cretaceous beds offer good oil prospects: World Oil, July, p. 116-120.

Kottlowski, F. E., 1963, Paleozoic and Mesozoic strata of southwestern and south-central New Mexico: N. Mex. Bureau Mines & Min. Res. Bull. 79, 100 p.

Kottlowski, F. E., and R. W. Foster, 1962, Pre-Tertiary strata of Tres Hermanas Mountains, Luna County, New Mexico: Amer. Assoc. Petrol. Geol. Bull., v. 46, p. 2090-2098.

Kottlowski, F. E., R. W. Foster, and S. A. Wengerd, 1969, Key oil tests and stratigraphic sections in southwest New Mexico; Guidebook, Twentieth Field Conf., N. Mex. Geol. Soc., The Border Region, Chihuahua and the United States, p. 186-196.

Lasky, S. G., 1947, Geology and ore deposits of the Little Hatchet Mountains, Hidalgo and Grant Counties, New Mexico: U.S. Geol. Survey Prof. Paper 208, 101 p.

Lochman-Balk, C., 1958, The Capitol Dome section, Florida Mountains: Guidebook of the Hatchet Mountains and the Cooks Range-Florida Mountain areas, Grant, Hidalgo, and Luna Counties, New Mexico: Eleventh Field Conf., Roswell Geol. Soc., p. 46-52.

Sandeen, W. M., 1953, The history of petroleum exploration in southwestern New Mexico: Guidebook of Southwestern New Mexico, Fourth Field Conf., N.M. Geol. Soc., p. 112-116.

Thompson, M. L., and F. E. Kottlowski, 1955, Pennsylvanian and lower marine Permian stratigraphy of south-central New Mexico: Guidebook of South-Central New Mexico, Sixth Field Conf., N.M. Geol. Soc., p. 71-76.

Wengerd, S. A., 1959, Regional geology as related to the petroleum potential of the Lucero region, west-central New Mexico: N. Mex. Geol. Soc. Guidebook, West-Central New Mexico, p. 121-134.

Wengerd, S. A., 1962, Wildcat oil prospects in southwest New Mexico: World Oil, v. 155, no. 2, p. 51-58 (August 1) .

Wengerd, S. A., 1969, Geologic history and the exploration for oil in the border region : Guidebook, Twentieth Field Conf., The Border Region, Chihuahua and the United States, N. M. Geol. Soc., p. 197-204.

Wilson, J. L., A. Madrid-Solis, and R. Malpica-Cruz, 1969, Microfacies of Pennsylvanian and Wolfcampian strata in southwestern U.S.A. and Chihuahua, Mexico: Guidebook, Twentieth Field Conf., The Border Region, Chihuahua and the United States, N. M. Geol. Soc., p. 80-90.

Zeller, R. A., Jr., 1958, The geology of the Big Hatchet Peak Quadrangle, Hidalgo County, New Mexico: Ph.D. dissertation, Calif. Univ. at Los Angeles, 260 p.

Zeller, R. A., Jr., 1965, Stratigraphy of the Big Hatchet Mountains area, New Mexico: N. Mex. Bureau Mines & Min. Res. Mem. 16, 128 p.