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FUTURE OIL POSSIBILITIES OF NEW MEXICO

by Robert L. Bates

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ALTHOUGH New Mexico produces more than 100,000 bbl. of oil daily, this production is concentrated in two small geographic areas of the state, the bulk in the southeast corner, and a smaller volume in the northwest corner. In terms of geographic area, most of the state remains undeveloped.

The purpose of this article is to examine the nonproducing areas to determine their future oil possibilities, using Levorsen's four major criteria for evaluating the possibilities of any given region. These are (1) thickness of sedimentary rocks; (2) evidences of oil and gas, such as seeps, shows in wildcats, etc.; (3) effects of unconformities; (4) wedge belts of porosity; and, in addition, because we are concerned with smaller areas; (5) geologic structure.

These criteria are applied to each of five areas of the state (see Fig. 1), as a means of measuring future oil possibilities. For convenience and reference, a correlation chart (see Fig. 2) has been added, listing the formations in the parts of the state considered to have appreciable future oil possibilities. -

It will be evident, after considering each area in detail, that roughly three-quarters of New Mexico has more or less promising future oil possibilities. To realize these possibilities without prohibitive expense will necessitate a revision of some of the exploration policies that have formerly prevailed in New Mexico.

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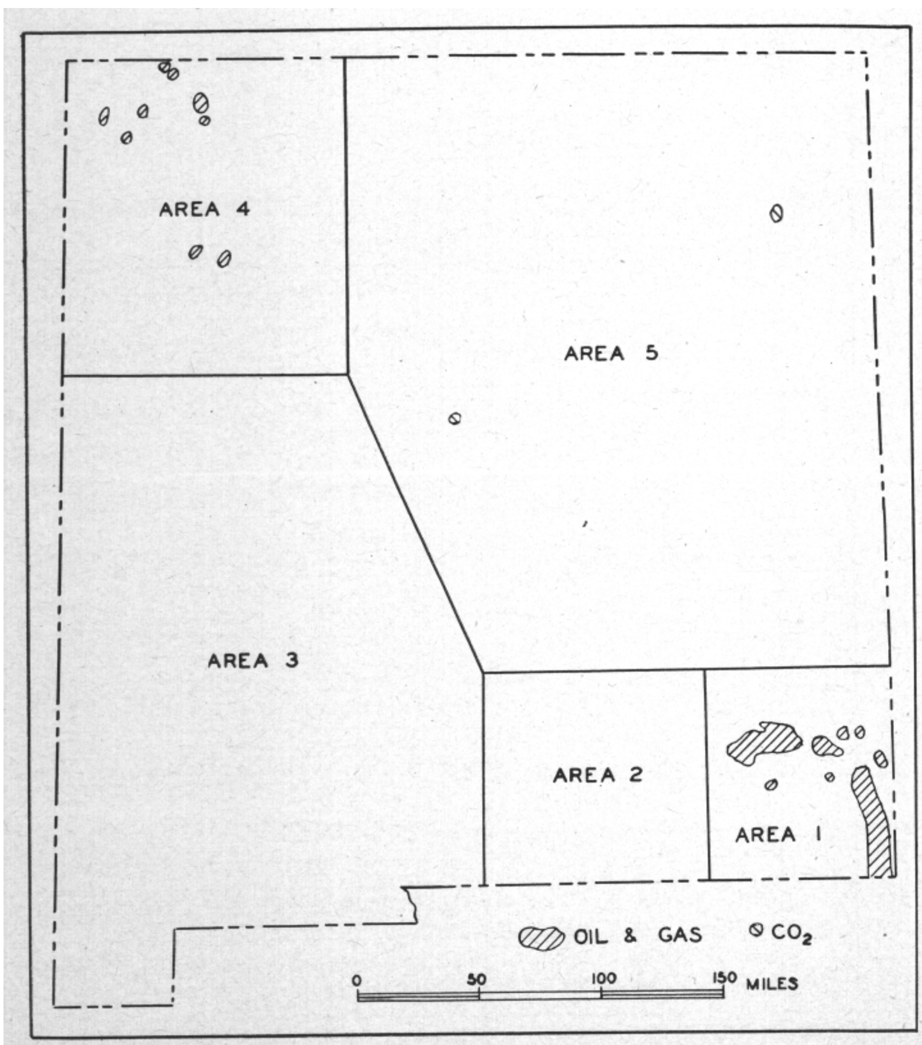

Fig. 1—Index map of New Mexico showing areas discussed and producing districts

The oil will not be found by drilling wildcats located solely because of convenient access or position of leased acreage, or on the basis of outdated geological concepts, or by accepting the advice of that fringe of so-called geologists who write enthusiastic reports based on a few days' field work.

To find these potential oil reserves, future wildcatting must be based on the best geological evidence, surface and subsurface, aided and abetted by geophysics. Specifically in Area 2, the possibility of reefing in the pre-Permian strata needs to be investigated. The number and distribution of lenticular sands in the Cretaceous of the San Juan basin is worthy of examination. Locating and exploring the buried belt along which the Paleozoic limestones of the San Juan basin wedge out against surrounding old land masses offers many challenges to good geology.

Other examples are northeastern and East Central New Mexico, which are in need of reexamination from the point of view that many of the so-called structures are not true folded anticlines, but merely the surface expression of buried pre-Cambrian hills, around which stratigraphic traps may be expected (see Fig. 3).

Area 1

The present producing area of southeastern New Mexico (Fig. 1) provides in many ways an excellent example for application of the five criteria of future oil possibilities. There are in the vicinity of 10,000 ft. of sedimentary rocks beneath the surface. In terms of volume, makingthe conservative estimate of an average sedimentary thickness of 1½ miles for this corner of New Mexico, there are over 11,000 cubic miles of sediments in which oil and gas might be expected—and from which, indeed, they have been produced in large amounts. These sediments are mostly marine in origin; they are free from metamorphism; and they are highly variable in composition. A feature of the area's sediments is the buried Capitan limestone reef, of Permian age, on or near which lie many of the great oil accumulations of southeastern New Mexico.

As to the second factor, evidences of oil and gas, certainly we cannot

AGE	NORTHWESTERN NEW MEXICO	NORTH CENTRAL AND NORTHEASTERN NEW MEXICO	SOUTHEASTERN NEW MEXICO
PLEISTOCENE			"Mescalero sands"
			Gatuña fm. 25±
TERTIARY – PLIOCENE		Santa Fe fm. 2000±; Ogallala fm. 0-500	Ogallala fm. 150±
		Abiquiu fm. 0-1200	
TERTIARY – MIOCENE		ElRito fm. 0-500; Popotosa fm. 3000±	
TERTIARY – OLIGOCENE		Galisteo fm. 700-3790	
TERTIARY – EOCENE	Chuska ss. 700-900; Wasatch fm. 1000	Raton fm. 600-2000	
	Torrejon fm. 275		
	Tohatchi sh. 200-1100; Puerco fm. 1200±		
CRETACEOUS	Ojo Alamo ss. 50-170	Vermejo fm. 425	
	McDermott fm. 30-200		
	Kirtland sh. 700-1180; Farmington ss. 0-480		
	Fruitland fm. 190-530	Trinidad ss. 70-100	
	Pictured Cliffs ss. 50-275		
	Lewis sh. 75-1800	Pierre sh. 0-2500	
	Mesaverde group 300-2000		
	Tocito ss. 0-35	Niobrara fm. 550	
	Mancos sh. 725-2000	Carlile sh. 150-720	
		Greenhorn ls. 25-40	
		Graneros sh. 60-350	
	Dakota ss. 50-250	Dakota ss. 20-200	
		Purgatoire fm. 0-50	Lower Cretaceous 0-250
JURASSIC	Morrison fm. 300-600	Morrison fm. 0-100	
	San Rafael group 0-40		
	Navajo ss. 100		
	Kayenta ss. 40		
	Todilto fm. 0-100	Todilto fm. 0-50	
	Wingate ss. 300	Wingate ss. 0-150	
TRIASSIC	Chinle fm. 1500±	Chinle sh. 1000±	Dockum group 1100-1550
		Santa Rosa ss. 50-200	
PERMIAN	Cutler fm. 1400±	Redbeds and evaporites 0-1000	Dewey Lake fm. 75-200
			Rustler fm. 150-250
			Salado fm. 1000-2000
			Castile fm. 0-1500
			Tansill fm. 100-200; Capitan reef; Delaware Mtn. gr. 2700±
			Yates ss. 200-300
			Seven Rivers fm. 350±
			Queen fm. 400±
			Grayburg fm. 300±
		San Andres fm. 15-400	San Andres ls. 400-1200; Bone Spg. ls. 2500±
		Glorieta ss. 175-500	Glorieta ss. 10-100
		Yeso fm. 750±; Sangre de Cristo fm. 250-1800	Yeso fm. 1750-2350; Upper Yeso 960-1400
		Abo fm. 1000±	Abo fm. 900; Lower Leonard lss. 1040-1550
			Hueco (?) ls. 350
PENNSYLVANIAN	Hermosa fm. 1000-1300	Madera fm. 0-2000	Ls. and dol. 525-1200
	Molas fm. 30-70	Sandia fm. 0-430	
MISSISSIPPIAN	Leadville ls. (Leadville ls. and Ouray ls. 150-200)		Lake Valley ls. 230-475
			Caballero siliceous sh. 318-510
DEVONIAN	Ouray ls.		Cherty ls. and dol. 600-1470
	Elbert fm. 150±		
SILURIAN			
ORDOVICIAN			Montoya ls. 300-425
			Simpson fm. 580-1060
			Ellenburger fm. 300-445
CAMBRIAN	Ignacio quartzite 2+		
PRE-CAMBRIAN	Granite and schist	Granite, schist and quartzite	Granite, diabase (?), and quartzite

Fig. 2—Generalized correlation of geologic formations in northern and southeastern New Mexico

consider an annual oil production of nearly 40,000,000 bbl. anything less than excellent evidence. It is of interest to note, in view of the variability of the sediments mentioned above, that indications of oil are present in sandstones, bedded limestones, and massive reef limestones.

Thirdly, there are at least five "layers of geology" separated by regional unconformities: Tertiary, Triassic, Permian, Pennsylvanian, and pre-Pennsylvanian. The sediments and their attitudes within each layer are different from those of the others. The Tertiary and Triassic layers have been tried and found wanting—in part because much of their sediments are nonmarine. The Permian layer has produced well over 400,000,000 bbl. of oil. The pre-Permian layers are now being actively prospected, and promising production has already been secured (R. E. King, 1945).

Wedge belts of porosity are well represented. An excellent example on a small scale is the so-called "sand belt of southeastern Lea County, where oil has accumulated in sand stones that wedge out updip toward the east (Denham and Dougherty, 1941; Bates and others, 1942, pp. 230-235). Other pools have formed where porous zones, either in sandstones or porous limestones, wedge out—generally, as in the sand belt, in an east, northeast, or north direction, away from the Delaware basin enclosed by the Capitan reef. Indeed, as Levorsen (1943, Fig. 9) points out, the whole arc of oil fields extending from southeast Lea County nearly to Carlsbad may be considered to lie along a regional wedging out of porosity away from the Delaware basin and toward the more compact and partly nonmarine sediments to the east, north and west.

While there are no evidences of favorable geologic structure at the surface or in the highest layer of geology, there is much evidence at depth. One has only to look at a subsurface contour map of the Hobbs or Eunice-Monument fields to appreciate this.

We arrive, then, at the more or less obvious conclusion that there are definitely possibilities of future oil production in the present producing area of southeastern New Mexico. In fact, new pools are constantly being discovered in Permian rocks, and the prospects in the pre-Permian appear to be excellent.

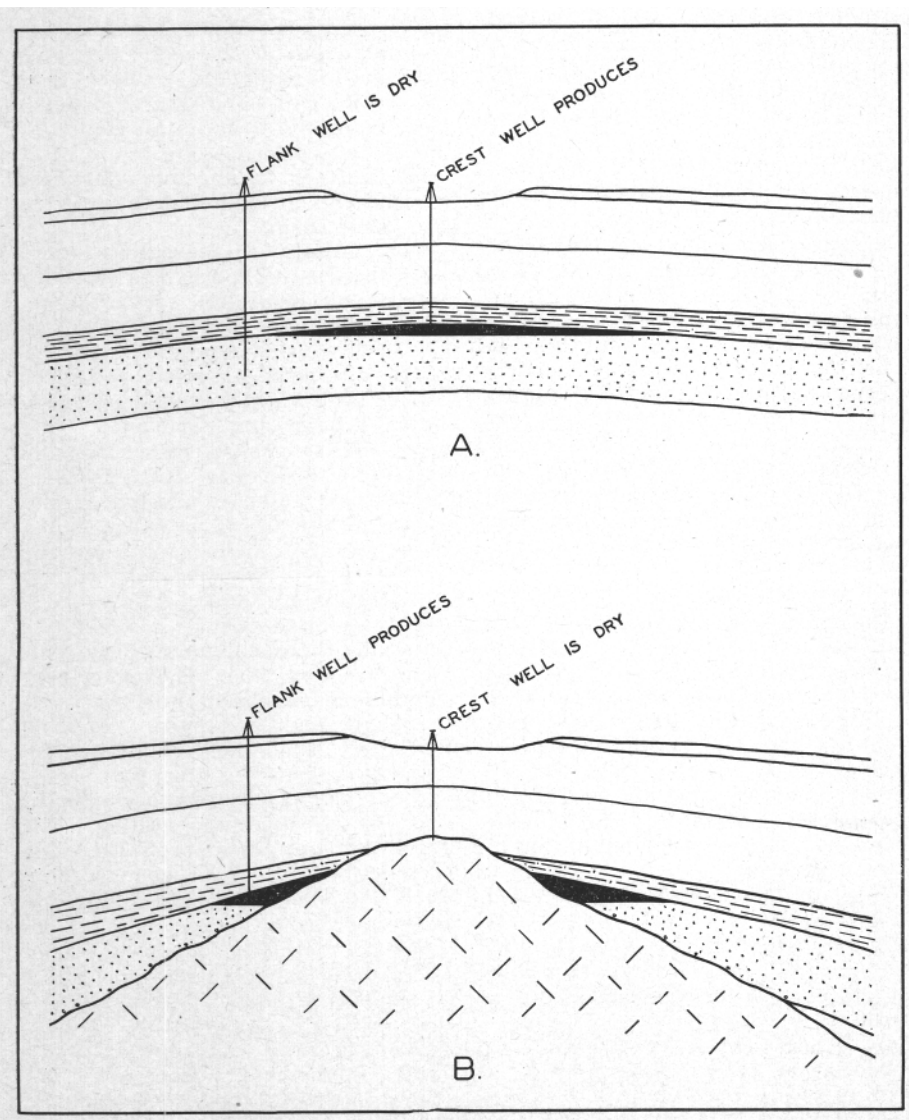

Fig. 3—Hypothetical cross sections. A—through a true anticline. B—through a buried pre-Cambrian hill. Surface expression of A and B are identical

Area 2

Consider now a rectangular area adjacent to Area 1 on the west (Fig. 1). Included in it are the Guadalupe Mountains and foothills, the Sacramento Mountains and foothills, Crow Flat west of the Guadalupes, and a wide area of mesas still farther west.

Several thousand feet of sedimentary rocks are present over all the area except possibly parts of the mesa country in the southwest and parts of the Sacramento Range. Even in these places there are apparently between 1,900 and 4,000 ft. of sediments above the pre-Cambrian basement. The beds are nonmetamorphosed. A combination of factors, however, seems to rule out much of the Permian strata from oil possibilities. The equivalents of sediments that produce oil in and above the reef zone east of Carlsbad—the Seven Rivers, Queen, and Grayburg formations (Fig. 2)—have been drilled at numerous places in the Guadalupe foothills and have been found to consist dominantly of uniform dense bedded limestone; the subcriterion of variation in sediments is lacking. Over the rest of the area these beds have been removed by erosion, and the underlying San Andres limestone, that also produces oil to the east, is exposed at the surface. Consequently we will have to consider possibilities in lower San Andres and older beds.

Immediately, however, we are faced with the question, are the lower Permian strata marine? So far as we know, they are marine in roughly the eastern half of the area; westward they grade laterally into such unfavorable shallow-water or continental types of rock as gypsum, silty red shale, and arkose.

Turning for a moment to the subject of reefs, it has been shown (P. B. King, 1942, Fig. 2) that around the Delaware basin the upper, younger reef masses are found on the rim of the basin, and the lower, older reef masses are progressively farther back, toward the area in which we are now interested. It has occurred to some geologists that possibly reefs in older beds than those forming the Capitan reef—say in the Yeso formation beneath the San Andres limestone—may be encountered by drilling to moderate depths in the Guadalupe Mountains.

Moving downward in the section, across a regional unconformity into Pennsylvanian and older strata, we find our knowledge much less complete; but nevertheless certain favorable factors appear. Beds of Pennsylvanian, Mississippian, Devonian, Silurian, and Ordovician ages seem to be marine. They present a rather variable lithology. They have not been regionally metamorphosed; they are thick enough to produce oil; and certain of them contain reefs. Laudon and Bowsher (1941) have shown the existence of quite sizable limestone-reef masses in Mississippian rocks exposed on the west escarpment of the Sacramento Mountains. It is possible that Mississippian reefs might be encountered by the drill down the dip toward the east.

Evidences of oil and gas in Area 2 range from slight to nil. Slight shows have been reported from wildcat tests—which, it might be noted, are extremely few and far between. No oil seeps have been reported. Unconformities, with their intervening layers of geology, certainly exist. The one at the base of the Permian may be seen beveling Pennsylvanian sediments in the Sacramento Mountains; possibly truncated Pennsylvanian structures may be found in the subsurface toward the east. Other regional unconformities are present in the lower section. Evidence on wedge belts of porosity is meager, in both Permian and pre-Permian strata.

Known structures in this area include a prominent one along the Huapache monocline that forms the east edge of the Guadalupes, and numerous large ones in the Sacramento foothills from south of Pinon north to the Hondo Valley. There is even some evidence of west closure on the whole Sacramento Mountain mass, which may turn out on further study to be an irregular dome rather than a simple block dipping uniformly eastward.

The application of the five criteria to this part of New Mexico definitely indicates future possibilities. These are probably poorest in the mesa country west of the Guadalupe Mountains and along the west fronts of these mountains and the Sacramentos; they are better in the eastern parts of the mountain ranges and in the bordering foothills.

Area 3

We may now consider a much larger region—one that embraces some 34,000 sq. miles of deserts, plateaus, and mountains. In it are included the western part of the state from the Mexican boundary north to approximately the latitude of Albuquerque (Fig. 1).

In discussing the sedimentary rocks of this large region we are forced to proceed with caution, for there are great areas about whose sediments little is known. Whereas the sediments have been studied intensively in certain mining districts—for example, the Organ Mountain, Silver City, and Lordsburg districts—and have been described rather disconnectedly from surface outcrops in some of the mountain ranges, veryfew wildcat tests have been drilled and consequently we lack the broad subsurface information that we have in other parts of the state. It is impossible to examine the sediments at the surface, for over four-fifths of the area they are covered by thick alluvial deposits and lava flows.

Notwithstanding these limitations, we can safely make certain generalities regarding the layer of geology between the base of the alluvium and the top of the pre-Cambrian. The sediments, for one thing, become thinner toward the west. Whereas in the San Andres and Organ Mountains, in the eastern part of the area, they total some 5,000 ft. in thickness, in the Silver City mining district, in the western part, they are only about 2,500 ft. thick. All the Paleozoic *systems,* except possibly the Cambrian, are represented; and there are Cretaceous strata in the eastern part of the region. All these rocks except the Abo and Yeso formations of Permian age are marine, and they are rather variable in composition. But they cannot be considered untouched by metamorphism; they have been intruded, silicified, folded, faulted, and intensely mineralized in many of the outcropping areas. We can only surmise that in the inaccessible depths, below the valley fill and lava flows, these rocks may likewise be much deformed, contact metamorphosed, and impregnated with introduced mineral matter.

The Tertiary and Quaternary sediments that fill basins in the older rocks to a thickness of several thousand feet in places consist chiefly of unconsolidated sands and gravels. Limestones and appreciable amounts of organic matter are, so far as known, notably absent. The beds are not marine but are of continental origin.

Evidences of oil and gas are confined to the eastern part of the area. Slight shows were logged in a deep test in the Tularosa basin, and an oil seep is reported in southern Jornada del Muerto.

Unconformities are present in such numbers as to divide the rocks into perhaps too many layers of geology. A recent report on the Silver City mining area (Entwistle, 1944) lists eight major unconformities in a thickness of 2,700 ft. of strata. Not all these breaks are angular, but nevertheless each represents changing sedimentary and environmental conditions.

The existence and alignment of wedge belts of porosity in the area is problematical. Both this matter and the possible presence of favorable structures will have to await future work.

It seems, then, a reasonable conclusion that the oil possibilities of southwestern and central western New Mexico are relatively slight—at least with our present knowledge. Two large structural features on theeast side of the region, the Tularosa Valley and Jornada del Muerto, may prove to have the requisite sedimentary section and structural conditions; but even these areas do not at present appear very encouraging. The remainder of the region must be classified as relatively unfavorable.

Area 4

An area of some 10,000 sq. mi. in the northwestern part of the state (Fig. 1) is underlain by a regional geologic feature known as the San Juan basin. This basin extends into Colorado and Utah, but the main part of it lies in New Mexico. It is bounded by the Fort Defiance uplift on the west, the Zuni Mountains on the south, the Nacimiento Range on the east, and the San Juan Mountains on the northeast. Only toward the northwest is the basin without an enclosing mountain mass.

In 1939 a deep test was drilled on the Rattlesnake anticline in the western part of the basin, and it was found that there are 7,400 ft. of sediments between the Tocito sandstone of Upper Cretaceous age at the surface and the Ignacio quartzite of Cambrian age at total depth of the well. As some 6,600 ft. of sediments younger than the Tocito can be measured in surface exposures toward the center of the basin, we arrive at a figure of at least 14,000 ft. for the total thickness of sediments in the middle part of the San Juan basin.

Very briefly, these sediments are constituted as follows: The Tertiary consists of about 2,000 ft. of fresh-water sandstones and shales; the Upper Cretaceous, of approximately 6,400 ft. of alternating marine and non-marine sandstones and shales; the Jurassic, Triassic and Permian, of red-beds and sandstones of continental origin to a thickness of about 4,000 ft.; the Pennsylvanian, Mississippian, and Devonian, of 1,600 ft. of marine limestone; and the Cambrian, of quartzite. Ordovician and Silurian rocks are apparently absent.

Taking the section as a whole, we can make these statements: The sediments are very thick. They show considerable variation in lithology — although it might be noted in passing that there is no thick evaporite section, as in southeastern New Mexico, nor has any reefing been identified in the limestone section. The strata are not metamorphosed. The presence of intrusions such as Ship Rock has apparently had no appreciable effect on the sediments, although there are those who believe the Ship Rock intrusion has had some effect on the oil in the neighboring Rattlesnake pool.

Evidences of oil and gas are abundant. Commercial production is obtained from 12 localities, and oil and gas shows ranging from slight to considerable have been encountered at many other places (Bates and others, 1942, pp. 88-90). Production comes from sandstones in the Upper Cretaceous and from limestones in the Paleozoic part of the section.

The Rattlesnake pool is of special interest in this connection. For one thing, it lies within 3 miles of an igneous intrusion. Secondly, it has a three-fold pay section: oil from the Dakota sandstone, oil from the Hermosa limestone, and gas from the Ouray-Leadville limestone sequence (Bass, 1944). Thirdly, the oil from the Dakota is of exceptionally high gravity, running as high as 76° A.P.I. when it comes from the well. Lastly, the gas obtained from the Ouray-Leadville has a high content of helium.

There is an angular unconformity at the base of the Tertiary; of the regional unconformities in the pre-Tertiary sediments none is angular except locally. Even though, however, all the sediments from Cambrian to Upper Cretaceous are essentially parallel, layers of geology are quite distinct, and have, as noted above, a direct bearing on oil and gas possibilities. In the upper layer that produces, the Upper Cretaceous sandstone and shale sequence, there are dozens of minor, local unconformities. They produce a section consisting of thin sheet sandstones that wedge out, thicken and thin, and overlap in the enclosing mass of shales (Sears, Hunt and Hendricks, 1941). An exception to this tendency of sandstones to appear and disappear along local unconformities is the Dakota sandstone, which is continuous through the entire area and, indeed, through much of the Rocky Mountain region and the plains to the east.

Owing to the presence of the numerous local unconformities in the Upper Cretaceous section, there are a like number of small local wedge belts of porosity. Oil or gas, or both, are being produced from seven of these stratigraphic traps; an example is the Bloomfield pool, where oil and gas have accumulated in shale-sealed lenses of sand in the Farmington sandstone.

Regional and highly interesting wedge belts of porosity undoubtedly exist in the Pennsylvanian and older limestones. Although we know from deep drilling in the basin that these limestones are many hundreds of feet thick and contain evidences of oil and gas, we also know that on the surrounding ancient land masses — the Zuni Mountains, for example— they are very thin or absent and younger strata are close to or directly on the pre-Cambrian. The conclusion cannot be escaped that the marine limestones are overlapped by younger strata on the flanks of the old land masses. It would seem well worth while to investigate the possibilities of testing these limestones around the margins of the basin.

No less than 45 geologic structures have been recognized in the New Mex-ico part of the San Juan basin. Two-thirds of these have been drilled, at least as far as the Dakota sandstone, and seven have made commercial production. So far as the upper productive layer is concerned, structure is undoubtedly the most important single factor in oil and gas accumulation.

But we cannot escape noticing that the Upper Cretaceous formations of the San Juan basin, even with their local stratigraphic traps and their abundant structures, account for only a little more than 1 per cent of New Mexico's annual production. Why is this? From a region underlain by some 7,000 ft. of shales high in organic matter, interbedded with porous sandstones that lens out and have been folded into suitable structures, why are the results to date so meager?

Disregarding the nongeologic factor of retarded development due to distance from markets, there seems to be an answer. In the first place, according to a report by E. W. Krampert (1934), fully 90 per cent of the structures in the Rocky Mountain region as a whole have been flushed of their oil and gas by migrating underground waters. Krampert says: "The otherwise favorable structures about the rim of the San Juan basin in northwestern New Mexico are generally barren excepting the northwest end, which, being topographically low, is the spillway for waters entering the reservoir sands at their outcrops on the periphery of the basin. The waters move from the outcrops adjoining the mountains through the structures and against the direction of oil migration from the basin to these structures. The oil entering the reservoir sands is carried northwestward toward the outlet, where some of it is trapped in suitable structures. The water escapes from the topographically low outcrops through springs." Whether or not this analysis is accurate—and it does not seem to take into account the commercial accumulations in the southern part of the basin, as at the Hospah dome in McKinley County—there is little doubt that the flushing action of underground waters in the San Juan basin has rendered many of the pools smaller than they might have been and has encroached heavily on the productive structures.

According to Levorsen (1943, p. 902), "Theoretically, the Dakota group of sandstones . . . of the Rocky Mountain region should be one of the most prolific oil-and-gas-producing formations of the United States." In attempting to account for its relatively poor showing, he points out that the large volumes of oil and gas that might be expected to have accumulated in the Dakota before the mountain-making movements at the end of the Cretaceous time would have been removed by erosion when the Dakota and overlying rocks, having been arched into open folds containing oil,were beveled off to make the profound angular unconformity now seen at the base of the Tertiary. Thus, only small remnants of the original oil and gas content were left in the Dakota, in regionally low areas such as the San Juan basin.

Structures in the lower productive layer of geology, the Paleozoic limestones, have given results of enough interest to justify further exploration. The Rattlesnake anticline contains, as noted above, oil in the Hermosa formation and helium gas in the Ouray-Leadville limestones; the Tocito dome gave a large show of gas from the Ouray - Leadville; and the Barker dome contains commercial amounts of gas in Pennsylvanian beds. If, around the edges of the basin, structures can be found that are superimposed on the regional wedging out of these Paleozoic strata, such structures can be expected to produce oil and gas in larger amounts than have heretofore been recovered in the San Juan basin.

Area 5

This area includes all or part of 20 counties (Fig. 1), and embraces the Sangre de Cristo Mountains and foothills, Glorieta Mesa, the Estancia Valley, the Pedernal Hills, Chupadera Mesa, and the great area of plains and mesas lying to the south and east. It is a varied region, both geologically and topographically.

The sedimentary rocks range in age from Pennsylvanian to Recent; pre-Pennsylvanian sediments are apparently absent. The thickness varies widely. It is, of course, zero where pre-Cambrian rocks are exposed in the Sangre de Cristo Mountains, the Pedernal Hills, and small pre-Cambrian outcrops northwest and southeast of the Pedernals; also in the southwest part of the area where Tertiary intrusives are exposed in the Gallina and Capitan Mountains and Sierra Blanca. Away from the mountains, the sedimentary cover in the northern two-thirds of the area ranges from less than 2,500 ft. over some buried pre-Cambrian hills to as much as 6,700 ft. over others. Thicknesses in the intervening troughs are unknown but must be in the vicinity of 8,000 or 9,000 ft. A test in the southeastern corner of the area penetrated 7,920 ft. of sediments before reaching the pre-Cambrian.

The wide range in sedimentary thickness in Area 5 results from the roughness of the pre-Cambrian surface on which the sediments rest. In the northern part of the area this surface is mountainous; in the central part, hilly; and in the southern part gently sloping toward the depths of the Permian basin to the southeast. The Sangre de Cristo Mountains and the buried Sierra Grande Arch on the north give way southward to a wide area that contains dozens of buried pre - Cambrian hills ("structures"), both isolated and in clusters, and these in turn seem to become less prominent and more deeply buried to the southeast. The highly uneven character of the pre-Cambrian surface is probably the result of regional normal faulting - some of which may have taken place as early as medial Pennsylvanian time and some of which was much later-combined with the erosion that would naturally follow.

The character of the sediments is highly variable. Marine limestone, shale, and sandstone; lagoonal gypsum and silt; and continental red-beds and arkose are all represented. The rocks are nonmetamorphosed.

Evidences of oil and gas are numerous. Surface seeps and appreciable shows in shallow water wells have been observed in the upper Pecos Valley (Read and Andrews, 1944), and seeps have been found in Pennsylvanian limestones in the Sangre de Cristo foothills west of Las Vegas. Shows have also been reported from several wildcat tests drilled for oil in the plains country to the east. There is a saturated oil sand near Santa Rosa, which has been used as an asphalt rock. A gas seep has been reported from a creek bed in Union County; a sample of the gas was analyzed by the U. S. Bureau of Mines and was found to be a hydrocarbon gas similar in composition to that from the Borger field in the Texas Panhandle (Bates and others, 1942, p. 155). The occurrence of carbon dioxide gas in commercial quantities at two localities in northeastern New Mexico is evidence that adequate porosity exists in certain areas. Finally, there are thick black shales in the Pennsylvanian section of the Sangre de Cristo Mountains - presumably good source rocks where buried.

Unconformities are present and highly important from the point of view of oil and gas possibilities. As elsewhere, they separate the layers of geology. These consist roughly of Cretaceous marine sandstone and shale; Jurassic and Triassic redbeds; Permian redbeds, evaporites, and limestones; and Pennsylvanian arkose and marine limestones. The Cretaceous sandstones and shales are present only in the area northeast of Las Vegas. Besides separating the layers, however, the unconformities are important because they all eventually merge with the profound unconformity at the top of the pre-Cambrian. This means that, where a pre-Cambrian high extends up through the sediments, the lower layers of geology are progressively overlapped by the higher ones, along the regional unconformities.

Layers of geology that may produce oil and gas in Area 5 are not numerous. The one that has the widest regional extent is the marine limestone of Pennsylvanian age. From surface evidence, including seeps, and from shows in wells, this is a relatively good prospective zone. Two others, about which less is known, are the thick arkoses-the so-called granite wash-of the upper Pennsylvanian and lower Permian, and the Dakota sandstone. The arkoses are of interest because they are in part porous, they are associated with possible source beds in the limestones and shales, and they are thought to overlap into pre-Cambrian masses; comparison is suggested between this part of the section in northeastern New Mexico and the section in the Panhandle oil and gas field near Amarillo. Possibilities from the Dakota sandstone are problematical; however, it is buried between considerable thicknesses of Cretaceous shale in an area in central Colfax County and should be worth testing.

The preceding discussion of unconformities and overlapping relations logically brings us to the subject of wedges of porosity. That such wedge belts are present and largely unexplored in northeastern New Mexico cannot be overemphasized. Many tests have been drilled in the plains area, and to date they have all been dry; but they have all been located on the top of apparent structures. Until recently it was not realized that many of these so-called structures are in reality not anticlinal folds (Fig. 3A), but reflections of pre-Cambrian highs (Fig. 3B). Consequently it is only natural that wells drilled on their crests should find a relatively thin and unfavorable sedimentary succession and should then enter pre-Cambrian schist or granite. But in proportion as the possibilities of conventional anticlinal production are reduced, the possibilities of production from wedging-out strata on the flanks of these highs is stepped up. More than 2 years ago Levorsen (1943, Fig. 17) pointed out that there are miles of unexplored wedge-belts of porosity around the Pedernal pre-Cambrian mass; and around every buried knob or ridge of pre-Cambrian rock in northeastern New Mexico we may expect to find Pennsylvanian limestones and Permo - Pennsylvanian arkoses wedging out. Surely a more stimulating set of wedge-belts of porosity was never set before the oil and gas operator!

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