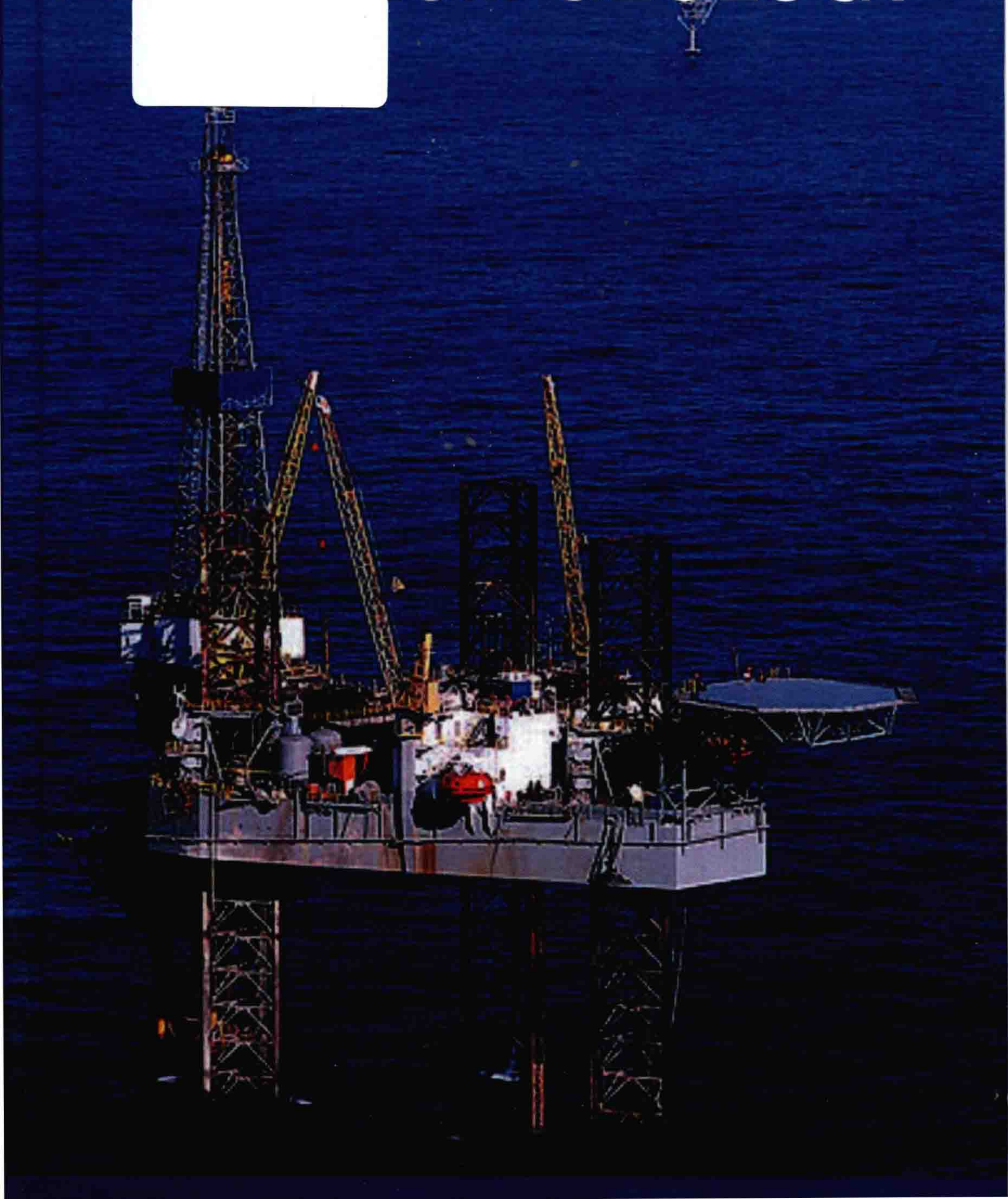
P. A. Rodgers

# Handbook of PETROLEUM GEOLOGY



Handbook of
# PETROLEUM GEOLOGY

Volume 2

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# Handbook of
# PETROLEUM GEOLOGY

# Preface

Exceptional progress has been made by geologists and other scientists in petroleum discovery methods during the past twenty-five years, even though it has become increasingly more difficult each year to find new reserves. Great advance have also been made in solving some of the more important problems of petroleum geology, such as the nature of source beds of petroleum, biochemical and geochemical changes in source materials, migration of petroleum, and origin and classification of oil and gas reservoirs. Continued active cooperation of geologists, engineers, chemists, physicists, and biologists in necessary to completely solve these problems.

In this book, for the first time, the stratigraphic and geographic distribution of petroleum is given in detail. Emphasis has been placed on principles of petroleum geology, the mode of origin of oil and gas structures, and petroleum geology, the mode of origin of oil and gas structures, and petroleum discovery methods. The oil and gas field described in this book have been selected from various petroliferous provinces in the world, and are grouped according to their origin. The writer believes a correct structural and stratigraphic interpretation of an oil or gas field early in its history is necessary for an efficient development and producing program.

The growth of the oil industry is one of the outstanding features of modern civilization. The story behind it is a fascinating study of the gradual development of perfect co-operation between science and engineering. Yet it was some time before tins was achieved; indeed it is interesting to note that until the advent of the present century little use was made of geology in oilfield exploration. During this same period, however, the foundations of the science were being well and truly laid and many of the outstanding principles of petroleum geology were enunciated.

The present century ushered in a greatly increased demand for oil. Drilling had to go deeper, and new areas of exploration and development were opened up. The old haphazard methods of searching for oil were gradually abandoned, and in their place science came to play a preponderant part in the guidance of drilling. The petroleum geologist became the spearhead of exploration, first of all with relatively simple tools, but later on with instruments of increasing accuracy and eventually with the aid of geophysics.

During this period of preoccupation with the main problem of increasing oil supplies, it is curious to note that there was a tendency to neglect for the time being the study of basic principles. The concentration of effort was largely on developing new tools of exploration. However, this position has been redressed more recently by the very fact that the great enrichment of the literature due to a wider knowledge of the world's oil pools has automatically led to a revival of interest m the fundamentals of the science. Petroleum geology has become less and less a mere study of structure, and more and more a study of the stratigraphic history of an area, on the principle that the life-history of the oilfields is interwoven with the history of the rocks.

The very complexity of the problems, and the fact that the answers lie not in one science alone, but often in a combined study of several sciences, has been somewhat of a hindrance to progress, and has resulted in an uneven state of knowledge on the various problems. On some subjects, such as the study of the movement of fluids through the sediments, and the principles governing the accumulation of gas and oil, a considerable measure of agreement has been reached, but other problems, such as the actual origin of the oil itself, are still highly debatable. There is therefore room for a new volume which attempts to clear the ground on some of these basic principles, and to focus attention on the more important opinions which have been formulated on different aspects of the problems.

This book has been written primarily for those who are deeply interested in the basic principles of petroleum geology. Its author is one who has studied his subject with infinite patience and with a wide knowledge of the literature. He brings to bear on the problems a detached mind which is equally at home with geology and the basic sciences. Those who read it must not expect to find ready-made solutions to every problem. That is not its purpose, but the aim is rather to stimulate interest and discussion with a view to further progress in the science.

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## PART-II
## FUNDAMENTALS OF PETROLEUM GEOLOGY

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# Chapter 15

## Buried Hills

### *Definition*

Buried hills are those structures which have been caused by the presence of an underlying buried hill distinctly different from the overlying sediments. The closure of such structures may be caused by several factors which include the unequal compaction of the overlying sediments, original dip of the sediments adjacent to the hills, and vertical uplift.

Buried hills vary considerably in composition in different part of the world. The pre-Cambrian buried hills of Kansas consist of granite, syenite, gneiss, schist, and quartzite. Apparently granite is the commonest of these rock types. Buried hills of pre-Cambrian granite have also been noted in northeastern Oklahoma by land and by Ham and Dott. In southern Oklahoma some of the buried hills are composed of Ordovician limestone. In the Texas Panhandle field they are composed of coarse red granite in a continuous series more than 125 miles in length.

There are buried hills of schist underlying some oil fields in the Los Angeles basin of California. Some pre-Cambrian buried hills have been observed in Ontario and Quebec, some of which underlie gas fields. Numerous pre-Cambrian hills projecting into overlying Cambrian and Ordovician beds have been observed in Missouri. Some of the oil fields of Egypt are underlain by buried hills of granite.

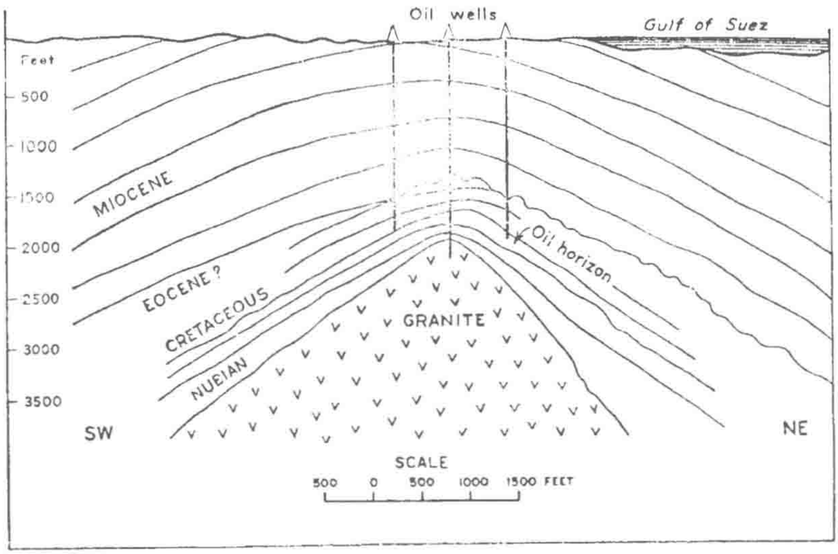


**Fig. 90.** Cross section of the Hurghada oil field, Egypt, showing the buried ridge and the overlying anticline.

## PLAYA DEL REY FIELD

### *Location and History*

The Playa del Rey oil field is located along the Pacific Ocean about 15 miles west-southwest of Los Angeles and partly within the limits of Venice, Los Angeles County, California. The field was discovered as a result of subsurface correlations of foraminiferal zones in wildcat wells in the area. The discovery well was completed in 1929 at a depth of 6,199 feet, with an initial production of 2 ,000 barrels of oil. The production was from the lower zone just above the schist. The early development of the field was rapid because of a town lot drilling campaign. The upper producing zone was discovered in 1950. The maximum daily production for the field was reached in December, 1930.

### *Structure*

The structure of the Playa del Rey field is anticlinal with the elongate axis trending in a northwest-southeast direction. The entire structure is underlain by a buried hill of schist. It is believed the anticlinal structure originated by differential compaction of the sediments over the buried hill. The buried hill of schist has a relief of 1,400 feet in a minimum distance of 3,000 feet.

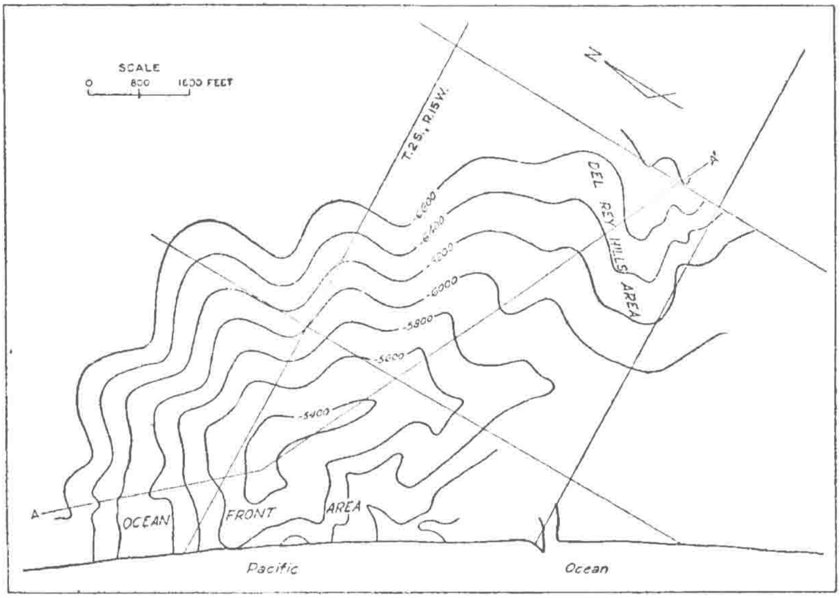


**Fig. 91.** Subrusface contour map of the Playa del Rey field, Los Angeles County, California, on top of the buried hill of schist. See figure 33 for the regional structural position of this field.

## *Producing Formations*

There are two zones productive of oil in the field. An upper zone, in the Repetto formation of Pliocene age, has a thickness of 1,100 feet. It consists of many indivdual sandstone beds which contain oil and gas and shale. The sandstone beds make up from 10 to 20 per cent of the zone. The top of this zone is encountered at a depth of 3,400 feet in the higher part of the structure.

**Table 52. Stratigraphic Section of Playa Del Rey Field.**

| *Age* | *Formation or Group* | *Thickness in Feet* |
|---|---|---|
| Pleistocene | Sand, clay and gravel | 375-425 |
| Upper Pliocene | Pico shale and sand | 2,000-3,000 |
| Lower Pliocene | Repetto shl., sdy. sh., and ss. | 2,400-2,800 |
| Upper Micocene | Modelo sh. and sdy. cong. | 350-1,135 |
| Jurassic (?) | Franciscan schist | |

The lower zone lies on the eroded surface of the buried hill of schist and below a nodular black shale. It has a thickness of 0-235 feet and occurs in embayments believed to be submerged drainage depressions in the surface of the schist. It is absent on the highest part of the buried hill. The lower zone consists of angular fragments of schist embedded in coarse sandstone. It occurs between 5,400 and 6,100 feet in depth. It is upper Miocene in age and part of the Modelo formation.

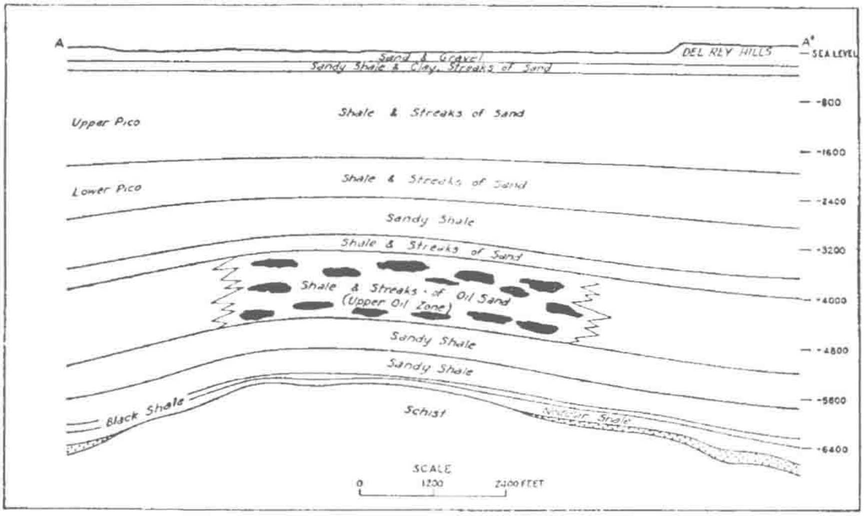


Fig. 92. Northwest-southeast cross section of the Playa del Rey field, Los Angeles County, California, along line A-A′ of figure 91.

## *Production*

The Playa del Rey field produced 51,490,630 barrels of oil from 670 acres to the end of 1945. During that year it produced 898,525 barrels. There were 125 producing wells in 1945, of which 122 were on artificial lift. In January, 1932, there were 269 producing wells.

The gravity of the oil from the upper zone ranges from 19° to 21° and from the lower zone from 21° to 24° A.P.I.

## THE TEXAS PANHANDLE FIELD

### *Location and History*

The Texas Panhandle oil and gas field is one of the largest continuous producing areas in the world. It has a productive area more than 120 miles in length and 35 miles in maximum width. It is located north and northeast of Amarillo in parts of Collingsworth, Wheeler, Gray, Carson, Potter, Hutchinson, Moore, and Hartley counties, Texas.

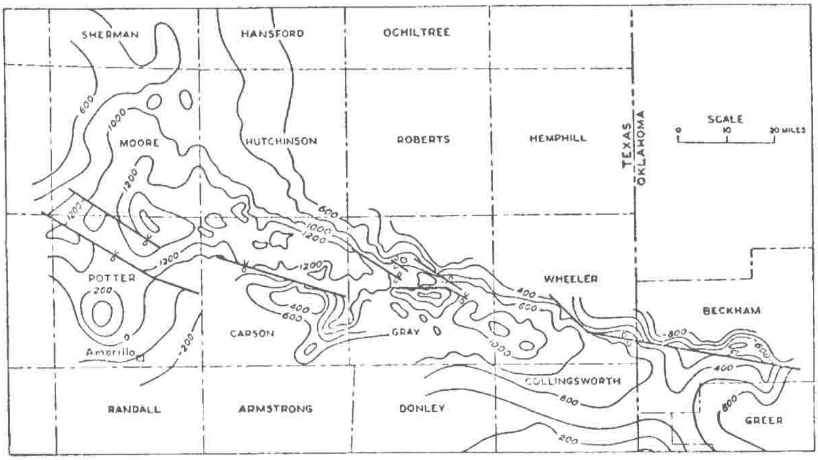


**Fig. 93.** Structure contour map of the Texas Panhandle field on the top of the "Big lime" of Permian age.

Anticlinal structures in the Texas Panhandle field were discovered by Charles N. Gould, in 1905, who mapped the area along the Canadian River. He noted the well-marked anticlines and synclines in the red beds in the area north of Amarillo. The discovery well of the field was drilled upon the recommendation of Dr. Gould on a surface anticlinal structure he had mapped on Permian outcrops in northern Potter County. The structure was later called the John Ray dome. The discovery well was completed as a large gas well at a depth of 2,605 feet in the Permian "Big lime" section.

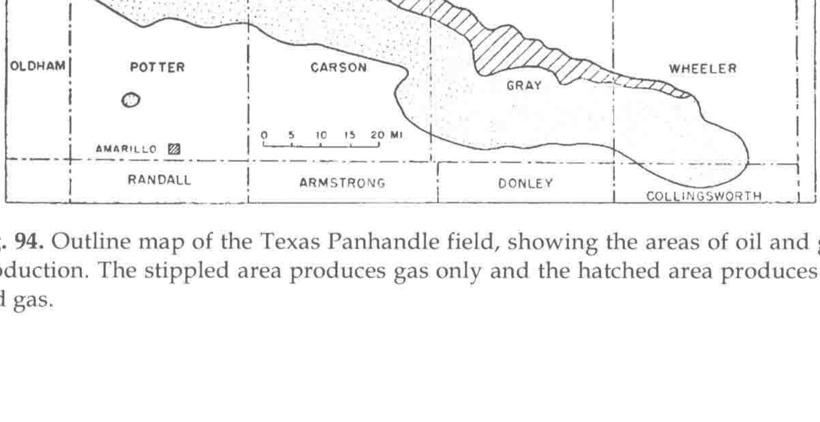


**Fig. 94.** Outline map of the Texas Panhandle field, showing the areas of oil and gas production. The stippled area produces gas only and the hatched area produces oil and gas.

The discovery of large quantities of gas in the Texas Panhandle attracted the attention of many oil and gas companies. Oil was first discovered in 1921 in the Burnett pool of northern Carson and southern Hutchinson counties. Extensive development of the oil fields along the north side of the Texas Panhandle field started after the completion of several large oil wells early in 1925. The development of the oil and gas producing areas of the field has progressed steadily, but the limits of the field have yet to be defined in several places. It is believed the ultimate combined oil and gas productive acreage will total 2,560,000 acres. More than 2,300 gas wells and 6,200 oil wells have been completed in the field.

### *Structure*

The major structural feature of the Texas Panhandle field is the buried Amarillo granite ridge. It trends in a northwest-southeast direction for more than no miles. Little is known about the granite of the ridge because so few wells have penetrated the thick beds of arkose which overlie it. It is generally composed of coarse red feldspar and quartz with the common accessory minerals. Diorite and diabase dikes cut the granite in some areas. In Wheeler and Potter counties the top of the granite ridge is at about 1,100 feet above sea level, although several buried monadnocks have been found which rise to about 1,300 feet above sea level. The north flank of the granite ridge slopes at the rate of about 100 feet per mile into the Anadarko basin. The south flank is bounded by faults in parts of Potter and Carson counties. The throw of the Carson County fault is about 500 feet on the top of the "Big lime." There are also some faults on the north flank of the granite ridge. All of the faults except one are upthrown on the granite ridge side and downthrown toward the basin.

The oldest sedimentary rocks which cover the granite ridge are those of the producing zone known as "B zone," which is of Permian age. This zone covers the entire ridge except for a few small areas where granite peaks project above the general surface.

Penn-sylvanian, Mississippian, and Ordovician rocks have been found on the north flank of the ridge in the Anadarko basin. The younger Permian rocks which extend entirely over the granite ridge are somewhat thinner than a normal section because of erosion and differential compaction subsequent to deposition.

The structure of the Permian "Big lime" in the field is that of alternating broad, flat domes and saddles. There are some closed structural basins. The formations dip more steeply on the northeast than on the southwest flanks of the granite ridge.

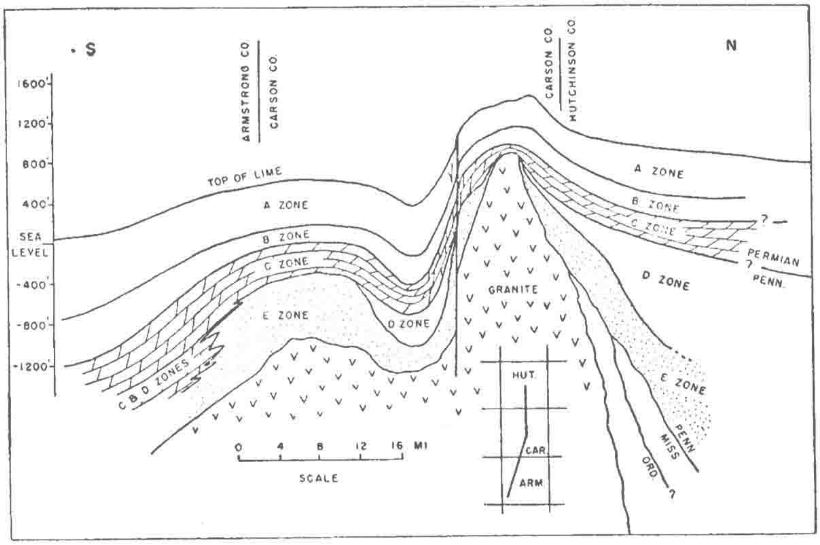


**Fig. 95.** Transverse north-south section of the Texas Panhandle field showing the relationship between the buried granite ridge and the overlying sediments.

## *Producing Formations*

There are four important producing zones in the Texas Panhandle field which are definite lithologic units known from top to bottom as "B," "C," "D," and "E" zones. Two of the zones, "C" and "E," are subdivided into subzones. The two upper zones are of Permian age and the two lower zones of Pennsylvanian age.

The oil or gas productivity of any zone in the field is based upon two factors: (1) the porosity of the zone; and (2) the relation of the zone to the gas-oil and oil-water contact surfaces. The water, oil, and gas in this field may occur in several inclined lithologic zones, with the oil-water contact and the gas-oil contact extending in a horizontal manner across the zones. Therefore, any porous zone which intersects the zone between the gas-oil and the oil-water contact surfaces will be productive of oil. The oil-water contact is normally found between sea level and 100 feet above sea level; however, it occurs at 100 feet below sea level in some areas. The oil-water contact is tilted and becomes progressively lower to the southeast. The depth of oil and gas production throughout the field varies from 2,000 to 3,100 feet.

*"B Zone"* This is the uppermost producing zone in the field and is the most widespread and uniform of the zones. It is the only zone which

overlaps the entire buried ridge. It occurs between the depths of 2,400 and 2,700 feet in the field. The "B zone" has a thickness of 150 feet throughout the field. The upper 80 feet consists of shaly dolomite and streaks of shale and anhydrite. The lower part of the zone consists of massive fine-grained granular dolomite with varying degrees of porosity. It is productive of gas and oil in different parts of the field.

"C *Zone.*" This zone occurs throughout the field except near the apex of the granite ridge. It lies upon granite where the underlying zones are absent. The thickness of the zone varies from 70 to 300 feet. It consists of medium-grained crinoidal and crystalline dolomite. It is oölitic in some areas, particularly in the West Pampa pool. It produces oil and gas.

*"D Zone"* This zone varies in thickness up to 300 feet. It does not cover the granite ridge, therefore it attains its best development on the flanks of the field. It consists of fine to coarse crystalline dolomite with varying amounts of arkose. The percentage of arkose varies both vertically and horizontally, reaching 100 per cent in local areas. This zone contains some streaks of shale and beds of limestone in certain parts of the field. It is productive of both oil and gas in the field.

**Table 53. Stratigraphic Section of texas panhandle field.**

| *Age* | *Formation or Group* | | *Thickness in Feet* |
|---|---|---|---|
| Tertiary | sands and gravels | | 0-100 |
| Triassic (?) | sandstone, sh., and gravel | | 200-350 |
| Permian | Quartermaster sh., ss., & gyp. | | 250-400 |
| | Whitehorse sh., ss., and gyp. | | 320-450 |
| | Blaine sh., gyp., and dol. | | 250-375 |
| | Clearfork sh., salt, and gyp. | | 1,350-1,475 |
| | Wichita-Albany | "A Zone" sh., dol., & anhy. | 350-450 |
| | | "B Zone" dol. | 130-140 |
| | | "C Zone" dol. | 0-300 |
| Pennsylvanian | Cisco | "D Zone" arkosic dol. | 0-300 |
| | | "E Zone" arkose, sh., & ls. | 0-1,000 |
| Pre-Cambrian | granite, diorite, and diabase | | |

*"E Zone"* This is the lowest of the oil and gas producing zones. It consists of arkose which grades into limestone on the flanks of the field. It contains red shale streaks and fragments of chert in certain areas. It varies in thickness up to 1,000 feet and is completely absent on top of the ridge in many areas. The sediments in this zone resulted from the erosion of the granite ridge.