A brief Geologic Sketch of the Delaware Basin

Anonymous

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A BRIEF GEOLOGIC SKETCH OF THE DELAWARE BASIN

The southern portion of the vast Permian Basin embraces two smaller but well-known important depressions, the Midland and Delaware Basins. The prolific oil-producing Central Basin Platform separates the two with the northwest-southeast trending Delaware Basin of southeastern New Mexico and west Texas lying to the west. The latter is notable in literature due largely to three conditions; (1) the thick accumulation of Ochoa age evaporites containing the world's largest deposits of potash minerals, (2) the thick sections of oil-producing Guadalupe age sands and dark carbonates and shales of Leonard age, and (3) the presence of Guadalupe reef deposits and their striking facies changes which cause considerable difficulty in correlating equivalent units in the fore-reef, reef, and back-reef areas. A columnar section of the Delaware Basin and a correlation chart indicating fore-reef, reef zone, and back-reef equivalents are included elsewhere in this guidebook.

The Delaware Basin is bordered by the Artesia-Vacuum Trend on the north, the Central Basin Platform on the east, the Glass, Davis and Apache Mountains on the south, and the Sierra Diablo Platform and Guadalupe Mountains on the west. It is frequently thought of as that area inclosed by the Capitan reef, however it must include the area back of the Capitan reef front into which the older and deeper lying basin sediments, Delaware Mountain Group sands (Guadalupe series) and the dark carbonates and shales of the Bone Spring (Leonard series), extend. These sediments have been penetrated by oil tests drilled in the so-called back-reef areas northwest of the northeastern prong of the Guadalupe Mountains, south of the Artesia-Vacuum Trend (Carlsbad Shelf), and west of the producing fields of the Central Basin Platform in New Mexico. They are well exposed in the Sitting Bull Falls area of Last Chance Canyon where it dissects the Huapache Flexure. Therefore, in its broader sense, the oval-shaped asymmetrical Delaware Basin comprises an area of approximately 12,000 square miles and measures some 100 miles in an east-west direction and 160 miles in a north-south direction.

Guadalupe reefing is generally considered to include the Goat Seep reef, equivalent to parts of the fore-reef Cherry Canyon sands and the back-reef San Andres carbonates, and the Capitan reef which is usually correlated with the fore-reef Bell Canyon sands and the back-reef Whitehorse section. The Victoria Peak "reef" is Leonard in age and is correlated with parts of the basinal Bone Spring formation and Yeso sediments of shelf facies. Newell, et al, define the Victoria Peak as a limestone bank deposit of bioclastic calcarenite rather than a reef. The Capitan reef zone completely incloses the basin proper except for a narrow opening at the south known as the Hovey Channel, a subsurface feature in Brewster County, Texas. The total length of the reef complex is approximately 400 miles. Surface exposures exist for a distance of 3 or 4 miles in the Apache Mountains in southern Culberson County, Texas; a distance of about 15 miles in the Glass Mountains of Brewster and Pecos Counties, Texas; and a distance of some 40 miles from Guadalupe Peak in extreme Culberson County, Texas, to a point near Carlsbad, Eddy County, New Mexico. Here, as the result of regional tilting during Cenozoic time, it disappears under the surface and remains covered all along the northern, eastern and southeastern rims of the basin. The Capitan reef, excluding the prolific deposits of reef talus generally included as part of the Capitan formation, averages about 1300 feet in vertical development according to Newell, et al, and measures from 1½ to 3½ miles in width where it outcrops along the northwestern rim of the Delaware Basin. Adams and Frenzel state that the width of the reef in the subsurface measures a maximum of 30 miles along the northern margins of the basin. During the different stages of growth, the Capitan reef built on its fore-reef detritus as it grew upward and obliquely basinward. Horizontal growth varied considerably resulting in the differences in widths mentioned above. Where horizontal growth lagged behind the general basinward advance of the reef, re-entrants were formed to modify the trend of the reef front and mark the positions of probable surge channels which furnished circulation between the basin and lagoonal areas. By contrast, predominate growth of the Goat Seep reef was vertical and did not spread very far basinward. Thus, biohermal reef-building processes as well as biostromal depositional processes were active, with but few interruptions, around the margins of the Delaware Basin from no later than San Andres time to the close of Tansill or Delaware Mountain time. Exposures of Leonard age "reefing" (Victoria Peak) have been mapped along the western margin of the Delaware Basin but Leonard age rocks having a reef origin are not generally recognized in the subsurface. Future exploration may well determine that a reef zone of

Leonard age rims the Delaware Basin in a similar manner to that of the Guadalupe.

Petroleum production is obtained from successively younger formational equivalents of the reef extending from the Artesia-Vacuum Trend and the Central Basin Platform basinward to the Capitan reef front. Conditions of porosity and permeability are apparently the controlling factor of oil accumulation, although production is often associated with small closures. The more favorable conditions of porosity and permeability appear to be on the shoreward side of the reef masses rather than within the reefs or on the basinward side.

The Delaware Basin is usually classified as a Permian feature, but the tectonic history of the region indicates that the general outline of the basin was conceived in late Pennsylvanian time as a result of orogenic movements coincident with the Marathon disturbance. It is generally agreed that regional subsidence in conjunction with broad arching, folding and faulting in Pennsylvanian time marked the beginning of the structural history of the Delaware Basin. Later rejuvenation took place along the same lines as those earlier movements. Wolfcamp beds, the first basin type sediments, were deposited upon an irregular Pennsylvanian surface, filling the low areas to create a comparatively flat surface upon which the Bone Spring dark carbonates and shales and Delaware Mountain Group sands were deposited. Downwarping of the basin area, accompanied by the development of flexures along the west side, continued during the deposition of these units. Additional evidence of continual adjustment of the basin area in response to sedimentation and structural forces is also found in the brecciated beds of the Wolfcamp and Leonard. These deposits, present around the margins of the basin, have been explained by Newell, et al, as the result of submarine slides occurring along a steeply sloping surface. By the end of Guadalupe time the margins of the Delaware Basin were clearly defined by the accumulation of reef deposits on the higher areas surrounding the basin. Deposition of the thick Ochoan evaporites is usually explained by the partial closing of the Hovey Channel to the south by reefing which restricted communication between the basin area and the open sea. Cenozoic eastward tilting of the basin shifted the deepest part of the basin to its present position close to and paralleling the Central Basin Platform. Recent exploration in the north and northeastern portions of the basin indicates that the deeper part of the basin in New Mexico may lie farther west than most workers had previously determined.

In addition to the enormous deposits of potash minerals now being mined within its boundaries, the Delaware Basin is showing very definite signs of becoming an oil province of sufficient importance to rival the prolific Midland Basin of west Texas. Until the past few years production was limited to the shallow Delaware Mountain sands (Bell Canyon) and younger beds of minor importance. At this writing important discoveries and significant shows of oil and gas have materialized in the deeper-lying Delaware sands, the Bone Spring carbonates, the Wolfcamp, and the Pennsylvanian. No discoveries have been made from the "Siluro-Devonian" but favorable conditions of porosity and permeability promise that major discoveries from this unit are sure to follow. The underlying Ordovician also offers reservoir possibilities. Thus, exploration has shown that important reservoirs may be expected almost at any horizon in the thick section of sediments filling the Delaware Basin. The depth at which these potential reservoirs lie and the lack of information as to the type and location of structures have retarded development. These conditions are now being confronted and carefully directed exploration will undoubtedly lead to the discovery of additional petroleum reserves. It seems appropriate to mention two oil tests drilled in the New Mexico portion of the basin (to which this paper is almost wholly confined) which have changed existing concepts pertaining to formational thicknesses and structure in the Delaware Basin. They provide examples of what might be expected in the future. The Continental #1 Bell Lake Unit (Sec. 31-23S-34E) encountered the top of the Lamar limestone at a depth of 5150 feet (minus 1518 feet), an average of some 200 to 400 feet structurally higher than most workers anticipated, and penetrated a much thinner Leonard section than was expected. Significant shows were logged in the lower Delaware sands and Bone Spring carbonates before it blew-out and caught fire (refer to photograph and report in this guidebook) at a depth of 12,616 feet in beds of probable Pennsylvanian age. This operator's #2 Bell Lake Unit, one mile north of their #1 well, tested an estimated 10-15 million CFGPD from this same zone near the top of the Pennsylvanian (?). At this writing the Continental #2 Bell Lake Unit is drilling at a depth of 12,700 feet. The Richardson & Bass #1 Harrison-Federal (Sec. 12-25S-30E),

deepest well in New Mexico, was drilled to a depth of 16,705 feet where it was bottomed in beds of "Siluro-Devonian" age. It penetrated 3820 feet of Delaware sands, 3355 feet of Bone Spring sediments, and 2485 feet of Wolfcamp beds, the thickest section of Wolfcamp sediments yet encountered in the New Mexico portion of the basin. Important shows were tested in the lower Delaware sands, the Bone Spring and Wolfcamp before the well was plugged and abandoned. These two test served to alter the ideas of most geologists by indicating a shift to the west of the deepest portion of the basin in New Mexico. Though the #1 Harrison-Federal is the deepest well in New Mexico, it is not located in the deepest part of the Delaware Basin which lies to the south in Texas. A table listing oil tests penetrating beds of Leonard age or older for the New Mexico portion of the basin follows this paper to indicate the pace of recent exploration, and to emphasize the small portion of the basin in New Mexico which may be considered condemned in respect to petroleum production. Wells listed in this table are in accordance with the broader definition of the limits of the Delaware Basin.

Though the Delaware Basin region has been the subject of numerous published articles, many problems remain unsolved. A few of the more pertinent problems relating to the area are listed below.

1. A detailed correlation of the outcrop area of Guadalupe reefing and associated sediments with the subsurface is lacking. The scope of such a study would add much to the understanding of the nature of reefoid conditions and associated facies changes, and probably clarify the confusion of back-reef and fore-reef equivalents. A number of geologists do not concur with explanations of the back-reef area, particularly where the Castile and Brushy canyon formations are concerned. The nature of reefing older than Guadalupe, if any, should also be considered. Existing literature is in general agreement in respect to the broad divisions of fore-reef and back-reef equivalents but discrepancies still exist in correlating the units of formation and member ranks. An enlargement of the scope of existing studies should add much to the understanding of this problem.

2. Comparatively little is known of the structure of the Delaware Basin which in the past has been interpreted largely on the basis of contours on top of the shallow "Delaware Lime." Deep control is now accumulating and structural and isopach maps based on older horizons will add to the knowledge of the tectonics of the basin area. The presence and nature of probable faulting associated with the margins of the basin should be considered along with a determination of the location of positive and negative elements existing within the basin proper. This, of course, will aid in establishing the direction of probable productive trends and will no doubt alter pre conceived ideas of exploration.

3. Though upper Pennsylvanian deposits are recognized around the margins of the basin, sediments younger than Des Moines (Strawn) have not been reported in the New Mexico portion of the basin proper. This may be attributed to non-deposition indicating the area to be a positive one during late Pennsylvanian time, or removal of upper Pennsylvanian sediments by erosion, or a combination of both. Some geologists believe that during late Pennsylvanian time the area existed as a starved basin. Perhaps isolated occurrences of these sediments exist but have not been recognized or penetrated by the drill. The presence of Pennsylvanian age reefs located within the basin proper or around its margins is a possibility which should not be minimized. The Pennsylvanian offers a field of research in which an important key to the stratigraphy and structure of the Delaware Basin region may be found.

4. Generally, the age of the sediments underlying the Delaware Basin have been satisfactorily determined. The most outstanding discrepancy is concerned with the beds underlying the Percha (Woodford) shale. Most operators refer to this unit as the "Siluro-Devonian". This is a problem common to a large portion of the southeastern New Mexico-west Texas region. Its solution could result in a definite change of concept of the early history of the region. Another problem relating to age relationship concerns the Leonard-Wolfcamp contact. Some geologists pick the top of the Wolfcamp at the top of the sand body occurring at the base of the Bone Spring while others prefer the base of this sand as the boundary horizone. This discrepancy is of minor consequence but uniformity in thought by the workers concerned should be reached. The Guadalupe-Leonard contact presents another stratigraphic problem upon which attention is being focused.

WELLS DRILLED IN THE NEW MEXICO PORTION OF THE DELAWARE BASIN
PENETRATING BEDS OF LEONARD AGE OR OLDER - CONT.

WELL NAME	COUNTY SEC.-TWP.-RGE.	ELEVATION (DF) TOTAL DEPTH	OLDEST FORMATION PENETRATED	DATE COMPLETED	REMARKS
Richardson & Bass #1 R. H. Legg	Eddy 27-22S-30E	3,309' 15,854'	"Siluro-Devonian"	5-11-54	Producing oil from lower Brushy Canyon.
Continental #1 Bell Lake Unit	Lea 31-23S-34E	3,632' 12,616'	Pennsylvanian (?)	5-17-54	Junked and Abandoned. Well blew-out and caught fire at total depth.
Richardson & Bass #1 Harrison-Federal	Eddy 1-25S-30E	3,378' 16,705'	"Siluro-Devonian"	5-22-54	Plugged and Abandoned.
Richardson & Bass #1 Beeman	Lea 2-24S-28E	2,995' 8,153'	Bone Spring	6-1-54	Well abandoned 6-1-54, but at time of this compilation operator has re-entered hole and now testing shows in the Delaware sands.
Union of Calif. #1 Gilmore-Federal	Lea 21-22S-32E	3,678' 8,770'	Bone Spring	7-16-54	Temporarily Abandoned.
British American #1 Fields-Federal	Lea 12-24S-35E	3,467' 8,703'	Bone Spring	7-18-54	Plugged and Abandoned.
Richardson & Bass #1 Federal-Welch, et al	Eddy 20-20S-31E	3,523' 7,400'	Bone Spring	7-21-54	Plugged and Abandoned.
Kelly #1 McMillan	Eddy 36-20S-26E	3,248' 11,565'	"Siluro-Devonian"	7-22-54	Plugged and Abandoned. Formerly Richfield #1 Lake McMillan. Richfield Oil Co. drilled this well to a total depth of 6020' before abandonment on 3-8-47.
Stanolind #1 Welch Unit	Eddy 21-26S-27E	3,245' 12,547'	Pennsylvanian	9-4-54	Listed by operator as Plugged and Abandoned. Tested 10,000,000 CFGPD from lower Pennsylvanian.
Superior #1 McAlpin	Lea 23-18S-35E	3,888' 12,355'	"Siluro-Devonian"	9-17-54	Producing oil from Bone Spring.
Continental #2 Bell Lake Unit	Lea 30-23S-34E	C 3,617'			Drilling at a depth of 12,700' at time of this compilation Tested estimated 10 to 15 million CFGPD from beds of probable Pennsylvanian age.
Continental #1-A Bell Lake Unit	Lea 31-23S-34E	C 3,633'			Drilling at a depth of 11,150' at time of this compilation.
Stanolind #1 Buffalo Unit	Lea 3-19S-33E	3,745' 14,916'	Fusselman		At time of this compilation operator attempting to complete as oil well from Wolfcamp.
Shell #1 Hooper	Lea 27-19S-35E	C 3,730'			At time of this compilation operator drilling at a depth of 10,400'. Well is projected to 13,100'. Free oil recovered on tests of upper Bone Spring.
Shell #1 Spencer Unit	Lea 25-17S-36E	C 3,829'			Drilling at a depth of 10,600' at time of this compilation.

A few controversial wells drilled in transitional areas where Bone Spring type sediments are encountered are purposely omitted.

WELLS DRILLED IN THE NEW MEXICO PORTION OF THE DELAWARE BASIN
PENETRATING BEDS OF LEONARD AGE OR OLDER

(Wells are listed chronologically according to completion dates. Included are those wells located on the shelf areas which penetrated basin type sediments. Omitted are a number of wells drilled in a controversial area of transitional sediments located north and northeast of Monument where some geologists postulate a channel connecting the Delaware and Midland Basins. Date of this compilation 9-20-54. Total number of wells listed 36.)

WELL NAME	COUNTY SEC.-TWP.-RGE.	ELEVATION (DF) TOTAL DEPTH	OLDEST FORMATION PENETRATED	DATE COMPLETED	REMARKS
Ohio #1 Tracy	Eddy 34-21S-36E	3,478' 5,805'	Bone Spring	12-20-24	Plugged and Abandoned.
Pecos Valley #1 McClelland	Eddy 22-22S-23E	4,150' 4,980'	Bone Spring	5-19-35	Plugged and Abandoned. Formerly Spearow, et al.
Getty #7 Dooley	Eddy 24-20S-29E	3,309' 6,683'	Bone Spring	11-30-35	Completed as oil producer from Yates.
Standard of Texas #1 Smith "23"	Eddy 23-22S-24E	4,272' 3,905'	Bone Spring	5-23-44	Plugged and Abandoned.
B. Cockburn #1 Wyatt	Lea 33-17S-33E	4,056' 7,044'	Bone Spring	7-30-45	This test completed as small producer from Queen Sand in 6-1-46 after being reworked by Snowden, et al.
Amerada #2 Record	Lea 25-19S-35E	3,689' 13,524'	"Siluro-Devonian"	5-24-48	Plugged and Abandoned.
Humble #1 Federal-Wiggs	Eddy 31-24S-27E	3,460' 14,865'	Ellenburger	2-8-50	Plugged and Abandoned.
Humble #1 Federal-Hobbs	Eddy 24-20S-24E	3,588' 11,580'	Ellenburger	4-26-50	Plugged and Abandoned.
Malco #1 Boyd, et al	Eddy 14-19S-25E	3,441' 4,799'	Bone Spring	3-2-52	Plugged and Abandoned.
Stanolind #1 State "X"	Lea 11-17S-36E	3,835' 11,500'	Pennsylvanian (?)	9-2-52	Plugged and Abandoned.
Shell #1 State "RA"	Lea 31-18S-36E	3,846' 12,418'	"Siluro-Devonian"	11-25-52	Plugged and Abandoned.
Ellis Hall #1 State	Lea 23-22S-35E	3,613' 8,165'	Bone Spring	12-30-52	Plugged and Abandoned.
Carper #1 Emery-State	Lea 28-17S-36E	3,859' 10,197'	Wolfcamp	1-5-53	Plugged and Abandoned.
Stanolind #1 Lakewood Unit	Eddy 34-19S-25E	3,542' 10,486'	"Siluro-Devonian"	1-27-53	Plugged and Abandoned.
Richardson & Bass #1 Cobb-Federal	Eddy 23-20S-31E	3,515' 16,459'	Pre-Cambrian	7-27-53	Producing oil from lower Brushy Canyon.
Stanolind #1 Guadalupe Foothills Unit	Eddy 20-22S-25E	3,961' 13,034'	Ellenburger	8-10-53	Plugged and Abandoned.
Sun #1 Harper-Federal	Lea 26-25S-35E	3,119' 14,997'	Pennsylvanian	9-16-53	Plugged and Abandoned. Formerly General American #1 Harper-Federal. Free oil recovered on tests of lower Bone Spring.
Richardson & Bass #1 Fidel-Federal	Eddy 27-21S-29E	3,433' 15,611'	Simpson	9-19-53	Producing oil from lower Brushy Canyon.
Amerada #1 State "WEC"	Lea 5-21S-35E	3,652' 7,955'	Bone Spring	1-2-54	Plugged and Abandoned.
Amerada #1 State "WED"	Lea 27-20S-36E	3,586' 7,201'	Bone Spring	4-17-54	Producing oil from lower Whitehorse.
Stanolind #1 State "AD"-10	Eddy 10-19S-28E	3,522' 13,260'	Ellenburger	5-1-54	Producing gas & distillate from Pennsylvanian.

Additional study and exploration will provide the solutions to many of the various problems relating to the Delaware Basin area. Resulting data will not only prove of value academically, but will no doubt hasten the time when this important feature, already a producer of the world's largest deposits of potash minerals, takes its place as a major province of petroleum.

THE ORIGIN AND DEVELOPMENT OF THE CARLSBAD CAVERNS

by

T. Homer Black, Park Naturalist,
Carlsbad Caverns National Park

Carlsbad Caverns, viewed by hundreds of thousands annually, stands unrivaled as an underground scenic attraction. Few of the visitors passing through and gazing in awe and amazement at the beauty of the myrid secondary structures, however, give thought to the slow processes involved in the creation of the gigantic cavity. For them beauty alone is sufficient. Nevertheless, lying as it does in the limestone upland of the Guadalupes near the edge of a great escarpment, rising abruptly from the flat plains to the south and east, which extends as a prominent barrier some 45 miles from El Capitan to the vicinity of Carlsbad where it dips underground, certain questions arise in the minds of almost everyone. How did the escarpment originate? Why are the caverns located as they are with the only opening some 700 feet above the valley floor?

The escarpment is, of course, but a relatively small segment of a great barrier reef, encircling the Delaware Basin, which developed during upper Guadalupian time. The key to its location however, is to be found in landscapes of the late Pennsylvanian and early Permian periods for on these inherited structures depended the successful development of the encircling reef.

During late Pennsylvanian narrow mountain chains, which had their origin early in the Pennsylvanian period and split this area into semi-isolated subrhomboidal basins, were rejuvenated and continued to act as positive elements throughout most of the Permian.[1]

1. Adams and Frenzel – Journal of Geology – July, 1950.

Structural hinge lines separated rapidly subsiding areas, such as the Delaware Basin, from the less actively negative ones and upon these platforms extensive shallow water, marine limestones developed. These hinge lines were favorable places for the growth of reef building organisms for here the water was clear and shallow enough for sunlight to penetrate to the bottom. Such penetration was mandatory for the growth of algae, the reef forming organisms primarily responsible for the formation of the Capitan Reef. It was also the limiting factor governing the depth at which the reef could establish itself. The clean bottom furnished an excellent surface for the attachment of fixed organisms, while water rising along the slope from the deep basins furnished an abundant supply of food. As a result reefs, beginning as isolated mounds, grew laterally, joined, and by mid-Guadalupian time had succeeded in encircling the Delaware Basin as a continuous barrier.

From mid-Guadalupian time onward the reef continued to alternate between periods of upward and seaward growth. During periods of active subsidence the reef grew rapidly upward in order to maintain its crest in the zone to which sunlight could penetrate and thus avoid drowning. During periods of slow subsidence it grew seaward on a talus slope of its own construction. In the main the reef grew vigorously and without interruption from back reef sediments moving into the Delaware Basin. At times, however, as illustrated by two deposits in the New Mexico Room which strike N68° to 70° E and dip 20° to 30° S and N40° E, 38° S respectively, sands, probably Yates in age, buried certain portion of the reef and emerged on the seaward face as foreset beds. However, reef organisms quickly re-established themselves and growth continued uninterrupted.

Toward the close of Guadalupe time the Delaware Basin was cut off from access to the open sea, probably by the formation of a barrier reef across a channel to the southwest just as the Capitan Reef cut off the Midland Basin. For a time the reef continued to grow upward and seaward but slowly back reef sediments encroached upon ut and by the end of Guadalupe time had buried much of the reef. In the vicinity of the entrance to Carlsbad Caverns the Tansill formation covers the reef to a depth of well over 100 feet.

At maturity the crest of the reef stood, in places, as much as 1800 feet above the basin floor and in the northern end of the Delaware Basin had advanced as