Waste Isolation Pilot Plant

Compliance Certification Application

Reference 112

Cartwright, Jr., L.D. 1930.
Transverse section of Permian Basin, west Texas and southeastern New Mexico.
American Association of Petroleum Geologists Bulletin, Vol. 14, pp. 969–981.

Submitted in accordance with 40 CFR §194.13, Submission of Reference Materials.

B. Not to be used for payment of invoices applying on purchase orders.

TO WIPP Site (LOCATION) DATE 10/24/96

OFFICE OR DEPT. Accounting

PLEASE DRAW CHECK TO ORDER OF A.A.P.G

ADDRESS PO Box 979, Tulsa, Ok. 74101-0979

PAY AMOUNT Thirty + 00 /100 DOLLARS IN THE AMOUNT OF $ 30.00

EXPLANATION TO BE USED ON CHECK STUB Copyright fee of 3.00 per copy for 10 copies of "Transverse Section of the Permian Basin, West Texas + N.M by Lon Cartwright

SPECIAL INSTRUCTIONS

CHARGE ACCOUNT W12130001932097	CHARGE ACCOUNT	CHARGE ACCOUNT
CHARGE ACCOUNT	CHARGE ACCOUNT	CHARGE ACCOUNT

APPROVED FOR PAYMENT (TYPE NAME) RL Leonard	SIGNATURE	PHONE (WIN)
APPROVED FOR PAYMENT (TYPE NAME)	SIGNATURE	PHONE (WIN)

Second approval line provided for locations whose local policies require multiple approvals.

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
AUGUST 1930

TRANSVERSE SECTION OF PERMIAN BASIN, WEST TEXAS AND SOUTHEAST NEW MEXICO[1]

LON D. CARTWRIGHT, JR.[2]
San Angelo, Texas

ABSTRACT

The Permian basin is divided into structural units each of which is characterized by a distinctive stratigraphic section. The Main Permian basin, Central basin platform, and Delaware Mountain basin are included in the transverse section presented in this paper. The strata of the Main Permian basin are divided into the Wichita-Albany, Clear Fork, and Double Mountain groups, the Double Mountain group being divided into the San Angelo, Blaine, Whitehorse Choudchief, and Quartermaster formations. The formations of the Main Permian basin are relatively uniform along the strike, but thicken and become more marine basinward.

The Central basin platform is a regional limestone "high" on which there are pronounced changes in the limestone section penetrated east and west across it. Two explanations of these changes are generally accepted. The first recognizes an extension of the Capitan reef system bordering the Delaware Mountain basin. Back of the reef is a lagoonal facies comprising dolomitic limestone, sandstone, and anhydrite. The second recognizes an older dolomitic limestone known as the "White lime," on the eroded surface of which there is a heterogeneous deposit of dolomitic limestone, sandstone, and anhydrite known as the "Brown lime."

The strata of the Delaware Mountain basin comprise the Bone Springs limestone, the Delaware Mountain sandstone, the Capitan formation, the Lower Castile, Upper Castile, and Rustler formations. Of especial interest are the Capitan, which is a reef phase of the upper Delaware Mountain, and the Lower Castile, which is a peculiar evaporite formation.

INTRODUCTION

The most recently published cross section of the Permian basin of West Texas and southeastern New Mexico was that of E. C. Edwards,[3]

Manuscript received by the editor, March 10, 1930.

[2] Geologist, Superior Oil Company of California.

[3] E. C. Edwards, "Stratigraphic Position of the Big Lime of West Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 7 (July, 1927), pp. 721-28.

Articles Scheduled for Publication in the September *Bulletin*

Review of Geophysical Prospecting for Petroleum in 1929

By DONALD C. BARTON

Torsion-Balance Survey of Esperson Dome, Liberty County, Texas

By DONALD C. BARTON

Electrical Prospecting for Oil Structures

By KARL SUNDBERG

Geo-Electric Investigations of Non-Conductors

By NORBERT GELLA

Electrical Survey of Structural Conditions in Salt Flat Field, Caldwell County, Texas

By HELMER HEDSTROM

Magnetic Susceptibility and Magnetite Content of Sands and Shales

By D. M. COLLINGWOOD

Magnetics and Geology of Yoast Field, Bastrop County, Texas

By D. M. COLLINGWOOD

Electric and Electromagnetic Prospecting for Oil

By W. P. JENNY

Volume 14 Number 8

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

AUGUST 1930

TRANSVERSE SECTION OF PERMIAN BASIN, WEST TEXAS AND SOUTHEAST NEW MEXICO[1]

LON D. CARTWRIGHT, JR.[2]
San Angelo, Texas

ABSTRACT

The Permian basin is divided into structural units each of which is characterized by a distinctive stratigraphic section. The Main Permian basin, Central basin platform, and Delaware Mountain basin are included in the transverse section presented in this paper. The strata of the Main Permian basin are divided into the Wichita-Albany, Clear Fork, and Double Mountain groups, the Double Mountain group being divided into the San Angelo, Blaine, Whitehorse-Cloudchief, and Quartermaster formations. The formations of the Main Permian basin are relatively uniform along the strike, but thicken and become more marine basinward.

The Central basin platform is a regional limestone "high" on which there are pronounced changes in the limestone section penetrated east and west across it. Two explanations of these changes are generally accepted. The first recognizes an extension of the Capitan reef system bordering the Delaware Mountain basin. Back of the reef is a lagoonal facies comprising dolomitic limestone, sandstone, and anhydrite. The second recognizes an older dolomitic limestone known as the "White lime," on the eroded surface of which there is a heterogeneous deposit of dolomitic limestone, sandstone, and anhydrite known as the "Brown lime."

The strata of the Delaware Mountain basin comprise the Bone Springs limestone, the Delaware Mountain sandstone, the Capitan formation, the Lower Castile, Upper Castile, and Rustler formations. Of especial interest are the Capitan, which is a reef phase of the upper Delaware Mountain, and the Lower Castile, which is a peculiar evaporite formation.

INTRODUCTION

The most recently published cross section of the Permian basin of West Texas and southeastern New Mexico was that of E. C. Edwards,[3]

[1]Manuscript received by the editor, March 10, 1930.

[2]Geologist, Superior Oil Company of California.

[3]E. C. Edwards, "Stratigraphic Position of the Big Lime of West Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11, No. 7 (July, 1927), pp. 721-28.

which accompanied a well prepared discussion of the stratigraphic problems of the basin as they were then understood. Since that time a wealth of new information has become available. Many additional wells have been drilled throughout the district, and samples of drill cuttings from them have been saved. Much has been written describing the stratigraphy of the Permian outcrop on the margins of the basin, and there have been comprehensive discussions of the subsurface stratigraphy.

In the light of this increased knowledge the early conceptions of the cross section of the basin have changed. It is the purpose of the writer to set forth a new interpretation. Plate 2 illustrates correlations across the basin, based on logs prepared chiefly from microscopic examination of cuttings. Plate 3 is an idealized section through the same wells. The discussion presented in this paper relates directly to the Permian stratigraphy along this line of section, and only indirectly to the general region.

GENERAL STRUCTURE AND STRATIGRAPHY

The Permian basin province is divided into several structural units as illustrated in Figure 1, each of which is characterized by a distinctive stratigraphic section. The units included in the transverse section presented in this paper are designated the Main Permian basin, the Central basin platform, and the Delaware Mountain basin. The Main Permian basin is an asymmetrical basin in which the Permian formations are relatively uniform in lithology along the strike, but thicken basinward from east to west and change from land-marginal to marine lithology in the same direction.

The Central basin platform is a broad, structural ridge with a huge dolomite reef on its western rim. Formations are relatively uniform along the strike, but across the strike there are pronounced gradations of the lower formations. Solution of salt and consequent slumping have disturbed the upper formations above the reef.

Inasmuch as the Delaware Mountain basin was an area of regional subsidence during the deposition of all its known formations, it received a great thickness of sediments. In the basin the lower formations are remarkably uniform in lithology, but the younger formations show variations both in lithology and thickness.

STRATIGRAPHY OF MAIN PERMIAN BASIN

On the east side of the Permian basin a broad belt of Permian formations is exposed from San Angelo at the south into western Kansas at the north. These beds are divided into the Wichita-Albany, Clear

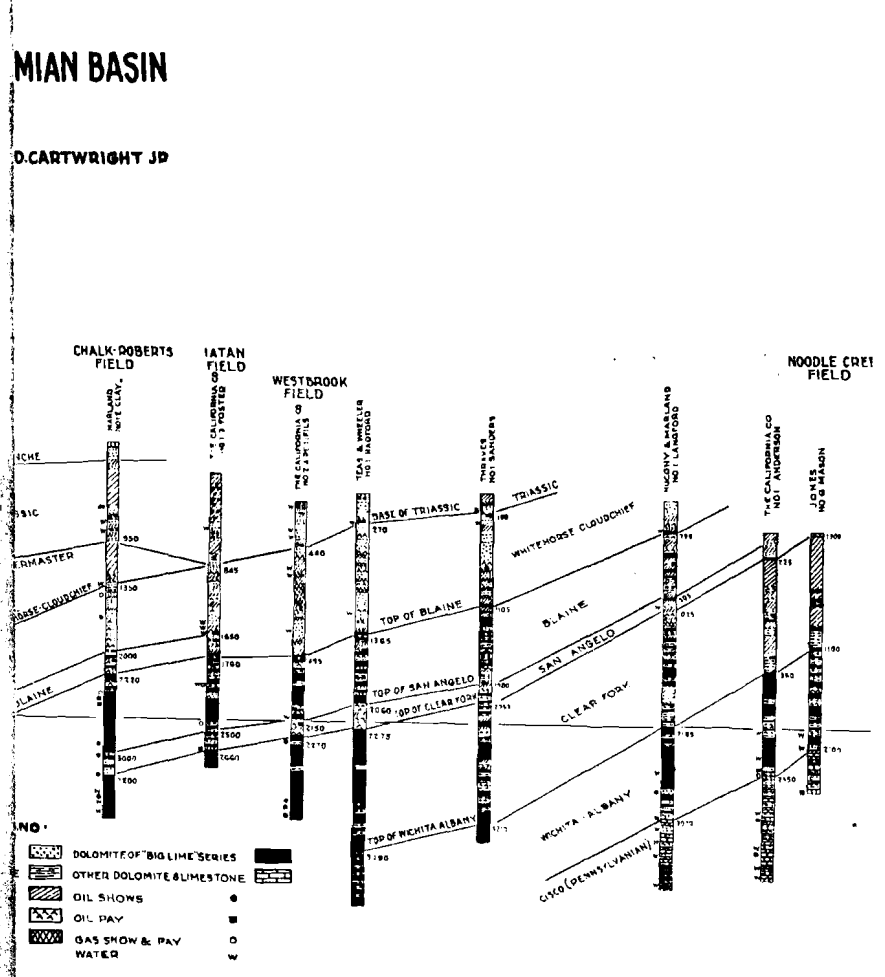
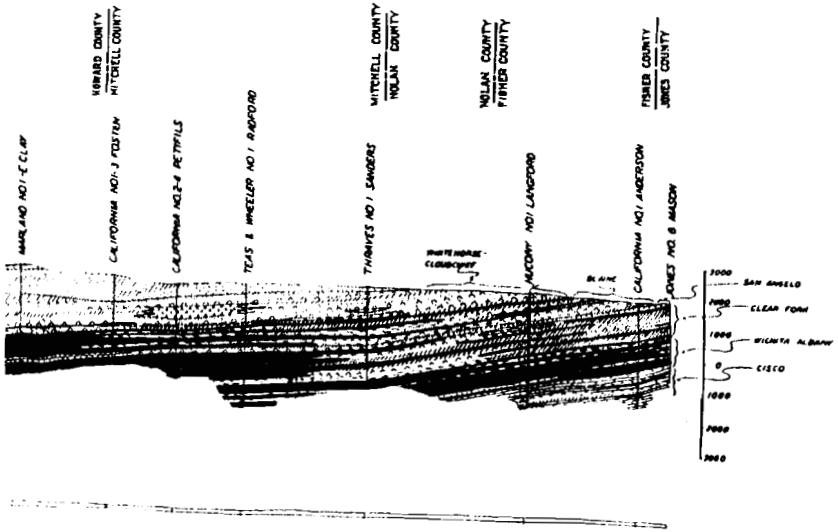
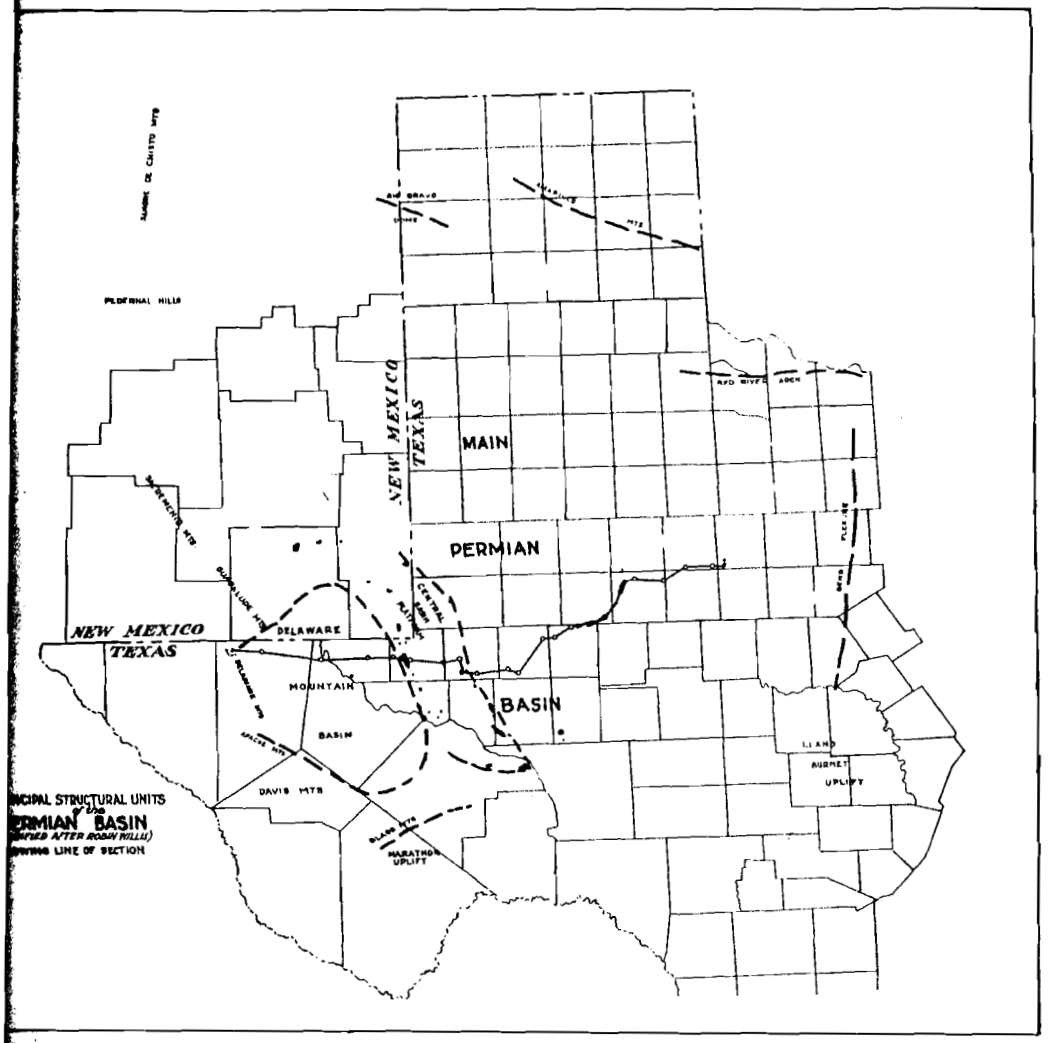


PLATE 3



HOWARD COUNTY
MITCHELL COUNTY
MITCHELL COUNTY
NOLAN COUNTY
NOLAN COUNTY
FISHER COUNTY
FISHER COUNTY
JONES COUNTY
MARLAND NO 1-E CLAY
CALIFORNIA NO 1-3 FOSTER
CALIFORNIA NO 2-4 PETTIFILS
TEXAS & WHEELER NO 1 RADFORD
THRAVES NO 1 SANDERS
WHITEHORSE-CLOUDCROFT
NUCONY NO 1 LANGFORD
CALIFORNIA NO 1 ANDERSON
JONES NO 6 MASON
SAN ANGELO
CLEAR FORK
WICHITA ALBANY
CISCO



PEDERNAL HILLS
NEW MEXICO
TEXAS
MAIN
PERMIAN
BASIN
DELAWARE
MOUNTAIN
BASIN
DAVIS MTS
MARATHON UPLIFT
LLANO
BURNET
UPLIFT
CENTRAL
BASIN
PLATFORM
NEW MEXICO
TEXAS
CIPAL STRUCTURAL UNITS
ERMIAN BASIN
FIED AFTER ROBIN WILLIS)
WING LINE OF SECTION

FIG. 1

Fork, and Double Mountain groups. The stratigraphic column and areal map recently published by Lloyd and Thompson[1] were used as guides in correlating the subsurface formations of the east side of the Main Permian basin.

The Wichita-Albany group is a fossiliferous marine limestone and shale series approximately 900 feet thick in the southern part of its outcrop. It continues westward in the subsurface as limestone and shale, limestone being predominant. In the upper part of the group the limestones are dolomitic and in the lower part non-dolomitic. Basinward from the outcrop the contact between dolomitic and non-dolomitic limestone is progressively lower in the section.

The Clear Fork group consists chiefly of Red-beds at the outcrop, but assumes more and more marine characteristics basinward, and passes through a phase in which it is represented by Red-beds, anhydrite, and dolomitic limestone, into a phase in which it is nearly all dolomitic limestone. This striking transition is illustrated in the idealized cross section (Plate 3).

The Double Mountain group, which is the most interesting group on the east side of the basin, consists of several distinct formations easily traceable on the surface. The lowest formation of this group is the San Angelo, which rests unconformably on the Clear Fork. It ranges from 175 to 225 feet in thickness and consists of pebbly sand and red shale at the east end of the section, passing through a sand, anhydrite, and red shale facies in Mitchell County into a fine sand and dolomitic limestone facies in eastern Howard County.

Overlying the San Angelo is the Blaine formation, which at the outcrop at the east end of this section consists of 375 feet of gypsum, red and blue shale, and a few dolomite beds. In the subsurface the Blaine thickens basinward and becomes more and more calcareous as far as eastern Howard County, where it is 780 feet thick and is predominantly dolomitic limestone.

The Blaine is overlain at the outcrop by the Whitehorse sandstone and Cloudchief gypsum, which were grouped by Lloyd and Thompson,[2] because of the difficulty of dividing them in the southern part of the area in which they crop out. The Whitehorse-Cloudchief is a formation ranging from 700 to 900 feet in thickness, consisting predominantly of

[1]A. M. Lloyd and W. C. Thompson, "Correlation of the Permian Outcrops on the Eastern Side of the West Texas Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 8 (August, 1929), pp. 945-56.

[2]*Op. cit.*

red sandstone and shale in the lower part and gypsum in the upper. It is overlain unconformably by the Triassic at the east end of this section.

Westward in the subsurface the Whitehorse-Cloudchief contains several salt beds in Mitchell County, which pinch out in the Chalk-Roberts field in southeast Howard County, but which occur west of that field. In Midland County, which is the lowest part of the Main Permian basin, the Whitehorse-Cloudchief increases to approximately 2,000 feet of red sand, red shale, anhydrite, salt, and dolomite. Westward from the Iatan field in Mitchell County, there is a dolomite bed low in the formation which constitutes the top of the "Big lime" in a large part of the Main Permian basin.

Although the sand of the Whitehorse-Cloudchief, which is composed of fine and very fine, subrounded, well sorted quartz grains, is red for the most part, it is gray and brown in the Chalk-Roberts field, where hydrocarbons and sulphur gas probably have reduced the ferric oxide stain to the easily soluble ferrous oxide. Mixed in some of the beds of fine sand are coarse, rounded, frosted quartz grains, which are especially noticeable in some of the shallow pay sands of the Chalk-Roberts field. The lithology of these phases of the Whitehorse-Cloudchief is identical with the lithology of the Yates sand as described by John Adams and the writer.[1] The top of the Whitehorse-Cloudchief extends westward into the top of the Queen sand zone, thus confirming a paleontologic correlation made by Beede[2] in 1910.

The Whitehorse-Cloudchief is normally overlain at the outcrop by the Quartermaster red sands and shales, but in the line of this section the Quartermaster is overlapped by Triassic. It comes in westward in the subsurface, however, as indicated on Plate 2.

Between the definite Quartermaster and definite Whitehorse-Cloudchief in the Main Permian basin, a thick salt wedge constitutes the "main salt" of the basin and is correlated with the Upper Castile of the Delaware Mountain basin. Although it is difficult to say what is the outcrop equivalent of this salt member on the east side of the basin, the writer suggests that it is either an intercalated bed not represented in the outcrop, or equivalent to a part of the lower Quartermaster.

The Triassic Dockum formation, composed of red and gray clays, coarse sands, and gravels of continental origin, occupies a considerable

[1]Quoted in G. C. Gester and H. J. Hawley's "Yates Field, Pecos County, Texas," *Structure of Typical American Oil Fields*, Vol. II (Amer. Assoc. Petrol. Geol., 1929), pp. 480-99.

[2]J. W. Beede, "Correlations of the Guadalupian and Kansas Sections," *Amer. Jour. Sci.*, Vol. 30 (1910), pp. 131-40.

interval in the stratigraphic section, as reference to Plate 3 shows. It has been well described by Adams[1] and is of little direct economic importance. In the southern part of the Main Permian basin it is overlain by Comanche sands, clays, and limestones.

STRATIGRAPHY OF CENTRAL BASIN PLATFORM

The stratigraphy of the limestone formations of the Central basin platform is probably the most disputed subject to-day among geologists studying the Permian basin, because of the rapid and important changes in section, as recorded in drill cuttings from relatively near-by wells. There are two main explanations for these changes. One attributes the changes principally to gradation in character of sediments of equivalent age. The other attributes the changes principally to overlap relations of a heterogeneous deposit on the eroded surface of an older homogeneous limestone formation.

The writer's conception of the Central basin platform is illustrated in Plate 3. The limestone formations of this structural unit are distinctive. It is the writer's opinion that the dolomitic limestone section of the west edge of the platform is a reef system consisting of the reef proper, probably penetrated in Humble's Hendrick No. 1-A, and a back-reef or lagoonal facies of detrital lime-mud beds, algal pisolite, sandstone, and, farther east, anhydrite. The Hendrick field, located close to the reef, is principally in the lagoonal facies, and its oil seems to be obtained principally from pisolite.[2]

This reef system is distinguished by its position on a high rim bordering the Delaware Mountain basin, and by pronounced lateral gradations from an entirely dolomitic limestone section, through a facies of dolomitic limestone and sandstone with progressively more anhydrite, into a section predominantly anhydrite with some sand and some dolomitic limestone. This gradation takes place in a direction normal to the rim of the Delaware Mountain basin and away from it, and is complete within a distance ranging from 8 to 15 miles.

The reef system is definitely traced in well logs through an arc from the Hendrick field to Carlsbad, New Mexico, where the Capitan reef

[1]John E. Adams, "Triassic of West Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 8 (August, 1929), pp. 1045-56.

[2]Through the courtesy of the California Company, the Shell Petroleum Corporation, the Atlantic Oil Producing Company, and the Southern Crude Oil Purchasing Company, in August, 1928, the writer was enabled to examine many sets of cores taken from the producing formations and found that almost invariably the oil was coming from a pisolite. Specimens of this pisolite sent to David White were pronounced to be the alga *Gervinella*.

system dips below younger beds. Moreover, the peculiarly distinctive lithology of many of the Hendrick field cores as shown in polished surfaces is practically identical with the lithology of outcrop specimens from the Capitan reef systems of the Guadalupe Mountains and the Apache Mountains; hence, the reef in the subsurface is correlated with the Capitan reef system. The relations of the Capitan, Delaware Mountain, Carlsbad, Queen, and Seven Rivers formations and members, as studied in the field, have been ably described[1] by Lloyd, Crandall, and Blanchard and Davis, and it is chiefly due to these data obtained from outcrops that a proper interpretation of the subsurface relations can be made.

The correlation of the "Big lime" section of the eastern part of the Central basin platform with the limestone series in the Main Permian basin farther east is still problematical. It may be as shown in Plate 2, or there may be gradations into anhydrite.

The alternative interpretation of the Central basin platform stratigraphy is illustrated in Figure 2. The Central basin platform is an eroded arch in the "White lime," a formation composed chiefly of white and gray dolomitic limestone and either equivalent to, or older than, the Delaware Mountain. The Hendrick field lies on a fold on the west rim of the platform. The platform was overlapped from the east by a heterogeneous deposit called the "Brown lime." This consists of a little brown dolomitic limestone, anhydrite, Red-beds, and sand and some salt members east of the platform, which, passing westward over the platform, thins and grades into brown dolomitic limestone and sandstone with a small amount of anhydrite on the east flank of the Hendrick fold, and into brown dolomitic limestone on its crest.

This second interpretation was formerly accepted generally, but the results of surface stratigraphic work in the Guadalupe Mountains and the evidence of many wells drilled during the past two years in Winkler County, Texas, and Lea and Eddy counties, New Mexico, have led to the widespread acceptance of the form of the interpretation first described.

[1]E. Russell Lloyd, "Capitan Limestone and Associated Formations of New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 6 (June, 1929), pp. 645-58.

K. H. Crandall, "Permian Stratigraphy of Southeastern New Mexico and Adjacent Parts of Western Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 8 (August, 1929), pp. 927-44.

W. Grant Blanchard, Jr., and Morgan J. Davis, "Permian Stratigraphy and Structure of Parts of Southeastern New Mexico and Southwestern Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 8 (August, 1929), pp. 957-95.

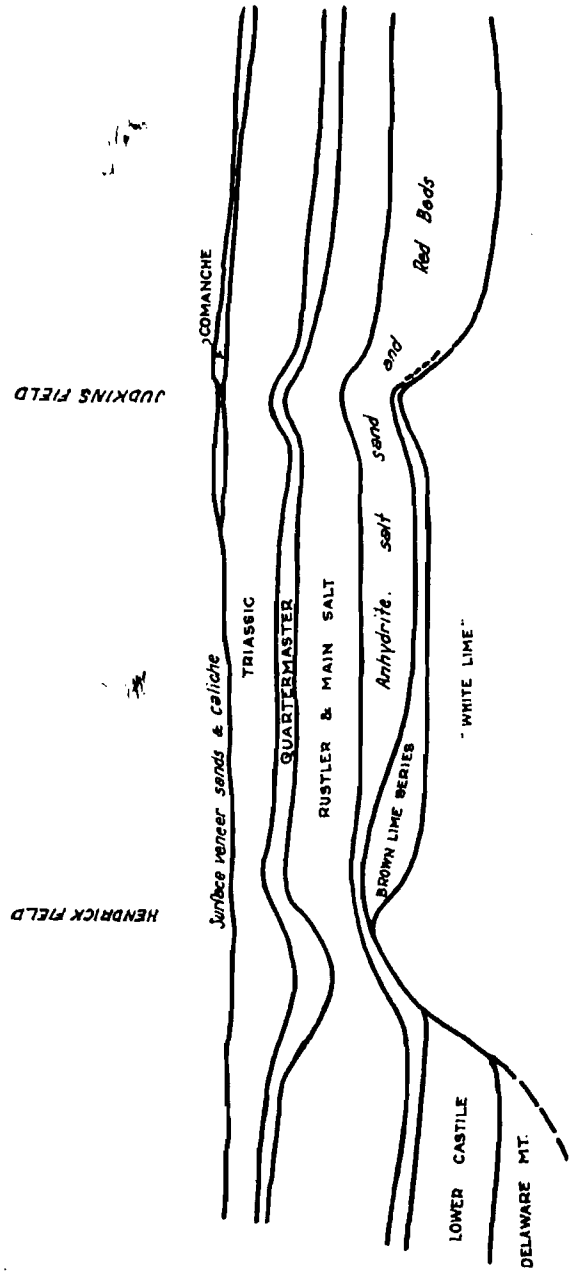


FIG. 2.—Stratigraphy of Central basin platform according to alternative interpretation.

The Permian formations of the Delaware Mountain basin are well exposed at the west side of the basin and consist of the Bone Springs limestone, Delaware Mountain sandstone, Capitan, Lower Castile, Upper Castile, and Rustler.

At the west end of this cross section, the lowest rocks exposed are 600 feet of black limestone and shale of the lower member of the Bone Springs formation. The Bone Springs limestone is the name given by Blanchard and Davis[1] to the lower part of the Delaware Mountain formation as originally described by Richardson[2] and has also been described by other writers as the Bone Canyon formation and the lower Delaware Mountain formation. Eastward along this cross section, 2,000 feet of this formation and probably older formations are penetrated in The Pure Oil Company's Quaid No. 1. The beds penetrated consist predominantly of black shale, but also contain a little limestone and two heavy sand beds.

In the idealized cross section (Plate 3), the top of the Bone Springs is extended eastward and raised in an arch to the Central basin platform. This correlation is assumed because the Bone Springs is correlated with the Leonard by the King brothers,[3] on paleontologic evidence, and the Leonard and possibly lower Word are correlated with the San Angelo and Blaine by Beede,[4] on the evidence of ammonites.

The Delaware Mountain sandstone, which rests on the Bone Springs, consists of 3,500 feet of gray and buff sandstone with a very little limestone and dark shale in the line of this section. The top of the formation throughout the Delaware Mountain basin is a distinctive member of dark shaly limestone, grading laterally into black shale, the average thickness being 50 feet.

On the southeast flank of the Guadalupe Mountains, the upper part of the Delaware Mountain sandstone grades abruptly into a limestone reef facies known as the Capitan formation. The details of this gradation as exposed in the walls of McKittrick Canyon are illustrated in Figure 3, cross sections made by Robin Willis, Alvin P. Loskamp, and

[1]W. Grant Blanchard, Jr., and Morgan J. Davis, *op. cit.*

[2]G. B. Richardson, *op. cit.*

[3]P. B. King and R. E. King, "Stratigraphy of Outcropping Carboniferous and Permian Rocks of Trans-Pecos Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, No. 8 (August, 1929), pp. 907-26.

[4]J. W. Beede and D. D. Christner, "The San Angelo Formation and Geology of Foard County," *Univ. Texas Bull. 2607* (1926).

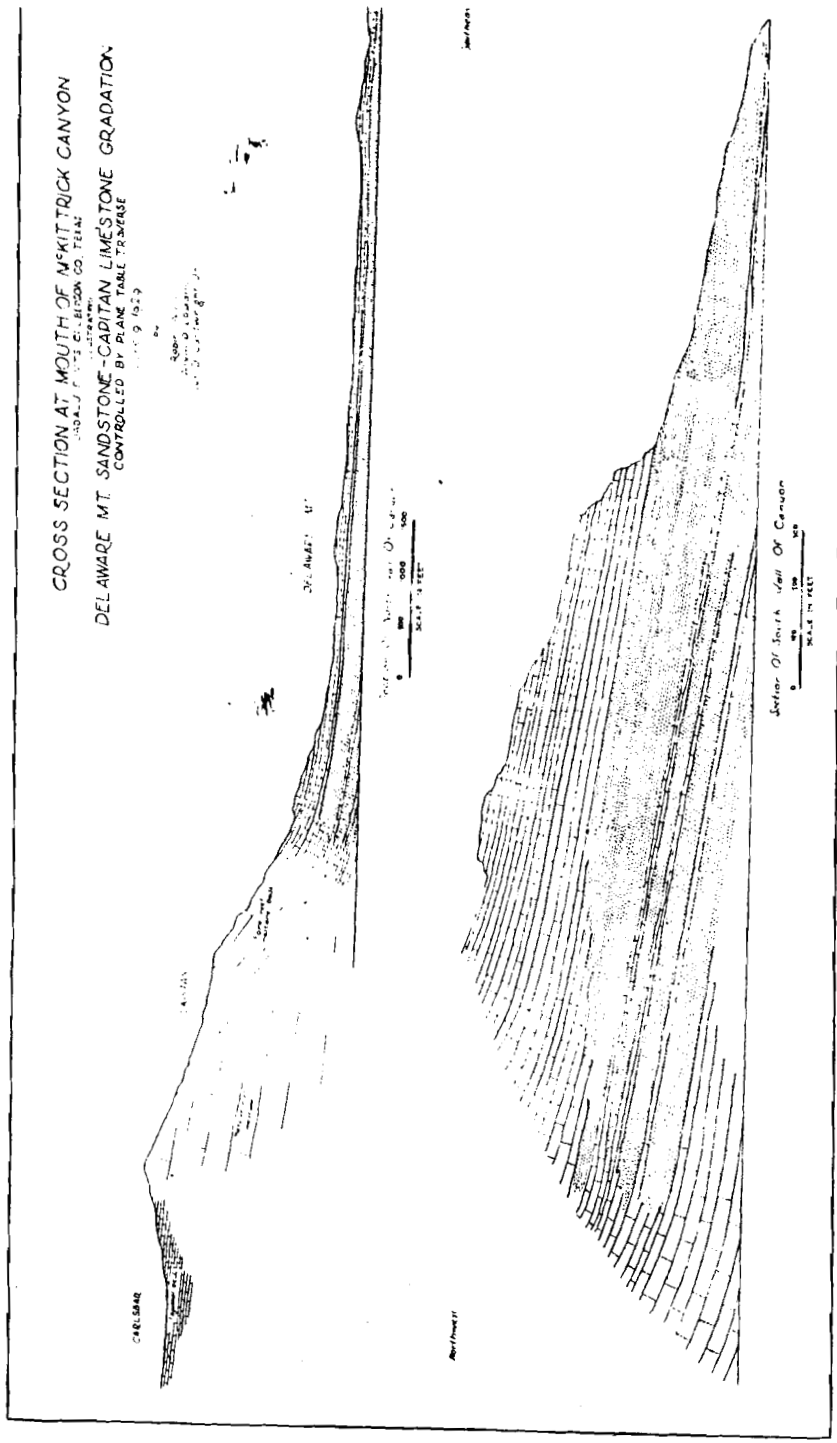


FIG. 3.—Drawn to natural scale.

the writer. Approximately 1,000 feet of the Delaware Mountain sandstone grades into limestone, according to Blanchard and Davis,[1] who describe this feature, as do Crandall[2] and Lloyd.[3]

The Capitan reef system consists of a huge core of massive limestone, poorly stratified fore-reef beds of limestone with an initial dip of as much as 25°, and lagoonal beds of thin-bedded limestone. The thickness at Guadalupe Point is 1,800 feet, and the limestone is both dolomitic and non-dolomitic. Profound lateral changes take place in the section behind the reef, the result being that the interval represented by thin-bedded dolomitic limestones immediately adjacent to the reef is represented by interbedded sandstone, dolomitic limestone, and gypsum back from the reef, and the proportion of dolomitic limestone decreases away from the reef and the proportion of gypsum increases.

The Delaware Mountain formation is overlain conformably by the Castile gypsum, originally described by Richardson[4] and named for the Castile Springs in northern Culberson County. Subsurface work from sample logs shows that the Castile consists of two very different evaporite formations.

The Lower Castile consists of 1,500 feet of interbedded pure gypsum, calcite-laminated gypsum, smaller quantities of laminated gypsiferous, petroliferous limestone, a very little gray shale; and, in the eastern part of the Delaware Mountain basin, white potash-poor salt. In the drill cuttings the gypsum is represented chiefly by anhydrite. The upper part of the Delaware Mountain formation is laminated, and the contact between it and the Lower Castile is a gradation from laminated limestone to calcite-banded, laminated gypsum. The salt beds of the eastern part of the basin are remarkably uniform throughout many miles, especially the two lower beds, and are not wedges thickening the part of the section in which they occur, for where they are absent there is an equivalent thickness of anhydrite.

The Lower Castile is restricted in areal extent to the Delaware Mountain basin, where it is of rather uniform distribution. This fact, considered with its character as an evaporite, indicates that it had its origin in an enclosed basin, the water in which was replenished from

[1]W. Grant Blanchard, Jr., and Morgan J. Davis, *op. cit.*

[2]K. H. Crandall, *op. cit.*

[3]E. Russell Lloyd, *op. cit.*

[4]G. B. Richardson, "Report of a Reconnaissance in Trans-Pecos Texas North of the Texas-Pacific Railway," *Univ. Texas Mineral Survey Bull. 1904.*

outside sources. The calcite laminae, which are ordinarily dark with petroliferous matter and organic residue, are interpreted by the writer to indicate that immediately following recurrent replenishing of the restricted sea with normal marine water, the calcium carbonate was precipitated because of super-saturation, and the organisms which were washed in were killed and their remains deposited with the calcite.

Udden[1] has contributed a well illustrated description of a series of cores of this formation taken in the David Flood core test drilled in eastern Culberson County. He[2] asserts "there is no doubt in my mind that these are annual cycles," referring to the time periods indicated by the laminae in the anhydrite. Since he says there are 300,000 laminae in the 1,600 feet of the formation, the time required for deposition of this remarkable formation may have been approximately 300,000 years, "somewhat commensurate with the estimated duration of some of our glacial periods in the Quaternary."

The salt beds of the Lower Castile are limited to the eastern part of the Delaware Mountain basin, and the total thickness there is approximately the same as farther west where the salt is absent. Thus, while salt was being deposited in the eastern part of the basin, anhydrite was being deposited in the western part. It is inferred from this fact that replenishing normal marine waters entered the basin from the west, probably over a barrier bar; that they moved eastward, becoming increasingly more saline, because of evaporation, as they moved; that evaporites of less solubility were precipitated first and evaporites of more solubility, for example, salt, were precipitated later farther from the source.

The Upper Castile formation, a massive gypsum and anhydrite unit approximately 800 feet thick at the outcrop, thickens within a short distance eastward in the subsurface and contains the massive potash-bearing "main salt" in the eastern part of the Delaware Mountain basin and farther east to Howard County. Dolomitic limestone, red shale, and sandstone are present in some places in the Upper Castile. Inasmuch as the Upper Castile differs from the Lower Castile in composition, primary structure, areal extent, sedimentary relations, and significance, it is here classed as a separate formation, although it is practically impossible to map the contact between the two formations on the surface because very poor exposures occur in the gypsum plain.

[1]J. A. Udden, "Laminated Anhydrite in Texas," *Bull. Geol. Soc. Amer.*, Vol. 35 (June, 1924), pp. 347-54.

[2]*Idem*, "A Neglected Field in Stratigraphy," *Univ. Texas Bull. 2801* (1928), p. 65.

The Rustler formation at the outcrop consists of approximately 200 feet of gray dolomitic limestone overlying 20 feet of yellow sandstone, locally conglomeratic, and 3 feet of red and gray clay which rests on the Upper Castile. The contact between this red and gray clay and the Upper Castile is probably unconformable. Eastward in the subsurface the Rustler extends beneath the Quartermaster Red-beds and pinches out possibly as far east as Midland County.

CONCLUSION

Throughout this paper the "top of the lime" correlations have received little mention. They are generally more or less arbitrary datum points, of value in limited areas only. As more information on the subsurface stratigraphy of a region becomes available, it becomes possible to divide the entire section into recognizable formations, and only after this has been done can the regional relationships and geologic history of a district be determined. With more and more information becoming available on Permian basin stratigraphy, it is increasingly important that correlations be made with formational units, and it is as an approach to this problem that this paper is offered.