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THE CAPITAN – CASTILE – DELAWARE MOUNTAIN PROBLEM

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During the years since E. Russell Lloyd in 1929 set forth the idea of reef origin for the Capitan limestone of southeastern New Mexico, numerous data have been released relative to the whole Capitan-Castile-Delaware Mountain problem. The great preponderance of the various issued statements have dealt with the so-called "Capitan Reef". Of the statements relative to the 'reef' hypothesis the great majority, if not all, have been in support of a wholesale reef concept.

An ever increasing number of geologists appear to be far from willing to accept the overall reef idea, for at least southeastern New Mexico, on the basis of published data. Personally, the writer believes that many questions remain completely unanswered, others are at best only partially answered, while some appear to be well answered.

Perhaps it might therefore be in point to offer very briefly certain data that in general present another possible interpretation to the Capitan-Castile-Delaware Mountain problem. Of necessity these notes must be brief and data supporting same must be kept to a minimum.

Through a period of nearly twenty years the writer has examined microscopically many thousands of well samples from the Capitan limestone series. Many of these samples were from test wells drilled with cable tools. Also, many feet of cores from the Capitan beds have been examined and described. Further, the writer has examined a very goodly number of samples from the Castile and Delaware Mountain beds. It might also be added that the writer is not unfamiliar with outcrop data.

The proponents of the later Permian reef concept of southeastern New Mexico and adjacent portions of Texas have very naturally done a very considerable portion of the Guadalupe Mountains and their southeastern foothills. There seems to be little reason to doubt that the various workers such as Lloyd, King, Dunbar, Newell and others have presented data that established the fact that during the deposition of the Capitan limestone series some reefoid developments took place in certain localized areas.

It would then appear thet perhaps the first question that should be answered might well be: "Does the surface work done in the Guadalupe Mountain area provide sufficient data and license to postulate widespread reef conditions in subsurface?" Before such a question is answered it would be in order to briefly set forth certain data relative to the Capitan limestone series.

Perhaps the first consideration is to realize that the Capitan limestone is present over a vastly greater area than is generally visualized by persons who more or less casually accept the "reef" hypothesis. There appears to be a tendency to mentally picture the Capitan as being present in a relatively narrow "reef" band or as a narrow limestone "bank". A detailed study of the unit from well samples and from cores clearly shows that the idea of its existing only as a narrow "reef" or "bank" is very definitely in error.

Zone 3 on the accompanying map shows the approximate area in New Mexico in which the Capitan formation is present at the surface and in subsurface as a predominantly limestone series. It must, however, be remembered that even in the area of zone 3 all available data show the presence of some inter-bedded sands, anhydrite and even occasional thin shaley partings. Of necessity the boundary lines cannot be exact, particularly on the north where the gradation from limestone into anhydrite is relatively gradual. However, using what are definitely conservative boundaries the predominantly limestone facies covers an area in excess of four thousand square miles. Perhaps one reason why it is not generally recognized that the Capitan as limestone is present over such wide areas is the fact that in such areas as northwest Lea County, northeast Eddy County and southeast Chaves County, it appears to be common practice to call the first major limestone encountered in tests as San Andres. This designation appears to be primarily based on electric logs. Unfortunately all too little attention has been given to the examination of upper hole samples in recent years. Samples from such areas as mentioned above reveal that the limestone commonly called San Andres is actually Capitan. Some typical examples of calls of San Andres for Capitan are as follows: Continental No. 1 Thurman Federal, Section 11-5. 16 fl.-R. 27 E., top of San Andres called at 1610'; actual top 2020'; Continental No. 1 Duffield, Section 21-T. 16S.-R.27E., San Andres called at 1375'; actual top 1790'; Makin Drilling Co. No. 1 Kincaid & Watson, Section 29-T.16S-R.28E., San Andres called at 1732'; actual top 2280'; Texas No. 1 A.S. State, Section 6-T. 15S.-R.32E., called at 3820'; actual top 4510'; Texas No. 1 A.Y. State, Section 29-T.14S.-R.32E., called

at 3855'; actual top 4480'.

Throughout a very considerable portion of the outcrop area of the Capitan the formation shows quite distinct bedding planes, indicating a normal type of deposition. Such conditions appear to be commonplace and by no means the exception. Such normal conditions of stratification do not fit too well into a widespread reef concept.

A study of the Capitan limestone in subsurface from test well samples and cores is possible over a more extensive area than in surface exposures. Some extremely interesting data are available from such sources. A few highlights from these data should be considered. Briefly they are as follows:

1. Throughout an area or approximately three thousand square miles the Capitan beds are present as a unit rather strikingly consistent lithology.

2. Throughout the three thousand square mile area the top of the formation is readily predictable as to depths at which it will be encountered in tests.

3. The top of the Capitan is sufficiently reliable to make it of value as a marker on which to do subsurface structural mapping.

4. Throughout much of its distribution the Capitan is to some degree anhydritic. Stringers and blebs of anhydrite are common and distinct beds are sometimes present. Further, all available data from samples and cores indicate that the anhydrite is primary and contemporaneous with the limestone. It is also interesting to note that the anhydrite appears to be best developed, in general, in that portion of the Capitan that is regarded as the "reef" proper. This condition immediately raises the question, "Would sea waters that had reached the concentration point for the precipitation of anhydrite have been areas in which prolific faunal development should be expected?"

Perhaps the best example of rapid lateral gradation from limestone into nearly pure anhydrite occurs between the Ohio No. 1 State McDonald, SW NW SW Section 15-T.22S.-R. 36E. and the same company's No. 2 State McDonald, C NW SW Section 14-T.22S.-R. 36E. From the No. 1 to the No. 2 McDonald, a distance of just over one mile, some 225 feet of limestone, by cores, grades laterally into anhydrite.

5. Sands are quite commonly interbedded with the limestones. These sands are medium to fine grained, clean, subangular to rounded and rather sharp in texture, as compared to the fine to very fine, to silty drab, dirty sandstones of the Delaware Mountain series. These latter sands are often of siltstone texture.

6. The numerous cores taken from the Capitan in the Monument-Eunice-Cooper-Jal general area of Lea County have failed to show any prolific faunal developments. As a matter of fact, fossils of any kind are scarce.

Recapitulating, we thus find the following characteristics in the Capitan: Considerable regularity of bedding; limestones present over a very extensive area; top of formation readily predictable in tests; top of formation a reliable marker for subsurface mapping of structure; beds commonly anhydritic; sands commonly interbedded with the limestones; faunal development relatively poor. All of these conditions appear to lack harmony in fitting into a widespread reef concept. Satisfactory explanations by the "reef" advocates would appear to be in point.

Since publication of the paper entitled, "Permian Stratigraphy of southeastern New Mexico and Adjacent Parts of Western Texas", by K.H. Crandall, in the August 1929 Bulletin of the A.A.P.G. it seems to have been a gdnerally accepted fact by many geologists that the generally southeast dips shown in the Capitan limestone outcrops in the general Carlsbad Cavern area are the result of foresetting in reef building. It is herein suggested that the dips in question are, in large part at least, comparable with other formational dips coming off the southeast and east flanks of the Guadalupe Mountains. Hence said dips could well be perfectly normal inclinations resulting from the post-Cretaceous orogeny that built the mountains. It is further suggested that if the position of the Capitan beds could be restored to their depositional positions there is a strong possibility that they might even show traces of foresetting in a northwesterly direction.

It is common practice to visualize the so-called "reef" front as being present in New Mexico in an arcuate pattern whose generally southern boundary is essentially coincidental with the southern boundary of zone 3 on the accompanying map. The recent publication by Newell and others actually presents no reef outline map.

The more or less generally accepted mental picture

of the so-called "reef" front seems to fall in line with the statement by John Emery Adams on page 1598 of the November 1944 Bulletin of the A.A.P.G. in his paper entitled, "Upper Ochoa Series of Delaware Basin, West Texas and Southeastern New Mexico." Quoting, we find as follows: "Topographically, at the inception of the Ochoan epoch, the Delaware basin was an unfilled geosynclinal bowl averaging approximately 1700 feet in depth and encircled by steep-faced, cliff-like reefs between 1200 and 2000 feet high." Incidentally, on the basis of thicknesses of the Capitan limestone series in the Getty No. 7 Dooley, Section 24-T. 20S.-R.29E. and in the Richardson & Bass No. 1 Cobb Federal, Section 23-T.20S-R.31E., we would have to visualize the "reef cliff" as being in places, at least, as much as 2500 to 2600 feet in height.

Let us then assume, as is commonly done, that at the close of so-called "reef" time the "reef" did stand as a great arcuate cliff with its open, or seaward side, in a generally south facing direction. Under such an assumption the whole problem becomes even more complex. Some extremely conflicting factors come into the picture, particularly as related to conditions of sedimentation. Briefly, some of these problems might well be as follows:

The "reef" advocates generally correlate the originally named Frijole limestone, or their Lamar, with the upper portion of the Capitan limestone. Also, their so-called Bell Canyon member of the Delaware Mountain group is generally classed as the equivalent of the main body of the Capitan series. If such is the case, then generally south of the "reef" face, where are the Bell Canyon beds? If the upper portion of the Delaware Mountain beds below the Castile anhydrite and salt are Bell Canyon in age and are the equivalent of the "Capitan Reef", how did they get in their present position? Did there suddenly occur, at the close of "reef" time a great arcuate fault that followed the "reef" front and elevated the latter, or drop the Bell Canyon, a matter of some 2000 to 2500 feet vertically? Or, following Bell Canyon-Capitan time were the Bell Canyon beds scoured out in their entirety away from the "reef" front?

It should be noted that it is by no means an exceptional practice among operators doing subsurface structural mapping on the top of the Delaware Mountain to use the top of said series as a datum plane regardless of whether it is overlain by Capitan limestone or by the Castile anhydrite-salt series. In other words it appears possible that even some of the "reef" advocates have used the top of the Delaware Mountain as being essentially the same stratigraphic horizon in such tests in the Capitan areas as the Ohio No. 1 McCullough, Section 1-T.20S.-R.27E.; Ohio No. 1 Tracy, Section 34-T.21S.-R.26E.; and the Getty No. 7 Dooley, Section 24-T.20S.-R.29E., as compared with tests in the Castile area such as the Snowden-McSweeney No. 1 McNutt, Section 4-T.21S.-R.30E.; Continental No. 1 Gardiner, Section 34-T.23S.-R. 31E.; Sun No. 1 Pew, Section 21-T.25S.-R.30E. etc. What then does this mean? Some of the various interpretations could be as follows:

1. Let us assume that the Delaware Mountain series beneath the Capitan and the Castile in New Mexico is all older than Bell Canyon. In that case it would mean that over a large portion of the Delaware basin there would be no Bell Canyon. Such a condition would then appear to call for some extraordinary thickening of the Cherry Canyon and Brushy Canyon members almost directly under the "reef" front when we take into account some of the Delaware Mountain thicknesses. For example: Ohio No. 1 Tracy, cited above had 2295 feet of Delaware Mountain; Getty No. 7 Dooley, cited above had 2495 feet of Delaware Mountain; Richardson & Bass No. 1 Cobb Federal, Sec. 23-T.20S.-R.31E. had 2375 feet of Delaware Mountain.

2. If the Delaware Mountain beds below the Castile are Bell Canyon in age and correlate with the "Capitan Reef", then any subsurface map crossing the "reef" front line from south to north would have to show an essentially vertical rise of some 2000 feet plus at the "reef" front.

3. If the Delaware Mountain beds below the Castile are Bell Canyon in age and of Cherry Canyon age below the capitan limestone, then any subsurface map, using the different stratigraphic points, would have to show an essentially vertical drop just north of the "reef" front to the extent of the postulated thickness of the Bell Canyon series.

Let us assume that Capitan and Bell Canyon are correlative and therefore were deposited essentially contemporaneously. We are then faced with a very strange condition of sedimentation. It seems to be generally agreed that mechanically deposited sediments gain thickness more rapidly than do those resulting from chemical origin. Under the Capitan-Bell Canyon pronounced relationship we find that the converse is true, in other words, some 600' to 800' of Bell Canyon Beds – mainly clastics – become the equivalent of some 2000' to 2500' of Capitan limestone. Perhaps such a

situation could have occurred if the organisms that built the "reef" were present in truly infinite numbers. However, if they aere sufficiently abundant to have accomplished the job assigned to them, their remains should be preserved in the Capitan beds in such masses as to leave no question of doubt. The evidence from samples and cores from the Capitan does not bear out such a conclusion.

Accepting the "reef" hypothesis that the "reef" was growing seaward, we would have to accept that the seaward direction lay generally to the south in New Mexico. Did the Bell Canyon clastics then come in from the open sea? If this sea was open to the south, what is a logical explanation as to why the Delaware Mountain sands tend to become more coarse going from north to south? Should not the converse be true? Further, if the fine Bell Canyon sands were being washed against a growing organic "reef", would such a condition have been conducive to the welfare of reef organisms? Still further, why do we not find stringers or lenses of Bell Canyon type sands in the Capitan limestone series?

It has been stated by some geologists that the Delaware Mountain sands came in from a generally north direction. If this were true and Capitan and Bell Canyon are of the same age, would it not mean that the Bell Canyon sands were being steadily carried in across the growing "reef" mass? Would such a condition have fostered an exceedingly rapid growth of colonial organisms?

Finally, let us again assume that the Capitan limestone series did actually stand as a great arcuate, essentially vertical, "reef" cliff, rising grandly to heights up to 2500 feet, facing generally to the south in New Mexico. Thus the stage was set for the beginning of Castile time. Then some strange things began to happen!

The "reef" had been growing seaward in a generally south direction. Then suddenly conditions apparently went into reverse and the seaward side – the inside of the great arc – became the lagoonal area in which began the restricted area deposition of Castile anhydrite and salt. What became of the "back reef" area when the former seaward area became lagoonal? Did it suddenly become the open sea area or did it become a land surface?

There followed than a period of time sufficiently long to make possible the deposition of some 2000 feet plus of Castile beds. During all this time did the great "reef" front stand undisturbed? Did no wave action break down portions of its front and incorporate "reef" rubble in the adjacent Castile beds? Perhaps it did, but wells drilled in the area of zone 2 on the accompanying map failed to show the presence of such material. Rather they show what appears to be normal interbedding of Capitan limestone and Castile anhydrite and salt.

Undoubtedly there remain many more unanswered questions and problems for which no explantations have been offered, but only one more will herein be suggested. It is a question that has been asked by many geologists and should therefore be answered by the "reef" school. It is, namely: what was taking place in the so-called "back reef" area during all the long period of time during which the Castile beds were being deposited?

The foregoing statements have not been made merely for the purpose of offering criticisms of the work of capable and conscientious geologists. Rather they are set forth, at the request of the field trip committee of the New Mexico Geological Society, for a two-fold purpose. First, in the hope that they will help keep alive the very intriguing Capitan-Castile-Delaware Mountain problem that many geologists believe is still far from settled, and secondly, in the hope that they may in some manner help in the ultimate solution of the problem. The questions set forth are among some of the many that have puzzled the writer for a goodly number of years. Also, through converstations with many geologists, the writer has come to realize that many besides himself are far from satisfied with some of the explanations that have been put forth, as well as with the sometimes glaring lack of explanations. It is therefore not surprising that a very appreciable number of geologists appear to feel that the advocates of the hypothesis of widespread "reef" development as the principal agency in the formation of the Capitan series should come forward with much more detailed factual data in defense of their proposed solution to the problem. This appears to be especially true as related to subsurface stratigraphy.

It is certainly not difficult to criticise the work of others, but as geologists we are aware of the fact that criticisms and questions often lead to clearer understandings and to the establishment of factual data. It is also in point for one offering criticisms to offer some alternative solution. To that end the writer herein presents the outline of a possible interpretation of the Capitan-Castile-Delaware Mountain problem, as relates to southeastern New Mexico. This simple

PROPOSED GENERALIZED CORRELATION CHART

SALADO	SALADO	SALADO	SALADO
CARLSBAD	TANSILL (Brown Lime) YATES SEVEN RIVERS QUEEN	TANSILL (Brown Lime) YATES SEVEN RIVERS QUEEN	CASTILE
	CAPITAN	CAPITAN	
GRAYBURG	FRIJOLE (LAMAR)		FRIJOLE (LAMAR)
SAN ANDRES	DELAWARE MOUNTAIN	BELL CANYON ? CHERRY CANYON ? BRUSHY CANYON ?	DELAWARE MOUNTAIN
YESO	BONE SPRING		BONE SPRING

NOTE: Question marks are placed after the Delaware Mountain divisions of Bell Canyon, Cherry Canyon and Brushy Canyon for the reason that the writer seriously questions the possibility of positive identification of the units in subsurface.

interpretation is the result of very appreciable amounts of work on the structural and stratigraphic history of the Permian of southeastern New Mexico. The writer sincerely believes that the proposed possible interpretation would not have required the violation of any basic principle of sedimentation, nor would it have required anyparticlularly complexstructural history.

The writer desires first to present herewith what he believes to be a warranted, generalized correlation chart. The proposed correlations are not, in very considerable part, original with the writer. Rather, they are essentially derived from some of the generally accepted ideas of numerous geologists working in southeastern New Mexico some years ago. It will be noted that in the chart and in the data following, the San Andres formation comes into the picture. This latter series was deposited over very extensive areas and very definitely must be taken into account in any problem relating to the upper Permian of southeastern New Mexico.

Available data indicate to the writer that as related to southeastern New Mexico the so-called Delaware Basin as we know it today was probably not a major structural basin at the time of deposition of the Delaware Mountain beds, but rather in the nature of a broad, relatively gently sloping, subsiding strandline, with the more seaward and more truly marine areas lying to the north. Along the northern and outer limits of the strandline the thin limestones, shaley limestones, fine sandstones and siltstones of the Delaware Mountain series appear to have graded laterally into the marine limestone beds of the San Andres. This interfingering and transition is well illustrated in such tests as the following: Richfield No. 1 McMillan; Section 36-T.20S.-R.26E.; Keohane, Inc. No. 1 Federal, Section 7-T.19S.-R.30E.; and Amerada No. 2 Record, Section 25-T.19S.-R.35E.

The relationship between the Delaware Mountain and the San Andres as set forth above will most certainly be opposed by persons holding to the belief that the Delaware Mountain beds came in from the north. However, their case remains unsupported by any data showing beds of Delaware Mountain lithology over the vast areas of New Mexico lying generally north of township 18 South.

By the close of lower San Andres time the San Andres-Delaware Mountain seas were becoming more restricted as evidenced by the presence of interbedded limestone, anhydrite and salt in the upper two units of the San Andres in the area of eastern Chaves County and northern Lea County and thence northward. By the end of San Andres-Delaware Mountain time the seas had become still more restricted, leaving a relatively small area in which the Capitan limestone series was being deposited, while simultaneously the salt and anhydrite of the Castile were being deposited in the salt pan area to the south and anhydrite, anhydritic limestone, red shale and some salt were being deposited in the other marginal areas. Restriction and shrinking of the seas continued through Salado time and ultimately reached the bittern stage of concentration over relatively wide areas.

The idea of simultaneous deposition of limestone and anhydrite in relatively closely adjacent areas may be, and probably will be, attacked as unreasonable. However, a study of the evidence reveals that such conditions were actually quite common in many areas of southeastern New Mexico during Permian time. Moreover, such gradations took place in beds of San Andres and Yeso ages as well as in beds of Capitan-Castile age. The evidence further reveals that the anhydrite was being deposited along the shallower salt pan or strandline areas while the limestones were being deposited in the more marine areas. Such conditions appear to be normal as related to solubilities of limestone and anhydrite, especially when temperature variations for varying depths of water are taken into account.

The writer regrets that time and space preclude the presentation of many possible cross-sections that would lend at least some strength to the relatively simple explanation set forth above.

The accompanying map is essentially self explanatory. Zone 1 shows the approximate distribution of the Castile series. Zone 2 shows the narrow zone in which the writer visualizes the rapid lateral gradation from the Castile facies into the Capitan facies. Zone 3, as previously stated, shows the approximate limits of the Capitan as a predominantly limestone facies. Zones 4, 5, 6 and 7 show areas in which the Capitan limestone series graded into the various different lithologies. Likewise on the map is shown the Seven Rivers gypsum tongue in the Rocky Arroya area where gradation from limestone into gypsum and anhydrite can be seen occurring in a very short distance in outcrops.

In conclusion the writer desires to go on record as stating that on available evidence he does not accept widespread "reef" orgin as the principal cause in the formation of the Capitan limestone series. There ap-

pears to be well presented evidence indicating the presence of bioherm or reefoid developments in various places in outcrop areas. Similar conditions may well exist in various places in subsurface. To date the "reef" school advocates appear to have submitted little in the way of factual data to indicate in what areas or to what extent reefing conditions existed subsurface in southeastern New Mexico. Statements to the effect that a great arcuate "reef" is present are relatively common, but detailed information to back up such statements seems to be largely lacking.

Under either the belief that the Capitan is Bell Canyon equivalent or that it is the equivalent of the Castile series it is quite difficult to picture the growth of a "reef" front in the location in which it is supposed to be. Either possibility would appear to call for conditions that would have been unfriendly for the prolific development of colonial organisms. However, of the two possible conditions, it would appear that it would actually have been easier to have developed a "reef" closely adjacent to the deposition of anhydrite. Special conditions would have had to exist, but they would probably not have been as complicated and special as would have been required to have an organic "reef" growing in juxtaposition to fine, silty sandstones.

The writer is fully aware that the foregoing notes will call forth a very appreciable amount of criticism and it is certainly to be hoped that they will. No claim is made that the generalized ideas as set forth herein are the final solution to the whole Capitan-Castile-Delaware Mountains problem. Personally the writer feels that the whole problem is far from settled and that it is therefore imperative that it should be kept alive. If the notes herein contained do nothing more than cause the "reef" school to amplify the data on which some of their statements have been based they will have accomplished something.

NEW MEXICO'S DEEPEST OIL TEST

P. W. Hughes, Geologist

The Richardson & Bass #1 Harrison-Federal, recently abandoned oil test in Southeastern Eddy County at a total depth of 16,705', is to date the deepest attempt for production in New Mexico. Location of the above test is in Sec. 12, Twp. 25-S, Rge. 30-E in the subsurface province referred to as the Delaware Basin. Approximately 2,000' of Siluro-Devonian and Ordovician rocks lie between the basement complex and therefore the total thickness of sediments is known to exceed 18,500' in the New Mexico portion of the Basin.

Listed below are the sample tops and thicknesses of the various lithologic units generally picked in this area. There is little agreement as to the tops of the Leonard and Wolfcamp Series of the Permian and the Strawn and Atoka Series of the Pennsylvanian. Division of Permian and Pennsylvanian units are difficult from an examination of samples alone, and other aids such as paleontology and electrical logs are desirable.

PERMIAN

	Top	Thickness
Ochoa Series	1160'	2880'
Guadalupe Series	4040'	3860'
Leonard Series	7900'	2920'
Wolfacmp Series	10820'	2918'
Total thickness		12578'

PENNSYLVANIAN

Strawn Series	13738'	232'
Atoka Series (and Morrow)	13970'	1890
Total thickness		2122'

MISSISSIPPIAN

Mississippian Shale	15860'	230'
Mississippian Limestone	16090'	390'
Woodford Shale	16480'	140'
Total thickness		760'

SIL-DEVONIAN

16620'