Regional Well-Log Correlation in the New Mexico Portion of the Delaware Basin

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Abstract
Although well logs provide the most complete record of stratigraphy and structure in the northern Delaware Basin, regional interpretations of these logs generate problems of ambiguous lithologic signatures and one-hole anomalies. Interpretation must therefore be based on log-to-log correlation rather than on inferences from single logs. In this report, logs from 276 wells were used to make stratigraphic picks of Ochoan horizons (the Rustler, Salado, and Castile Formations) in the New Mexico portion of the Delaware Basin. Current log correlation suggests that: (1) the Castile is characterized by lateral thickening and thinning; (2) some Castile thinnings are of Permian age; (3) irregular topography in the Guadalupian Bell Canyon Formation may produce apparent structures in the overlying Ochoan units; and (4) extensive dissolution of the Salado is not apparent in the area of the Waste Isolation Pilot Project (WIPP) site.
Acknowledgment

Well-log picks were initially made by a team consisting of Steven J. Lambert, Terri Ortiz, and the authors. The Appicon data base was set up by Bruce Whittet and Robert Williams. Meredith Edwards assisted greatly in preparing the final graphics.
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Regional Well-Log Correlation in the New Mexico Portion of the Delaware Basin

Introduction

Borehole geophysical logs provide records of stratigraphy and structure in the northern Delaware Basin that are more detailed than previous data obtainable from incomplete coring and poor outcrop. Structural and stratigraphic variations in a bedded evaporite sequence may be caused by sedimentation, deformation, or dissolution. Well logs provide the critical and sometimes only data for inferring which processes were or are active. Interpretations of lateral continuity of structures also come from log correlation.

Well logs from the New Mexico portion of the Delaware Basin were examined for this report (Figure 1). The area covered is a 30 X 36-mi rectangle (T21S to T25S and R29E to R34E). The northern edge of the area lies adjacent to the Capitan Reef. The resulting log correlation in this area provided a data base for previous reports on dissolution and deformation (Lambert, 1983; Borns et al, 1983, respectively) as well as for this current evaluation of earlier log correlations in the region (e.g., Anderson, 1978). In particular, this report addresses the specific problems of one-hole anomalies and ambiguity of log interpretation.

Ideal Stratigraphy

Powers et al (1978), Snyder (in Borns et al, 1983) and Lambert (1983), discuss the stratigraphy of the northern Delaware Basin in great detail. We briefly review the stratigraphy in this report; the interested reader seeking more information may refer to the references cited.

The strata studied in this report are all of Permian age. The younger Permian formations (the Rustler, Salado, and Castile) are Ochoan, and the Delaware Mountain Group (DMG) is Guadalupian. The Rustler is the uppermost evaporite unit used in this study (see Figure 2). The top of the Rustler is considered to be the top of the first persistent anhydrite bed as penetrated by oil and gas drillings. This anhydrite bed is a clear marker for stratigraphic correlations. The Rustler contains two major members, the Culebra and Magenta Dolomites, within alternating beds of anhydrite, halite, and siltstone.

The underlying Salado Formation is primarily halite. The formation is here divided into three units: the Upper, Middle, and Lower Salado. The upper and lower boundaries, respectively, of these units are the Salado-Rustler contact and Marker Bed 124 for the Upper Salado; Marker Beds 124 and 136 for the Middle Salado; and Marker Bed 136 and the Salado-Castile contact for the Lower Salado. The Lower Salado includes the Cowden Anhydrite and the Infra-Cowden Halite; the base of the Infra-Cowden is the unconformable Salado-Castile contact (cf Adams, 1944). Marker Beds 124 and 136 are 2 of the 45 numbered siliceous or sulfatic units that are numbered 100 to 145 in the Salado. This usage originated in the local potash industry (Jones et al, 1960). These marker beds are traceable in the subsurface for several kilometers, although they are not recognizable in every hole.

The Castile Formation is composed of alternating anhydrite and halite units (Lambert, 1983). The complete section of the Castile is divided into seven members (in descending order): Anhydrite IV, Halite III, Anhydrite III, Halite II, Anhydrite II, Halite I, and Anhydrite I. The section is not universally complete because of the cross-cutting effects of the Salado-Castile unconformity and lateral facies variations. In some areas within the basin, the anhydrite units are blocky, nodular, or brecciated. Such zones are interpreted to be the result of deep dissolution (Anderson, 1978).

The Bell Canyon Formation is the uppermost unit of the DMG, but it is the lower-most unit of interest in this report. The Bell Canyon is a thick section of sandstone and siltstone with some shale (King, 1948; Davies, 1983).
Figure 1. Well location and Applico.
Results of Log Correlations

This report is an accumulation of geophysical well-log data from 276 drillholes in the northern Delaware Basin. The maps (Figures 3 through 26) portray these data in a 30 x 36-mi area. The 24 contour maps are based on our log correlations and include maps of stratigraphic surfaces and isopach maps. The results of this study are presented here, and detailed discussions of the methods that we used for correlation are presented in later sections. The following basic observations can be made from the contour maps:

- The units incline towards the Capitan Reef, with deflection of contour lines into a parallel position with the margin of the reef.
- Away from the margin of the reef, the contour lines run N-S, reflecting a west-to-east dip for the stratigraphic surfaces.
- Stratigraphic surfaces reach their maximum depths within the southeast corner of the map area.
- Within the Rustler and Salado Formations, a linear high that runs northwest to southeast appears in the southern third of the map area. This high becomes indistinct across the Salado-Castile contact. With depth, Castile surfaces more closely parallel the top of the DMG.
- Local highs and lows are observed for any given surface within the map scale. The number of highs approximately equals the number of lows.
- Isopach maps show a generally uniform thickness in the middle of the map area, with thickening or thinning adjacent to reef and irregular structures along the southern edge of the map area.
- The middle Salado is more constant in thickness than the upper or lower Salado.
- Very broad zones of thickening and thinning are observed in the lower Salado and Castile in the southern third of the map area.

The observations made above are based on broad-scale correlations of oil- and gas-industry holes. Therefore, the detail of structures in the area adjacent to the WIPP site may be lost at the scale of mapping in this report. Structures such as the FC-92 depression (Davies, 1983 and Snyder in Borns et al, 1983) are lost. For relatively fine-detail structures in the WIPP area, the reader is referred to Griswold (1977).

As the study progressed, we became aware of the following considerations of specific interest to the WIPP project:

- Stratigraphic picks can vary among workers. Therefore, such picks need to be reviewed and compared by the entire working group.
- Variations in log signature, caused either by operational conditions or real stratigraphic complexities, can make stratigraphic picks ambiguous.
- MB 136, Cowden Anhydrite, Infra-Cowden, and Anhydrite III are commonly the most ambiguous surfaces to pick; therefore, isopachs that are based on MB 124 and the top of Halite II are less prone to error.
- Assumptions of post-Permian lateral continuity of key marker beds are not always valid.
- Structures based on one-hole anomalies need to be carefully evaluated for ambiguities in picks, errors in transcribing data, quality, and type of log used, and consistency with nearby holes. After such checks, some one-hole anomalies remain. In the course of constructing the contour maps in this report, we drew contour nests where the one-hole anomaly is supported by trends in adjacent holes. However, if adjacent holes are not consistent, we did not deflect the contours but marked the anomalous hole with an asterisk.
Figure 3. Top of the Rustler (E).
Figure 4. Top of the S
Figure 6. Top of
Figure 8. Top of It
TOP OF ANHYDRITE III

CONTOUR INTERVAL IS 100 FEET

ONE-HOLE ANOMALY AT CERTAIN HORIZONS
Figure 12. Top of Hali
Figure 14. Top of H
Figure 16. Top of D
Figure 13. Upper Salad
MIDDLE SALADO ISOPACH

CONTOUR INTERVAL IS 50 FEET

ONE-HOLE ANOMALY AT CERTAIN HORIZONS
Figure 20. Lower Salac
MARKER BED 136 TO HALITE II ISOPACH

CONTOUR INTERVAL IS 50 FEET

*ONE-HOLE ANOMALY AT CERTAIN HORIZONS
Figure 22. Infra-Cowde
HALITE II ISOPACH

CONTOUR INTERVAL IS 50 FEET

ONE-HOLE ANOMALY AT CERTAIN HORIZONS
Figure 24. Halite II t
HALITE I ISOPACH

CONTOUR INTERVAL IS 50 FEET

ONE-HOLE ANOMALY AT CERTAIN HORIZONS
Figure 26. Halite I
Methods and Problems of Log Correlation

A file of well-location symbols, each with an associated identification text, was constructed on an Applicon Graphics System. Well locations were digitized from well ownership maps published by the Midland Map Company. The selected wells were marked on the maps and individually identified by unique seven-character identifiers. An example identifier is PO8,2533 in which the well name is identified by a letter (PO8), the township (2533), and the range (PO8). The latter requires core data to corroborate the inferred structure or unit identity. Logs such as density, gamma ray, and acoustilog allow the dominant rock-forming mineral (e.g., anhydrite, halite, polyhalite or clay) to be inferred for the section of interest. A specific example is the use of the gamma-ray spike to identify the base of the Cowden Anhydrite. The question arises whether specific rock types such as dissolution breccias can be inferred from log signatures. Logs alone identify only a physical property from which to infer mineralogy. To identify a rock type, some assumptions must be made regarding the unit's mineralogy, porosity, density, etc. This can be done only with core truth, as Lambert (1983, p 75) has done by using logs from Nash Draw where dissolution is known to occur. The characteristic signature from Nash Draw is used, herein, to distinguish dissolution residues elsewhere in the basin. Even in this example the assumptions are important; e.g., that dissolution processes are similar between Nash Draw and the rest of the basin. However, other processes such as original rapid depositional oscillations in rock type may result in log patterns similar to those of a dissolution residue. Thus, the validity of any log interpretation depends on its corroboration by drill core and correlation to other logs from additional holes.

To develop a regional correlation map, a geologist needs to convert the geophysical data of well logs into stratigraphic picks. This process suffers from various degrees of subjectivity. We will begin with a discussion of ideal log signature and progress into the complications of stratigraphic picks.

Ideal Well-Log Signatures

Logs can be used in two basic ways:

- To determine specific properties, such as rock type, porosity, and permeability within a single hole
- To correlate hole-to-hole the continuation of structure or rock unit.

The latter requires core data to corroborate the inferred structure or unit identity. Logs such as densilog, gamma ray, and acoustilog allow the dominant rock-forming mineral (e.g., anhydrite, halite, polyhalite or clay) to be inferred for the section of interest. A specific example is the use of the gamma-ray spike to identify the base of the Cowden Anhydrite. The question arises whether specific rock types such as dissolution breccias can be inferred from log signatures. Logs alone identify only a physical property from which to infer mineralogy. To identify a rock type, some assumptions must be made regarding the unit's mineralogy, porosity, density, etc. This can be done only with core truth, as Lambert (1983, p 75) has done by using logs from Nash Draw where dissolution is known to occur. The characteristic signature from Nash Draw is used, herein, to distinguish dissolution residues elsewhere in the basin. Even in this example the assumptions are important; e.g., that dissolution processes are similar between Nash Draw and the rest of the basin. However, other processes such as original rapid depositional oscillations in rock type may result in log patterns similar to those of a dissolution residue. Thus, the validity of any log interpretation depends on its corroboration by drill core and correlation to other logs from additional holes.

To develop a regional correlation map, a geologist needs to convert the geophysical data of well logs into stratigraphic picks. This process suffers from various degrees of subjectivity. We will begin with a discussion of ideal log signature and progress into the complications of stratigraphic picks.

The most useful logs for stratigraphic picks in the evaporite section of the Delaware Basin are Borehole Compensated Sonic (BHC) or Acoustilog and Natural Gamma-Ray Spectrometry (NGS, or γ-log). The
marked density differences between halite and anhydrite or polyhalite interbeds show up distinctly in the BHC and Acoustilog. The γ-log can often pick up clay seams that characterize the base of certain marker beds.

Figure 27 shows the ideal well log signature on which stratigraphic picks were based in this study. Using this log signature as a basis, we made picks where possible in 276 holes for the tops of the following units: the Rustler Formation, the Salado Formation, Marker Bed 124, Marker Bed 136, the Cowden Anhydrite, the Infra-Cowden Halite, Anhydrite IV, Halite III, Anhydrite III, Halite II, Anhydrite II, Halite I, Anhydrite I, and the Bell Canyon Formation.

**Ideal Versus Ambiguous Logs**

The information obtainable from a log can vary greatly due to whether the log is characterized as ideal or ambiguous. Examples of ideal and ambiguous logs are shown in Figures 28 and 29: Figure 28 shows the Rustler, Salado, and uppermost Castile Formations in an ideal log (ERDA 9) and two ambiguous logs; Figure 29 depicts the lowermost Salado, the Castile Formation, and the upper Bell Canyon in an ideal log and an ambiguous log. (An ideal log is legible and displays the expected signature of the ideal stratigraphy. Ambiguous logs may be too noisy, such as when the sensitivity is too high.) Some of the available logs have been taken through the casing of the well, diminishing the reliability of lithologic information. Departures from the ideal stratigraphy make stratigraphic picks uncertain in ambiguous logs. The problems of ambiguity are discussed in sections below.

In our specific examples of ideal and ambiguous logs (Figures 28 and 29), the ideal log comes from the ERDA 9 borehole, which is substantiated by a drill core. Marker Bed 124 shows its characteristic signature (a double spike) in the ERDA 9 log. In the ambiguous logs, a double peak is not distinct. Lower in the section, the Cowden Anhydrite takes a typical shape in the ERDA 9 density log, accompanied by the characteristic gamma log spike at its base. In the ambiguous logs, the density or acoustilog signature of the Cowden is not identifiable; any pick, if it can be made, is based on a gamma log spike. An ideal log from ERDA 9 is on the left of the figure. (Stratigraphic units in the Rustler, Salado, and uppermost Castile Formations are distinct in the ERDA 9 logs. However, in the well logs from the two holes that are represented in the center and on the right side of this figure, the same stratigraphic indicators are indistinct over the same depth interval.)

**Log-Correlation Error**

It is difficult to assess the amount of error incorporated in log correlation and the stratigraphic picks in one well log. To our knowledge, no systematic study has been made of the reliability and reproducibility of interpretations of stratigraphy and correlations therebetween wells. The data used in reports such as this are the products of human inference; hence, errors are individualistic and not systematic. Other possible errors are in the original well data. Examples are in the elevation of the hole; location, whether ground level or, the Kelly-bushing is used as the base level, and deviation of the hole from vertical. Barring total mislabeling of the log, such errors are not significant for the maps in this report since the contour intervals, whether 50' or 100', are larger than the possible error.

**Basic Assumptions of Stratigraphic Picks**

Important theories for stratigraphic anomalies in the evaporite sequence in the northern Delaware Basin have originated from log interpretation and correlation. Namely, Anderson (1978) and Davies (1983) postulated deep solution from their regional deformation patterns. Snyder (in Borns et al., 1983) proposed that gravity-driven salt flowage was indicated by the Salado-Castile stratigraphy. Borns and Barrows (in Borns et al., 1983) advanced the idea that syndepositional salt flowage has originated from log interpretation and correlation. Important structures are based on log data to these theories. We also examine some log data in much finer detail, e.g., single holes or arrays of closely spaced holes, than log correlation maps permit. This exercise allows us to examine the problems of one-hole anomalies and log correlation in regional interpretation. Important structures are based on stratigraphic picks from logs. Such correlation of a log-signature-lithotype to a specific stratigraphic unit is an inferential process based on certain assumptions:

- Log signatures are easy to interpret and unambiguous (see sections above and Figure 27 for discussion of the ideal log).
- All units initially exhibited lateral continuity. For example, Anderson (1983) has stated that virtually every salt bed in the upper Castile can be traced laterally with little change in thickness until it encounters the Salado-Castile unconformity.
### Formation or Marker Bed | Basis for Stratigraphic Picks | Sample log
--- | --- | ---
Rustler Formation | The top of the Rustler is the 1st continuous anhydrite encountered—an increase on velocity, acoustic or density logs is seen, and a decrease on gamma logs. | ![Sample log for Rustler Formation](Image)
Salado Formation | The top of the Salado registers as a sharp change from the Rustler, with an abrupt, brief increase on the gamma log and an abrupt, brief decrease in acoustic, velocity or density logs. | ![Sample log for Salado Formation](Image)
Marker Bed 124 | Marker Bed 124 is the lower of two well-developed spikes; it frequently registers as a double spike itself on both gamma logs and acoustic, velocity, or density logs. | ![Sample log for Marker Bed 124](Image)
Marker Bed 136 | Marker Bed 136 generally is seen as a heavy spike with triple peaks or as a group of three spikes on acoustic, velocity, or density logs, and has a well-developed spike or spikes on the gamma log. | ![Sample log for Marker Bed 136](Image)
Cowden Anhydrite | The Cowden shows as a heavy spike on velocity, acoustic, or density logs, and is characterized by a small, sharp gamma peak at the base of the anhydrite. | ![Sample log for Cowden Anhydrite](Image)
Infracowden | The anhydrites show a regular, fairly high trace on acoustic, velocity, or density logs, and a small less regular trace on gamma logs. Halites have a regular, medium level trace, somewhat lower than anhydrites on a acoustic, velocity, or density logs, and a decrease in the gamma logs as well. | ![Sample log for Infracowden](Image)
Castile Formation Halite-Anhydrite Sequence | The top of the Bell Canyon shows a sharp increase in gamma logs and a sharp decrease in acoustic, velocity, or density logs, followed by an irregular trace on the logs. | ![Sample log for Castile Formation Halite-Anhydrite Sequence](Image)
Bell Canyon Formation Delaware Mt. Group | | |

*Sample log from Neil H. Wills Continental State No. 1, T25SR33E, S. 32, Gamma Ray and Acoustilog*

**Figure 27.** Gamma-ray and acoustilog signatures for ideal well log from which the stratigraphic picks are unambiguous (Neil H. Wills Continental State #1, T25SR33E, S.32)
Figure 28. Comparison of ideal and nonideal well logs for the section from the Dewey Lake formation through the Salado Formation. (An ideal log from ERDA 9 is on the left.)
Figure 29. Comparison of ideal and nonideal logs of the lower Salado and Castile stratigraphy. (Ideal log is on the left. Stratigraphy is more complicated in the right-hand log; e.g., halite interfingers in AIII and anhydrite bed in HL.)
With regard to the first assumption, these logs are not necessarily straightforward to interpret. Such difficulties are caused either by the quality of the log or the deviation of the log signature from the ideal. These ambiguities are greatest for the Lower Salado (MB 136 and below) and Upper Castile (above Halite II). For comparison of isopachs, the approach of Lambert (1983) is recommended in which distinct markers such as MB 124 and Halite II are used.

The second basic assumption is lateral continuity of halites in the Upper Castile. This assumption precludes any syndepositional thickening and thinning and lateral facies variation (Anderson, 1981 and 1983). Thus, any observed thickening and thinning would be construed as the result of post-Permian deformation and/or dissolution. However, the inferred Poker Lake structures (see following sections) show the problems with this assumption. Within the cluster of four holes in Section 8, a thin halite bed that has been tagged in some logs as HIII can be traced at a consistent elevation but with variable thicknesses.

**Poker Lake Structures**

At first glance, the numerous industry exploration holes in the Delaware Basin seem to provide an excellent record for log correlation. However, the distribution of holes from which logs have been analyzed is not uniform. Of the 276 holes used in this report, large localized concentrations occur; e.g., in T25S R32E (see Figure 1). Hence, the structural detail cannot be extended with the same confidence from area to area. Early log interpretations in the Delaware Basin resulted in contour maps (e.g., Figure 4, Anderson, 1978 and Figure 30 in this report). This specific example of a Halite I isopach map is instructive. The map shows detailed contouring and a fabric that is imparted by the orientation of contour structures. However, the map detail is misleading since the synforms and antiforms are largely based on one-hole anomalies. The areal extent and fabric of the structures shown have been inferred and drawn in; the actual size of such structures needs to be carefully established. We will concentrate on the Poker Lake structures in T25S R30E to illustrate the problems of extrapolation of one-hole data.

![Figure 30. Isopach Map of Halite I in the northern Delaware Basin (from Anderson, 1978. Such maps can display a fabric and topography of structures that are indicated not so much by well data as by inference of expected geology. Hence, such fabrics may be misleading.)](image-url)
Poker Lake structures were shown as a N-S-trending syncline-anticline pair by Anderson and Powers (1978). The contour maps in Anderson and Powers (1978 Figure 6, p 82) suggest an apparent N-S length for these doubly plunging structures of 15,000 ft, and an apparent E-W width of 6000 ft (Figure 31 in this report). Such inferred structures are curiously large when the detail of available boreholes is examined (Figure 32). The anticline-syncline pair is based on two holes, AO5,2530 and PO8,2530, respectively. Within Section 8, the synclinal node (PO8,2530) is constrained by three other holes (LO8,2530, RO8,2530, and KO8,2530). These three holes are within 0.5 mi north, east, and south of the anomalous hole (Figure 33). Horizons can be correlated with normal stratigraphy and structure within the Castile among the three bounding holes. Hence, the size of any synclinal structure is less than the spread of the boundary holes (0.5 mi), and the existing structure is much less in areal extent than portrayed in the older contour maps.

*Figure 31.* Poker Lake structures (as shown in Anderson and Powers, 1978. The complete square outlines the township boundaries. Section 8 is astride the two structures in the northwest corner of the township.)
Poker Lake Syncline

Synclinal structures such as this one are most often taken as evidence of dissolution (Anderson, 1983; Davies, 1983). In their models, the synform is produced by removing salt through fractures that connect the Bell Canyon aquifers with the Castile halites, or through some as-yet-undiscovered aquifer in the upper Castile or Salado. Since the Poker Lake synform is the result of thinned Castile halites (see Figure 34), the former process would need to be the active one for dissolution to have occurred in this area. However, dissolution-caused downbuckling apparently does not affect the upper Castile and Salado (see Figure 34). This observation would suggest that the synform developed before the Permian deposition of the units above it.

The evidence for this conclusion is that the upper anhydrite, Anhydrite III and lower Salado, in the center of the synform (PO8:2430), is level with or above the same unit in adjacent holes. The structural low could be interpreted as having developed by salt flowage or by sedimentary channel-cutting before deposition of the overlying anhydrite. Thickening of the overlying anhydrite was a compensation response to the downwarp of the deposition surface after deformation.
A counterargument is that the nonbuckling of the upper anhydrite units in the synform is unreal and that the near equivalent elevation of upper anhydrite is coincidental. In this argument, the massive upper anhydrite masks downwarped Anhydrite III and Cowden layers in the synform. Hence, the synform extends upward but cannot be seen in this argument. This type of conclusion, coincidental, can be disregarded if one observes the nearly level correlation of secondary markers in the upper Castile and the lower Salado between adjacent holes in the Poker Lake structures (Figure 35). Therefore, this very localized depression of mid-Castile surfaces is an example of syndepositional thinning related to salt flowage or to sedimentary channel-cutting or channel-dissolution.
Figure 35. Detail of upper section of massive anhydrite from holes in Poker Lake structures (Lines indicate inferred continuity of distinctive markers. “C”, “124”, and “136” represent different stratigraphic picks made for the same unit by different workers, which again attests to the inherent ambiguity. Log on the far right (M32,2530) is an “ideal” log for comparison of thicknesses and position of markers.)
Poker Lake Anticline

The second major structure in the Poker Lake area is the antiform (Figure 36). The significant difference between this structure and the Poker Lake synform is that the upper anhydrite is displaced in the antiform. Hence, deformation probably occurred after deposition of the units. Halite I and II are thickened relative to adjacent holes; Halite I is the most thickened. This structure is typical of a salt-flowage structure as seen north of the WIPP site (Borns et al, 1973).

Figure 36. Fence diagram along an east-west line through the Poker Lake structures. (See Figure 32 for location of line and an explanation of units. Stippled pattern is anhydrite; unpatterned is halite.)

Another observation from the dense pack of holes in the Poker Lake area is that the upper surface of the DMG exhibits an uneven topography. Such irregularities can produce apparent flow or dissolution structures in the lower and mid-Castile. However, the depression on the sedimentary surface existed before and during deposition.

Examples have been provided above for (1) the misleading contour extrapolation for one-hole anomalies and (2) the ambiguous nature of certain stratigraphic picks. However, resultant maps (Anderson, 1978; Davies, 1983) have been used as compelling evidence for dissolution and other processes in the Delaware Basin. In the case of the Poker Lake structures, the actual sizes of the anticline and syncline are significantly smaller (6x) in map view, than the structures extrapolated by Anderson (1978) and Anderson and Powers (1978). The remaining smaller structures (one-hole anomalies) can still be attributed to salt flowage and/or dissolution since the Permian.

Disruptions of Ideal Stratigraphy

The preceding example of the Poker Lake structures demonstrates the lateral variations in a stratigraphy from one hole to another in a closely spaced array. The sources of such variations can be deformation, dissolution, or lateral facies change. Deformation and facies changes such as the Salado-Castile unconformity cannot be detected from individual well logs. We infer such structures by regionally comparing logs and following distinctive units through lateral correlation. In this step, log ambiguity is the greatest hazard.

Figure 37 shows the conceptual effects on log signatures of the Salado-Castile unconformity and selective dissolution in the upper Castile and Lower Salado. Anderson (1983) has argued that the stacking of anhydrite residues can produce an apparently compensated thickness of anhydrite across the unconformity. The massive anhydrite signature would need to mask intervening residues after halite removal. The volume of halite that must be removed to create the stacked effect should probably create residue zones of an extent that would be hard to mask. From Figure 37, we see the feasibility of the apparent thickening by dissolution and collapse. However, the compensation of thickness for Castile thickening and thinning can only be fortuitous. Some depression of a marker bed surface would probably be observed and would reflect the mass removal of halite only if removal were post-Permian.

The arguments above have depended on log-to-log comparison. Within an individual log, dissolution breccias or residues may be detected by rapid oscillations in the log signature as corroborated by Nash Draw core (Lambert, 1983). One needs to be careful that such oscillations are not merely the result of amplified background when the log sensitivity is relatively high.
A halite  anhydrite

B

Figure 37. Idealized effects of (A) Castile-Salado unconformity (Anderson, 1983) on acoustilog (similar on Sensilog or Sonic Log) (Note thickening of anhydrite signature.); and (B) selective halite dissolution in addition to unconformity. (Thickening of anhydrite occurs, but marker surfaces do not remain level.)

Conclusions

Regional log correlation remains our most useful tool for determining the regional stratigraphy and structure in the northern Delaware Basin. Because interpretation cannot be based on inferences from single logs but needs regional log-to-log correlation, we need to continuously update our data base. The basic conclusions will remain the same, but as coverage increases, current ambiguities will decrease. Current log correlations suggest the following:

- The Castile is characterized by thickening and thinning. Hence, mass redistribution rather than mass removal is the dominant process.

- Thinning in some lower Castile structures was compensated for by thickened upper Castile and lower Salado sedimentation. This relationship suggests that the synform existed during Permain (Ochoan) sedimentation.

- Irregular topography in the top of the Bell Canyon can produce apparent structures in the overlying Ochoan units.

Anderson (1978, 1981, 1983) has proposed deep dissolution as a major mechanism of salt removal in the northern Delaware Basin. He suggested that dissolution was marked in two zones, which are linear series of sinks. One zone trends SSE from the Poker Lake structures with a linear extent >30 km; the other zone, which includes San Simon Sink, is a line of troughs overlying the Capitan Reef on the eastern side of the basin. The northern end of Anderson’s dissolution structure appears in the southwestern corner of the area covered in Figures 3 through 26. This zone is 20+ km SSW of the WIPP site. It is conceivable that this set of troughs was caused by dissolution, although the mechanism may not be deep dissolution but dissolution related to the ancestral Pecos River (Bachman, 1983). At the scale of resolution for the spacing wells, no continuation is observed of this structure NNE towards the WIPP site.

Locally, Davies (1983) has proposed that finger sands within the Bell Canyon control dissolution; such finger sands have higher transmissivities than do adjacent rock types. These finger sands trend NE. Structure contours do not reflect these sands; nor, in fact, do Anderson’s line troughs. Davies has also proposed that a structural depression in the mid-Salado is evidence of deep dissolution two miles north of the WIPP site center as marked by the contour maps of Snyder in Borns et al (1983). The size of this structure is such that it does not appear on maps based on hydrocarbon industry holes. However, DOE has proposed to drill this structure to investigate its origins.

Lateral dissolution within the Rustler has occurred ~15 km west of the WIPP site as marked by Nash Draw. Within this 15-km radius, there is no compelling evidence for deep dissolution.
Bibliography


King, P. B., Geology of the Southern Guadalupe Mountains, Texas, USGS Prof Paper 215, 1948.


APPENDIX

Well-Log Data Arranged by Township, Range, and Section (all elevations in feet)

Example Entry

Hatmesa 2#2/Phillips Pet. Co alpha identification
H11, 2132, 3861 

Elevations
1 Top of Rustler
2 Top of Salado
3 Top of MB 124
4 Top of MB 136
5 Top of Cowden
6 Top of Infra-Cowden
7 Top of Anhydrite IV
(in this case, -1 indicates that no pick was made)
8 Top of Halite III
9 Top of Anhydrite III
10 Top of Halite II
11 Top of Anhydrite II
12 Top of Halite I
13 Top of Anhydrite R
14 Top of Bell Canyon Formation
BASSFEDERAL#1/RAHLPLOWE
L19,2232,3620
762,1230,2020,2422,2830,2857,-1,-1,3180,3590,3869,3999,4365,4640
#1FEDERAL/R.J.ZONNE
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