PS Subsurface Seven Rivers (Guadalupian) Anhydrite-Dolomite Transition, Eddy Co., New Mexico, USA: Modification of a Depositional Facies Change by Permian Meteoric Dissolution*

Alton Brown[1] and Robert G. Loucks[2]

Search and Discovery Article #50800 (2013)**
Posted June 30, 2013

*Adapted from or presentation given at AAPG 2013 Annual Convention and Exhibition, Pittsburgh, Pennsylvania, May 19-22, 2013

[1]Consultant, Richardson, TX (altonabrown@yahoo.com)
[2]Bureau of Economic Geology, The University of Texas at Austin, Austin, TX

Abstract

The anhydrite - dolomite facies change in the Seven Rivers Formation (SRF) exposed on outcrop can be interpreted as depositional or dissolution. To reduce ambiguity resulting from Cenozoic outcrop dissolution, the facies change was examined in the subsurface of eastern Eddy County, New Mexico.

North of the facies boundary, over 80% of the SRF section is anhydrite with thin dolomites and siltstones. Over a narrow zone approximately two kilometers wide, anhydrite abundance drops to about 20% anhydrite as dolomite thickens. By four kilometers south of the start of anhydrite thinning, all of the SRF is tight (1 - 4% porosity) dolomite with thin siltstone beds. The dolomites in the transition zone have high, irregular gamma ray (GR) related to high uranium. The high-GR dolomite grades southwards into low-GR dolomite with higher porosity.

The SRF thins by about 30.5 meters in the transition zone, with the most abrupt thinning near the northern end of the facies transition. The abrupt SRF thinning is equal to the thinning of net SRF anhydrite. Farther south within the transition zone, SRF thinning is irregular, and thinner anhydrite is compensated by thicker dolomite. Net SRF thinning is compensated mainly by thickening in the Yates Formation.

The SRF depositional anhydrite-dolomite facies change is interpreted as an originally gradational facies change that maintained a relatively constant position on the shelf interior. SRF sulfate thickness was modified during Yates deposition. Permian subaerial exposure, especially along the Yates B surface, could have caused meteoric, shallow-subsurface sulfate dissolution selectively within the carbonate facies, making the overall facies transition more abrupt.

Although the shelf margin during SRF deposition shows significant seaward progradation, the anhydrite-dolomite transition shows no evidence for seaward progradation. SRF shelf-interior processes are apparently decoupled from shelf margin processes. The same lack of seaward

progradation is evident in the Yates anhydrite-dolomite facies transition. Major sea-level events (such as SRF-Yates boundary) reset the position of shelf-interior facies boundaries, and these boundaries remain rather static between major sea-level events.

The outcrop Seven Rivers facies change thus represents a gradational facies change modified first by Permian meteoric dissolution throughout SE New Mexico and then by Cenozoic dissolution near the outcrop belt.

Subsurface Seven Rivers (Guadalupian) Anhydrite-Dolomite Transition, Eddy Co., New Mexico, USA: Modification of a Depositional Facies Change by Permian Meteoric Dissolution

Alton Brown, Consultant, Richardson, TX altonabrown@yahoo.com
Robert G. Loucks, Bureau of Economic Geology, The University of Texas at Austin

Abstract

The anhydrite - dolomite facies change in the Seven Rivers Formation (SRF) exposed on outcrop can be interpreted as depositional or dissolution. To reduce ambiguity resulting from Cenozoic outcrop dissolution, the facies change was examined in the subsurface of eastern Eddy County, New Mexico.

North of the facies boundary, over 80% of the SRF section is anhydrite with thin dolomites and siltstones. Over a narrow zone approximately 2 km wide, anhydrite abundance drops to about 20% anhydrite as dolomite thickens. By 4 km south of the start of anhydrite thinning, all of the SRF is tight (1 - 4% porosity) dolomite with thin siltstone beds. The dolomites in the transition zone have high, irregular gamma ray (GR) related to high uranium. The high-GR dolomite grades southwards into low-GR dolomite with higher porosity.

The SRF thins by about 100 ft in the transition zone, with the most abrupt thinning near the northern end of the facies transition. The abrupt SRF thinning is equal to the thinning of net SRF anhydrite. Farther south within the transition zone, SRF thinning is irregular, and thinner anhydrite is compensated by thicker dolomite. Net SRF thinning is compensated mainly by thickening in the Yates Formation.

The SRF depositional anhydrite-dolomite facies change is interpreted as an originally gradational facies change that maintained a relatively constant position on the shelf interior. SRF sulfate thickness was modified during Yates deposition. Permian subaerial exposure, especially along the Yates B surface, could have caused meteoric, shallow-subsurface sulfate dissolution selectively within the carbonate facies, making the overall facies transition more abrupt.

Although the shelf margin during SRF deposition shows significant seaward progradation, the anhydrite-dolomite transition shows no evidence for seaward progradation. SRF shelf-interior processes are apparently decoupled from shelf margin processes. The same lack of seaward progradation is evident in the Yates anhydrite-dolomite facies transition. Major sea-level events (such as SRF-Yates boundary) reset the position of shelf-interior facies boundaries, and these boundaries remain rather static between major sea-level events.

The outcrop Seven Rivers facies change thus represents a gradational facies change modified first by Permian meteoric dissolution throughout SE New Mexico and then by Cenozoic dissolution near the outcrop belt.

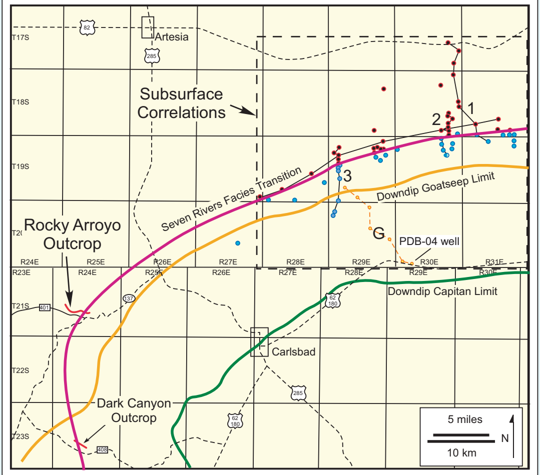

Figure 1. Location of subsurface sections relative to outcrops. Cross section G is location of Garber et al. (1989) NW dip section. Reef limits from Garber et al. (1989). Seven Rivers facies transition near outcrop modified from Cox (1967).

Location

Introduction and Background

The transition from carbonate to evaporite in the Guadalupian Seven Rivers Formation is well exposed along Rocky Arroyo NW of Carlsbad, NM. The transition is abrupt, and is traditionally interpreted as a depositional contact (Bates, 1942, Ball et al. 1971, Sarg 1989).

There is strong evidence that the transition has been modified by selective evaporite dissolution. Thinner sulfate beds intercalated with dolomite have been dissolved but thicker sulfate beds have not. This steepens the abruptness of the sulfate-carbonate transition and hides the true fine-scale stratigraphic relationships.

Because of problems with incomplete outcrop and overprint by Cenozoic dissolution, the facies transition was examined in the subsurface in eastern Eddy Co., NM. This is beyond the limits of Cenozoic dissolution and sulfate is entirely anhydrite (hydration effects on thickness are absent). The nature of the subsurface transition may then be correlated back to outcrop and fine-scale outcrop relations better understood.

This poster will first review Seven Rivers outcrop data near Rocky Arroyo and its previous interpretations. Cross sections and lithology interpretations from wireline logs will then show subsurface relations in eastern Eddy Co. The lithology and thickness patterns seen in the subsurface will then be interpreted in terms of processes, and the concepts taken back to the outcrop to better understand the nature of the outcrop facies transition.

Stratigraphic Framework

The Seven Rivers Formation is an early Late Guadalupian (early Capitanian) shelf interior facies equivalent of the Capitan Reef (Figure 3). Four major Seven Rivers Formation facies are recognized (from landward to seaward): (1) sulfate-rich evaporite with interbedded dolomite, and siliciclastics forming a facies belt tens of km wide, (2) thin-bedded shelf-interior dolostone about 3 - 10 km wide, (3) a narrow shelf-crest fenestral carbonate facies, and (4) a narrow outer-shelf carbonate facies (Sarg 1989, Wheeler 1989). Sarg (1989) recognized three shelf-interior dolomite facies seaward of the evaporite facies: a grapestone grainstone, skeletal-peloidal packstone-wackestone, and a peloidal wackestone-mudstone.

This study examines the Seven Rivers evaporite-dolomite contact (blue, Figure 3). Overlying units help constrain timing of dissolution events. Some stratigraphic units not figured here will be discussed with the subsurface correlations on the next panel.

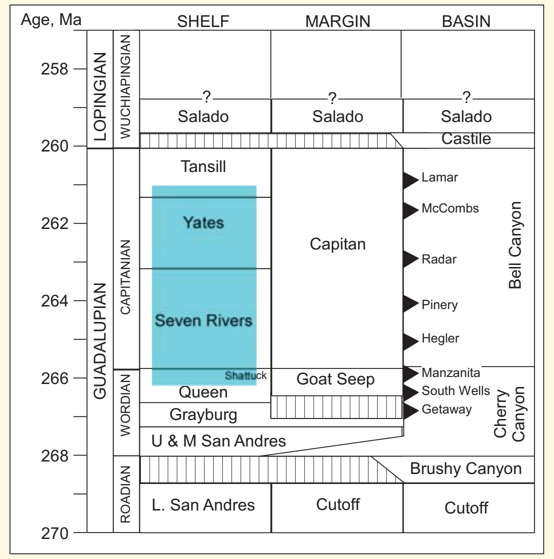

Figure 3. Correlations of Guadalupian shelf to basin strata following Garber et al. (1989). Numerical ages from ICS International stratigraphic chart.

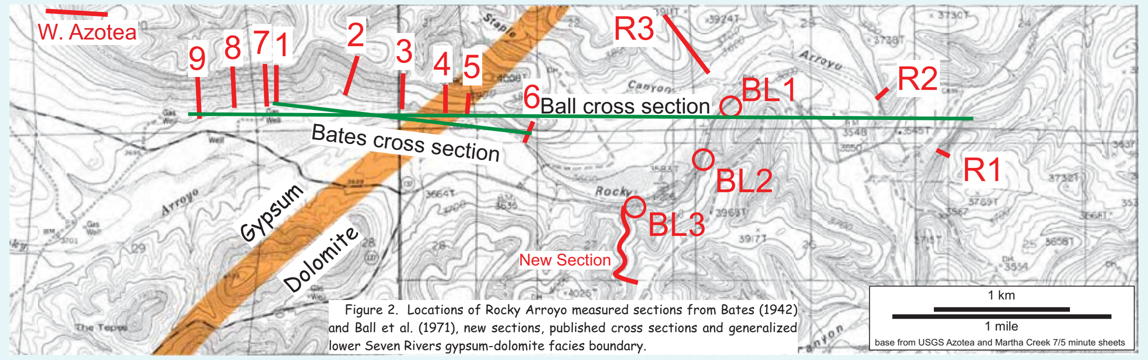

Figure 2. Locations of Rocky Arroyo measured sections from Bates (1942) and Ball et al. (1971), new sections, published cross sections and generalized lower Seven Rivers gypsum-dolomite facies boundary.

Rocky Arroyo Outcrop

Previous Work

The transition from Seven Rivers gypsum facies to dolomite facies is marked by abrupt thinning of gypsum beds (Figure 4) that decreases Seven Rivers thickness. Dolomite bedding dips in the overlying Azotea member locally steepen over the facies change, whereas underlying Shattuck and Queen dolomite have a uniform easterly dip. Thin dolomite beds within the gypsum facies can be traced into the dolomite facies (Bates 1942). A red stained, brecciated calcareous "transitional material" is the lateral equivalent of gypsum beds (Bates 1942). The transitional material thins eastward (Figure 5).

Ball et al. (1976) document termination of a gypsum facies in the Shattuck Member of the Queen Formation in outcrops slightly west from of the Bates (1942) sections (Figure 6). No breccia is reported in this siliciclastic interval, but the Shattuck Member thins considerably at the edge of the gypsum, and Seven Rivers gypsum beds overlying the Shattuck gypsum termination have slightly steeper dip.

Sarg (1989) interpreted the gypsum-dolomite transition as an abrupt facies change with no thickness change. He recognized a grapestone grainstone marginal to the evaporite facies with evaporite dissolution fabrics in silty zones. This facies grades into peloidal wackstones farther east.

New Observations

Our reconnaissance field work indicates that Bates (1942) transitional material is an evaporite dissolution breccia. (Figure 7). Abundant porosity and semilithified nature indicates that dissolution may be Cenozoic in age and is certainly not Permian in age. Oblique aerial photography confirms continuity of dolomite marker beds from the Seven Rivers gypsum facies into the dolomite facies as mapped by Bates (1942). These characteristics indicate that the modern gypsum - dolomite transition has been affected by selective gypsum dissolution and collapse and is not a simple depositional contact.

Probable evaporite dissolution fabrics were found in lower Seven Rivers outcrops up to about 2.5 km east of the preserved gypsum edge (Figures 8, 9). Some are associated with red siliciclastic silt, but others are in pure carbonate. Some show evidence of pre-lithification deformation (Figure 9), whereas others show post-lithification brittle collapse (Figure 8). At least some of the features previously interpreted as stromatolites are deformation features in probable evaporite dissolution residues (Figure 9).

Interpretation and Problem

At this point, it became clear that the incomplete outcrop exposure, potential for multiple dissolution events, and thickness of the rather monotonous Seven Rivers dolostones with few obvious marker beds make interpretation of pre-dissolution lithofacies patterns and patterns of dissolution from the outcrop belt difficult and subject to multiple interpretations.

It was therefore decided to look first at the subsurface, where wireline log markers can provide much tighter stratigraphic control, where Cenozoic evaporite dissolution is not obscuring older evaporite features, and where sulfate is entirely anhydrite so expansion due to hydration does not complicate thickness or facies interpretations. The disadvantage of the subsurface work is the wide spacing of wells. Interpretations from the subsurface are therefore taken back to the outcrop to better interpret the rapid lateral facies changes that are on a scale too small to see from wireline logs.

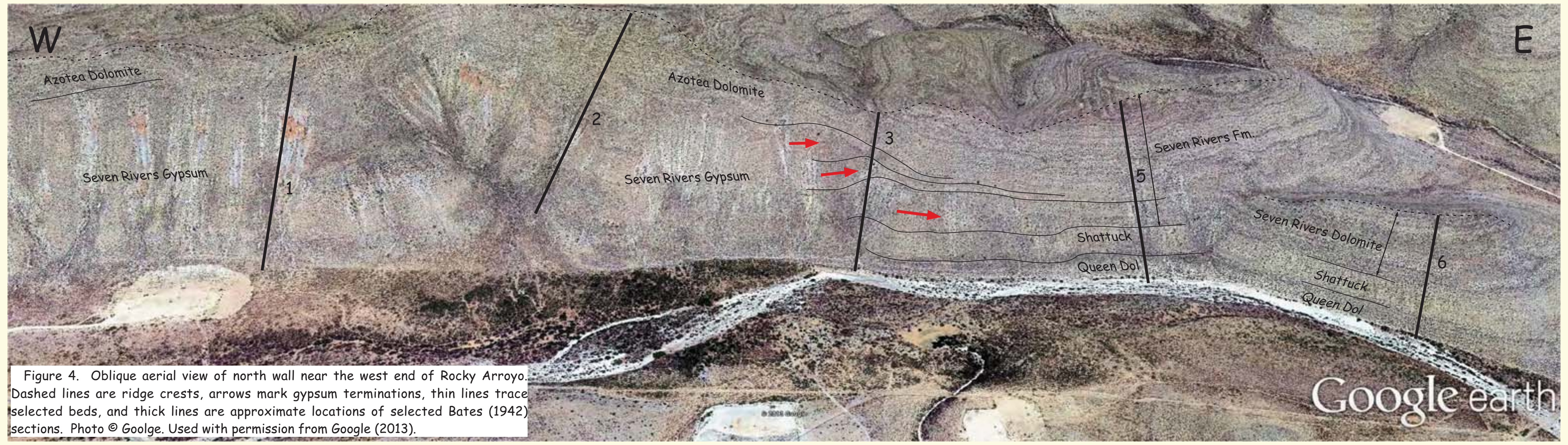

Figure 4. Oblique aerial view of north wall near the west end of Rocky Arroyo. Dashed lines are ridge crests, arrows mark gypsum terminations, thin lines trace selected beds, and thick lines are approximate locations of selected Bates (1942) sections. Photo © Goolge. Used with permission from Google (2013).

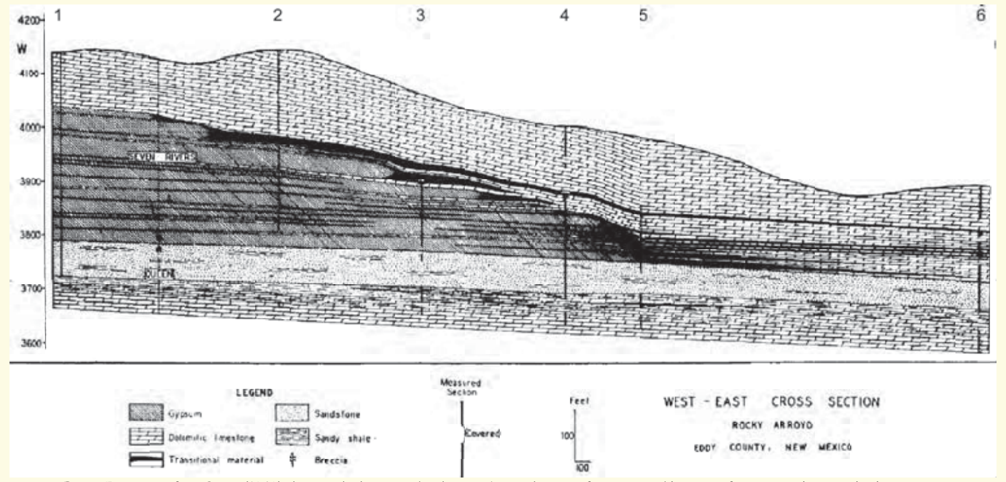

Figure 5. Section from Bates (1942) showing thicknesses, dip change, abrupt thinning of gypsum, and location of transitional material relative to gypsum. AAPG© 1942. Reprinted by permission of the AAPG, whose permission is required for further use.

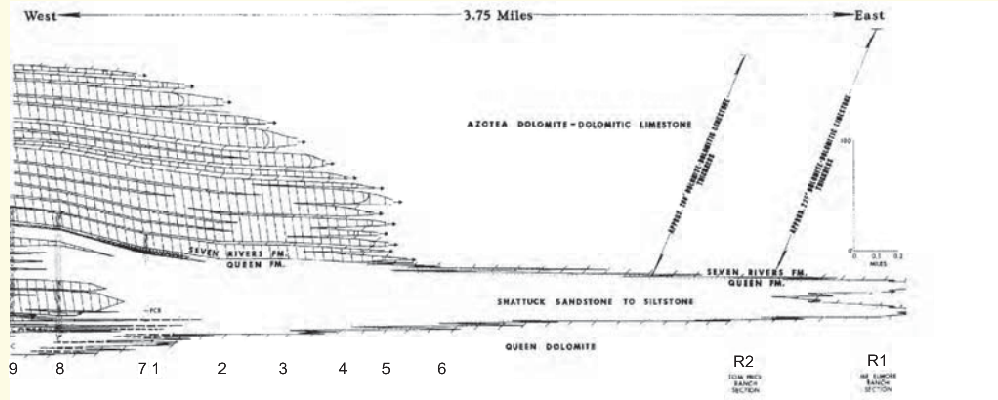

Figure 6. Ball et al. (1976) cross section of the Rocky Arroyo sulfate-dolomite transition. Sections 1-6 are the Bates (1942) sections, and Ball's sections are added at the west end to document termination of Shattuck gypsum and Seven Rivers total thickness estimated at the east end of the section. AAPG© 1976. Reprinted by permission of the AAPG, whose permission is required for further use.

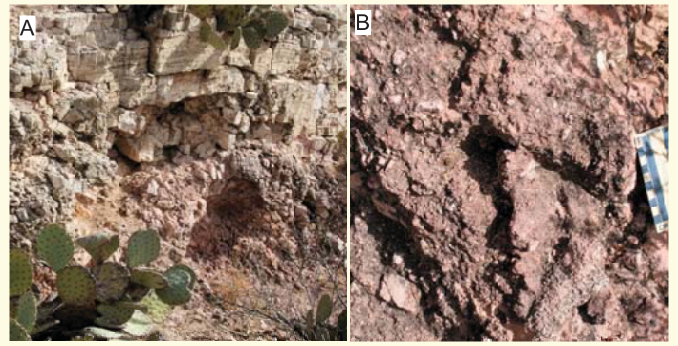

Figure 7. Bates transitional material. (A) Interbedded transitional material and thin dolomicrite from section 5 of Bates (1942) showing brecciation and collapse features indicative of dissolution residue origin. Section is about 2.5 m thick. (B) Detail of fine grained dissolution residue showing small angular dolostone clasts and silty residue. Bates section 5.

Figure 8. Evaporite dissolution fabric showing characteristic inverse grading, angular clasts, and crackle breccia. Fine-grained material contains siliciclastic silt. Outcrop BL1 a short distance above the base of the Seven Rivers Fm.

Figure 9. Possible early evaporite dissolution fabric dominated by soft=sediment deformation within silty dolomite, brecciation in thin dolostone layers, and crackle breccia in overlying thin-bedded dolomite. These are concentric folds, not stromatolites, based on deformation structures. Similar features previously interpreted as possible stromatolites are present up to 8 km east of the current gypsum termination. Near top of outcrop BL1, lower Seven Rivers Formation.

Subsurface Seven Rivers (Guadalupian) Anhydrite-Dolomite Transition, Eddy Co., New Mexico, USA: Modification of a Depositional Facies Change by Permian Meteoric Dissolution

Stratigraphic Comments

Stratigraphic horizons follow generally accepted picks for the area, with the following additions/clarifications.

- Base salt is picked rather than top Tansill evaporite facies or Fletcher Anhydrite. In the discussion, the unit below base salt is referred to as Tansill Formation, but this is for convenience only.
- An additional pick at the base of massive anhydrite beds in the Yates Fm. shows consistent lithology and GR response across the area. Underlying strata are clearly Yates based on high siliciclastic content.
- Base Yates/top Seven Rivers is the base of the dominantly siliciclastic section as indicated by FDC-CNL cross plot. Local detailed correlation follows GR variations.
- Section is hung on the base of the Bowers Sandstone Member of the Seven Rivers Formation. The top Bowers appears to locally amalgamate with another thin siliciclastic unit, causing Bowers sandstone to be anomalously thick towards the middle of the cross section.
- The thick section of Seven Rivers dolomite below the Bowers Sandstone at the east end of the section may be in part Capitan Formation, based on correlations in Garber et al. (1989).
- Top of the Queen is picked at the top of the Shattuck Sandstone. The Shattuck Sandstone picks were correlated from areas of Shattuck production and is restricted to the upper sandstone in the Queen Formation. There is a thin correlative dolomitic sandstone in the lower Seven Rivers that may be an alternate pick for top Queen. There are other porous Queen sandstones below the Shattuck Sandstone picked here. The Shattuck pick may be erroneous at the south end of the section due to confusion of these sand bodies.

Methods

Three north-south cross sections and one east-west section were constructed to assess the nature of the evaporite - carbonate facies change in Eastern Eddy Co. (Figure 1). This area was chosen because it is as close to the outcrop as possible where anhydrite is preserved and well density is high.

Sections extend from the base of the Shattuck Sandstone to the base Salina salt. Tops were picked from a combination of GR response and lithology indicated by Pe, density, and CNL logs. Only Section 3 is displayed and discussed in detail. Similar features are seen on the other two north-south sections, but those sections do not extend as far south as section 3 or lack close well control.

Lithodensity or FDC-CNL logs were used so that anhydrite can be identified and differentiated from dolomite and argillaceous siltstones/sandstones. A cutoff of 2.88 g/cc was used to identify anhydritic beds from the density or density-porosity curves in Cross Section 3. This cutoff probably includes some non-porous anhydrite-cemented dolostones, but it is convenient and quick and does indicate anhydrite in the rock. Also, older FDC tools had poor counting statistics at high density, so density measurement has a higher uncertainty. By choosing a low density cutoff rather than a value close to the true grain density for anhydrite, massive anhydrite is correctly interpreted in the presence of poor counting statistics. The Pe curve is used to confirm anhydrite where the curve is available.

Unfortunately, the southern end of the studied interval is part of the Capitan aquifer on this and the other sections, so most wells have only neutron and GR logs through casing. The base salt can be identified, but lithology could not be interpreted in these wells. Other picks in these wells are based entirely on GR.

Thicknesses of units and net thicknesses of anhydrite are tabulated and used to analyze controls on the facies change. Core and thin section data were not examined.

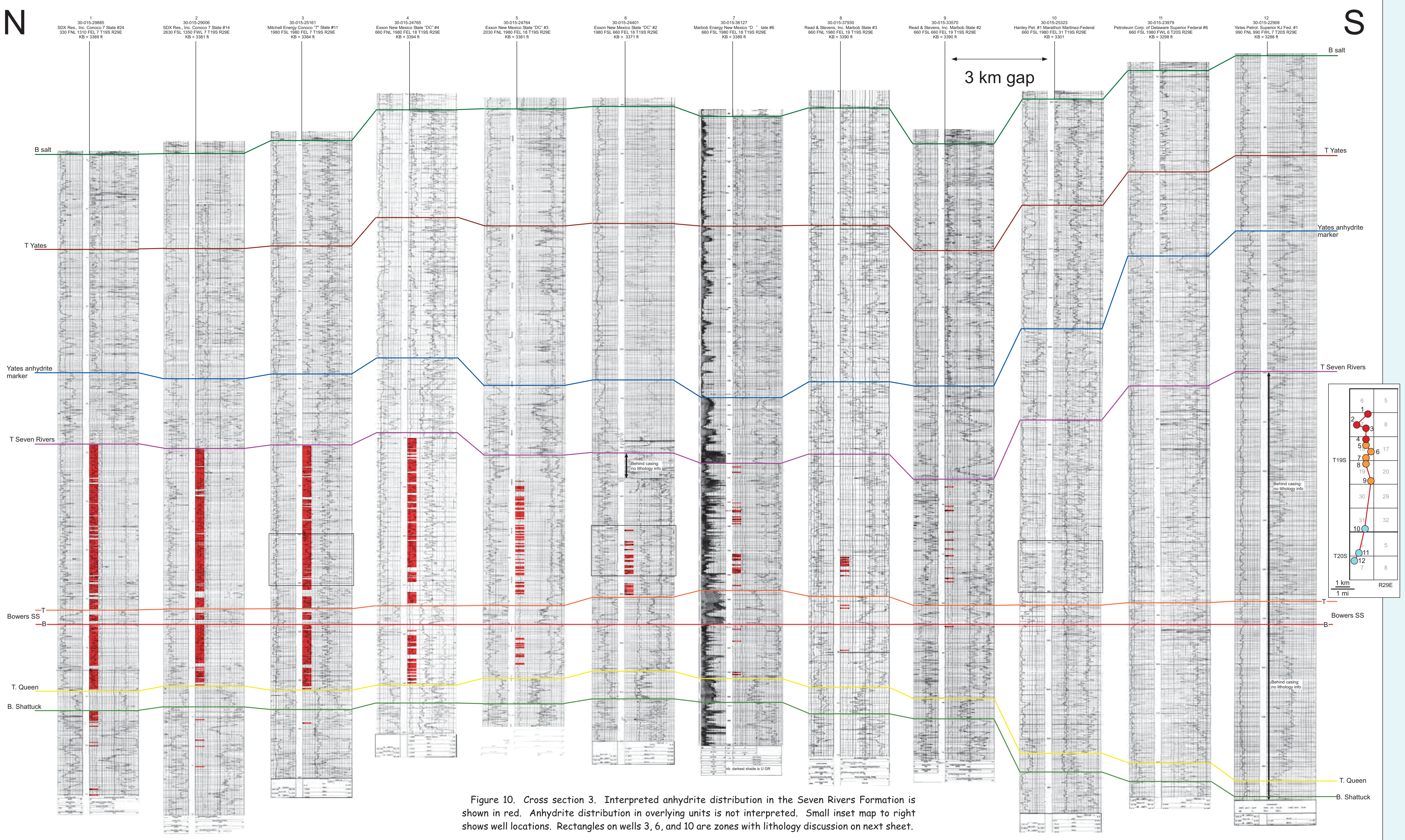

Figure 10. Cross section 3. Interpreted anhydrite distribution in the Seven Rivers Formation is shown in red. Anhydrite distribution in overlying units is not interpreted. Small inset map to right shows well locations. Rectangles on wells 3, 6, and 10 are zones with lithology discussion on next sheet.

Structural Configuration

Cross Section 3 (Figure 10) is hung on the base of the Bowers Sandstone. Well spacing is not to scale. Actual well spacing is irregular. Note especially the 3 km gap between wells 9 and 10.

Stick figure cross sections with well spacing to scale are shown below. The upper cross section is a structural section (Figure 11). The lower figure is a stratigraphic section hung on base salt (Figure 12).

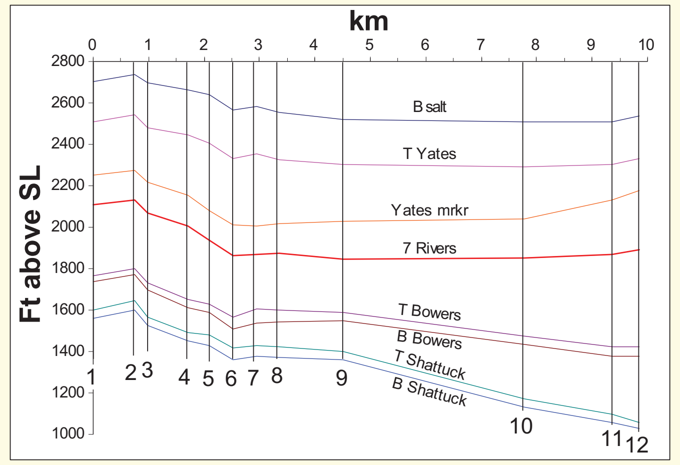

Figure 11. Structural cross section. See cross section at left for well names and locations.

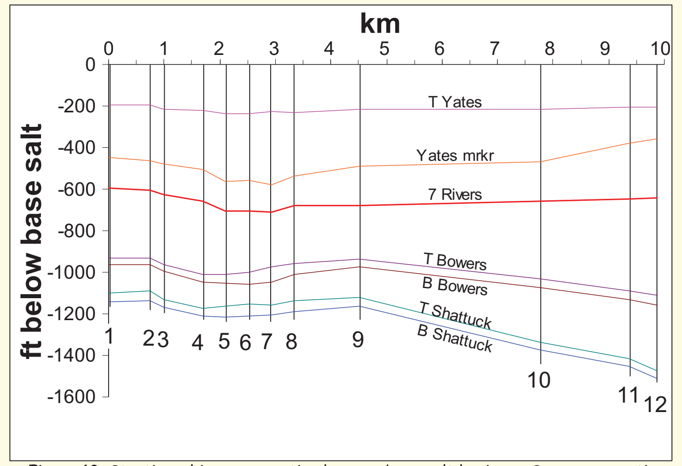

Figure 12. Stratigraphic cross section hung on base salt horizon. See cross section at left for well names and locations.

Subsurface Seven Rivers (Guadalupian) Anhydrite-Dolomite Transition, Eddy Co., New Mexico, USA: Modification of a Depositional Facies Change by Permian Meteoric Dissolution

Lithofacies Characteristics

Generalized lithology can be interpreted from density, neutron, and Pe wireline characteristics. Intervals from wells 3, 6, and 10 are shown to illustrate general characteristics of the three Seven Rivers lithofacies: evaporite, transition, and carbonate.

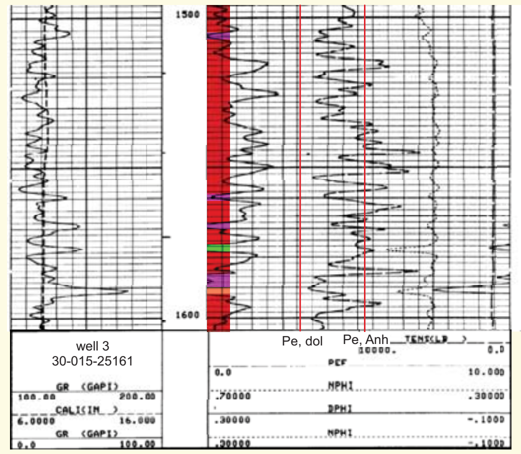

Figure 13. Example of Seven Rivers evaporitic facies from Well 3.

Evaporite Facies

Anhydrite (high density, high Pe, CNL near zero) with thin interbeds of anhydritic dolomite (intermediate Pe and density; elevated GR), and slightly argillaceous dolomite zones (higher CNL and lower Pe). Sandstone, if present, is dolomite- and anhydrite-cemented so that porosity is low and Pe elevated.

- Anhydrite
- Anhydritic dolomite
- Dolomite
- Argillaceous
- Anhydritic siltstone
- Dolomitic siltstone

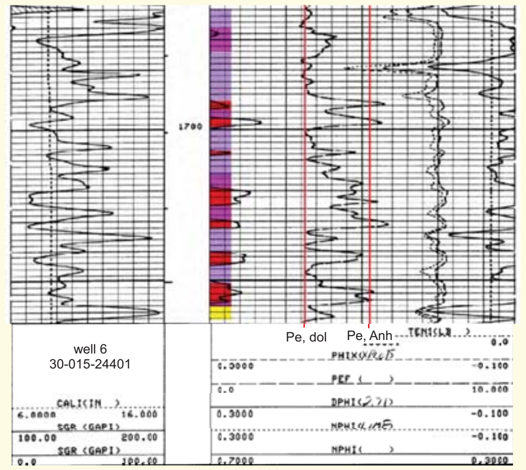

Figure 14. Example of Seven Rivers transition facies from well 6.

Transition facies

Transitional facies is an informal name for the zone where evaporitic facies interfinger with carbonate facies. Anhydrite beds 2 - 10 ft thick are interbedded with dolomite and anhydritic dolomite. Most pure dolomites (from Pe-CNL-FDC) are not porous. Most high GR units are dolomite, but some siliciclastic content is evident in some based on low Pe. Clay- or sand-rich zones are sparse. Mostly low porosity with a few thin porous dolomites (e.g., 1679 ft). This facies is characterized by higher total GR due to higher uranium content (see spectral GR on cross section).

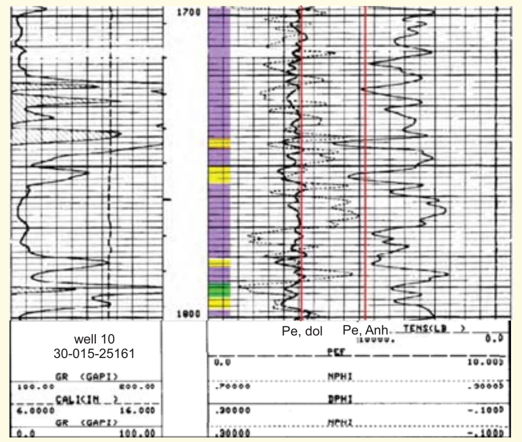

Figure 15. Example carbonate facies from well 10.

Carbonate facies

Low GR zones are dolomite averaging 10% porosity with some zones exceeding 17% porosity. Most high GR zones are dolomite. However, thin zones with high GR, low Pe, and lower (CNL-denpor) are argillaceous (e.g., 1790 ft) and silty (1754 ft). Some high GR streaks are porous dolomitic siltstones, based on Pe and CNL-denpor (e.g., 1742 ft). Thin zones with low density in low GR zones may indicate the presence of gypsum, similar to that seen in the Chevron-Gulf PDB-04 well. Wells close to evaporite transition show higher GR due to elevated uranium concentration.

Subsurface Interpretations

General

- Facies change is relatively abrupt. Most anhydrite is lost in a zone 1.5 km wide, with the remaining anhydrite systematically lost over an additional 2 km-wide zone.
- Facies change is caused by fine-scale interfingering of dolomite and anhydrite rather than abrupt loss of thick anhydrite beds or wholesale, abrupt lateral replacement of anhydrite by dolomite (shazam line).
- There is no evidence for a widespread depositional Azotea Dolomite above the anhydrite facies. Up-dip, Seven Rivers anhydrite facies is abruptly overlain by siltstones, anhydrite, and dolostone of the Yates Formation. Within the transition zone, the upper part of the Seven Rivers Fm. above the Bowers Sandstone selectively loses anhydrite so that the transition zone is characterized by a dolomite unit overlying an interbedded dolomite and anhydrite unit (Figure 10). This anhydrite-free interval might be the subsurface Azotea Dolomite equivalent. If so, the Azotea dolomite is a unit present only in the transition zone.
- As picked here, Shattuck Sandstone is thinner in the subsurface than at Rocky Arroyo outcrop. Anhydrite beds are not present in the Shattuck Formation, but are present in well 1 below the Shattuck sandstone and above another Queen sandstone (Figure 10). It is possible that the outcrop Shattuck Sandstone of Ball et al. (1971) correlates to the two uppermost Queen sandstones in the subsurface with their interbedded anhydrite. However, the subsurface anhydrite beds are associated with a 20 ft thick, persistent dolomite zone which is not evident in the Shattuck Formation on outcrop.

Thickness Variations

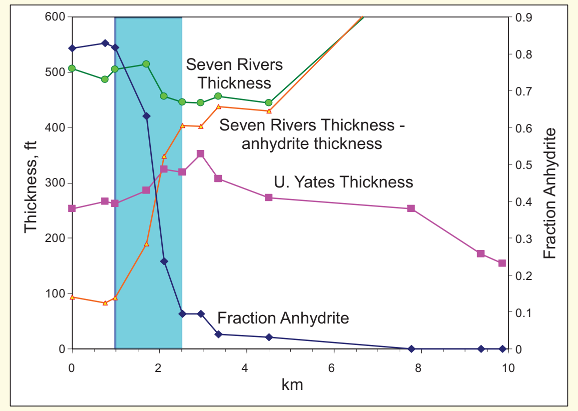

Figure 16. Plot of thickness of Seven Rivers and Upper Yates compared to fraction of anhydrite in the Seven Rivers and thickness of non-anhydrite Seven Rivers Fm. Zone of major anhydrite loss is shown in blue.

Fraction of anhydrite in the Seven Rivers Formation decreases from over 80% to approximately 10% of the total Seven Rivers thickness within about the first 1.5 km from the northern edge of the facies change zone (blue, Figure 16). The remaining 10% of Seven Rivers section that is anhydrite is lost over the next 2 km +.

The total thickness of the Seven Rivers decreases from its regional average by about 10% (50 ft, 15 m) in the transition zone (Figure 16). South of the transition zone, the Seven Rivers equivalent thickens considerably as it approaches the Capitan Fm. (Wells 10 - 12). Thinning in the Seven Rivers in the transition zone is approximately matched by about 50 ft thickening of upper Yates.

Nature of Evaporite-Carbonate Facies Transition

Comparison of Seven Rivers thickness, fraction anhydrite, and Seven Rivers thickness of non-anhydrite lithologies clearly indicates that anhydrite-carbonate transition is, in general, sedimentological in origin. If entirely dissolution, Seven Rivers thickness would decrease by over 50%, much more than observed. Likewise, anhydrite and carbonate are interbedded on a fine scale in the transition zone, a characteristic not expected if facies change was entirely dissolution in origin.

However, there is a dissolution overprint on the sedimentological facies change. The Seven Rivers Fm. thins in the transition zone coincident with thickening in the Upper Yates Fm. This indicates evaporite dissolution during Yates deposition, and specifically between deposition of the Yates marker and the top Yates. The area with evidence for Permian-aged dissolution corresponds to the area where anhydrite is selectively removed from the upper Seven Rivers. This is the area of possible subsurface Azotea Dolomite equivalent discussed previously.

This "top down" dissolution pattern is evidence for meteoric phreatic dissolution during Late Yates deposition. Where anhydrite comprises almost all of the Seven Rivers Formation, there is limited or no evidence for early dissolution. The phreatic dissolution is only effective where sulfate is interbedded with carbonate. The carbonate beds may be necessary to provide a fluid flow pathway for sulfate dissolution. Unlike salt dissolution, dissolution of sulfate requires many pore volumes of water per volume evaporite dissolved. In the absence of such pathways north of the facies transition, sulfate dissolution was ineffective due to inadequate contact with water during the Permian.

Upper Yates isopach thickens over the entire width of the transition zone. This may indicate that prior to the Yates dissolution event, there were more sulfate beds extending seaward from the major facies transition which are now absent or represented by slightly argillaceous dolomite. The high uranium concentrations responsible for the high and erratic GR over most of the transition zone may be a product of Permian meteoric interaction with the Seven Rivers strata.

Implications for Outcrop

Width of Evaporite-Carbonate Transition

The outcrop gypsum-dolomite transition was interpreted from Bates and Ball et al. cross sections (Figure 5 and 6, sheet 1) with an additional section interpreted from aerial photos at the western edge of the Azotea Dolomite north of Rocky Arroyo (W Azotea, Figure 2).

The outcrop gypsum-dolomite transition occurs over a relatively narrow distance like the subsurface facies transition, but there are major differences.

- The outcrop transition occurs in two steps, a western and eastern step. The western step is formation of the Azotea Dolomite (Figure 17). The Seven Rivers changes from a presumed 80%+ sulfate thickness seen in subsurface sections to about 60 - 70% sulfate thickness. The eastern step is loss of anhydrite from the middle and lower Seven Rivers as documented in the Bates (1942) section.
- There is essentially no preserved sulfate east of the major, abrupt gypsum-dolomite facies transition.
- The preserved Seven Rivers thickness on outcrop significantly decreases across the gypsum-dolomite transition and remains thin for at least 3 km east of the gypsum pinchout (Figure 17).

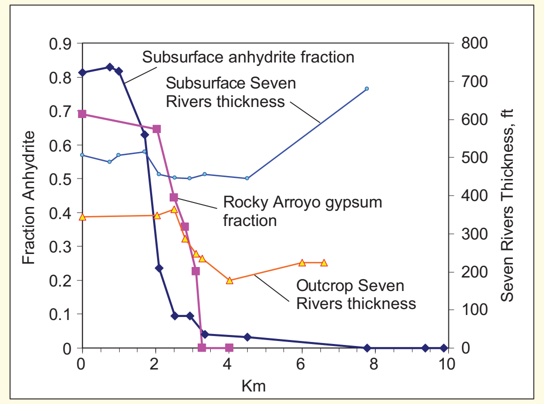

Figure 17. Plot of fraction of Seven Rivers Formation thickness that is anhydrite (subsurface, Cross section 3) or gypsum (outcrop, Rocky Arroyo) vs. distance. Subsurface distance starts at north end of cross section. Outcrop distance starts at the farthest west Azotea dolomite north of Rocky Arroyo, about 2 km west of the west end of Bates (1942) section.

Controls on Outcrop Evaporite-Carbonate Transition

The preserved outcrop transition shows an overprint of Cenozoic (or possibly Cretaceous) dissolution on a pattern that is otherwise similar to that of the subsurface.

- The Azotea Dolomite is interpreted to be the product of Permian dissolution. The depositional Azotea was thin bedded carbonate and gypsum similar to the preserved interbedded transitional facies of the subsurface (Figure 14). Permian dissolution removed sulfate, reducing total Seven Rivers thickness and leaving a relatively intact bedded dolomite. Any remaining anhydrite was removed by outcrop weathering. Azotea Dolomite extends about 2.5 km NE of the interpreted major depositional sulfate-carbonate transition. This is a wider zone of Permian dissolution than seen in the subsurface.
- The facies transition mapped by Bates (1942) is basically depositional in origin similar to that of the subsurface, but it has a greater overprint of dissolution. Most dissolution at the major preserved gypsum-dolomite transition is post-Permian and probably postdates King's (1948) pre-Cretaceous "Summit" peneplain. Based on thickness patterns, the depositional sulfate-dolomite transition is probably near Bates (1942) section 6, about 1 km east of the preserved position of greatest gypsum-dolomite change.
- The evaporite dissolution features present several km east of the major sulfate-dolomite transition are entirely consistent with the subsurface anhydrite distribution. Some dissolution is clearly telogenic in origin, but other dissolution features may be related to the Yates dissolution event or even to syn-sedimentary Seven Rivers dissolution.

Stratigraphic Implications

When effects of Permian and Cenozoic dissolution are removed, the pattern of sulfate - carbonate transition shows a gradational pattern that occurs at approximately the same position in the lower and upper Seven Rivers Formation. During Seven Rivers deposition, the shelf margin in eastern Eddy County progrades about 12 km southward (Garber et al. 1989). The evaporite facies transition is about 8 km behind the shelf crest at start of Seven Rivers deposition and lies about 20 km behind the shelf crest at end of Seven rivers deposition.

Given the cyclical nature of Seven Rivers deposition and the interbedded nature of the contact, the lack of a systematic progradation in step with shelf margin progradation is puzzling. Seven Rivers shelf-interior processes are apparently decoupled from shelf-margin processes. This implies that fine-scale Seven Rivers cyclicity is forced by some other means than carbonate sediment supply or sea-water influx over the shelf margin.

Apparently, only major sea-level changes drive events far onto the shelf interior. The same lack of seaward progradation is evident in the Yates anhydrite-dolomite facies transition. The upper Yates evaporites extend at least as far south as well 11 in section 3 without systematically increasing dolomite content. Major sea-level events (such as Seven Rivers - Yates contact) reset the position of shelf-interior facies boundaries, and these boundaries remain statistically static between major sea-level events.

References

Ball, S. M., J. W. Roberts, J. A. Norton, and W. D. Pollard, 1971, Queen Formation (Guadalupian, Permian) outcrops of Eddy County NM and their bearing on recently proposed depositional models: AAPG Bulletin, v. 55, p. 1348 - 1355.

Bates, R. L., 1942, Lateral gradation in the Seven Rivers Formation, Rocky Arroyo, Eddy County, New Mexico: AAPG Bulletin, v. 26 #1, p. 80 - 99.

Cox, E. R., 1967, Geology and hydrology between Lake McMillan and Carlsbad Springs, Eddy Co., New Mexico: USGS water supply paper 1828, 59 p.

Garber, R. A., G. A. Grover, and P. M. Harris, 1989, Geology of the Capitan Shelf Margin - Subsurface data from the northern Delaware Basin, in: Subsurface and outcrop examination of the Capitan Shelf margin, northern Delaware Basin: SEPM Core Workshop No. 13, p. 3 - 272.

King, P. B., 1948, Geology of the southern Guadalupe Mountains: USGS Professional Paper 215, 183 p.

Sarg, R., 1989, Stratigraphy and sedimentology of the back reef upper Queen-Lower Seven Rivers strata, Goat Seep-Capitan reef complexes (middle - late Guadalupian, Permian) , SE NM: in: Subsurface and outcrop examination of the Capitan Shelf margin, northern Delaware Basin: SEPM Core Workshop No. 13, p. 347 - 364.

Wheeler, C., 1989, Stratigraphy and sedimentology of the Shattuck Member (Queen FM) and lowermost Seven Rivers Formation (Guadalupian), North McKittrick and Dog Canyons, Guadalupe Mountains, NM and west TX: in: Subsurface and outcrop examination of the Capitan Shelf margin, northern Delaware Basin: SEPM Core Workshop No. 13, 353 - 364.

One Minute Summary

The Guadalupian (Permian) Seven Rivers shelf-interior sulfate-to-carbonate facies change was examined on outcrop and in subsurface. The facies change is predominantly depositional in origin, but it has been modified extensively by dissolution.

Thickness changes along subsurface cross sections document Yates-aged (Permian) dissolution that appears to be responsible for formation of the Azotea Dolomite Member. The gradational, interbedded nature of the facies change on outcrop has been further obscured by near surface (Cenozoic ?) dissolution of the thinner sulfate beds formerly interbedded within the carbonate facies. The result is a lithofacies change more abrupt than the original depositional facies change.

The depositional facies change itself does not appear to be coupled to shelf-margin progradation, because facies change shows no systematic progradation during the long period of Seven Rivers deposition and shelf-margin progradation.