

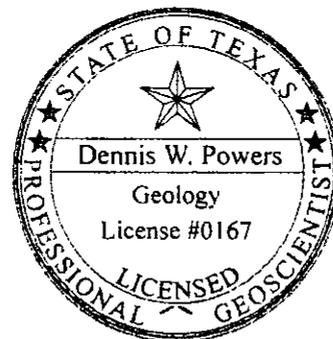
Potential Horizons for Salt Water Disposal
in the Delaware Mountain Group
T22S, R26E, Section 36,
Eddy County, New Mexico

prepared for Key Energy Services

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March 21, 2012

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BEFORE THE OIL CONVERSATION
DIVISION
Santa Fe, New Mexico
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EXECUTIVE SUMMARY

Key Energy Services proposes to drill and operate a salt water disposal (SWD) well in section 36, T22S, R26E, in Eddy County, New Mexico. The interval of primary interest is the lower formation (Brushy Canyon) of the Upper Permian Delaware Mountain Group (DMG). The formations were evaluated from readily available geophysical logs.

The DMG consists of three formations of mainly sandstone, siltstone, and some limestone intervals. From the top of the Bone Spring Limestone, the formations in order are Brushy Canyon, Cherry Canyon, and Bell Canyon. They are equivalent stratigraphically to Guadalupian rocks of the Guadalupe Mountains, with the uppermost (Bell Canyon) stratigraphically equivalent to the Capitan Limestone (reef and related rocks).

The formations were evaluated for best continuous intervals of ~20 ft thick (or more) for the following characteristics: lower gamma (more sand), middle range acoustic travel time

(generally sand), lower neutron (higher H content), and lower resistivity (fluid content).

The Brushy Canyon includes the most intervals with favorable characteristics, and several are recommended for penetration and testing for hydraulic properties. The Cherry Canyon is more uniformly high in gamma, indicating less sand and poorer prospects for porosity and permeability suitable for injection. The Bell Canyon has limited potential intervals.

Some zones at the top of Cherry Canyon and basal Brushy Canyon are producing in the general area around the prospective site. These zones are to be minimized as possible.

The Brushy Canyon has no stratigraphic connection to the Capitan reef or older Goat Seep reef rocks. The elevation of the upper contact of the Bone Spring Limestone across the Capitan reef front does not show displacement due to faulting that could potentially connect deep zones to Capitan.

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INTRODUCTION

Task

Key Energy Services proposes to drill and operate a salt water disposal (SWD) well in section 36, T22S, R26E, in Eddy County, New Mexico (Figure 1). The interval of primary interest is the lower formation (Brushy Canyon) of the Upper Permian Delaware Mountain Group (DMG).

This report provides the background information used to evaluate the DMG formations for intervals suitable for testing as injection sites. These formations were evaluated from geophysical logs readily available from the New Mexico Oil Conservation Department (OCD), supplemented in a few instances by purchasing logs from TGS-NOPEC.

Methods

Geophysical logs provide basic properties that are useful as a guide to the suitability of intervals for fluid injection. The main desired properties are adequate porosity and thickness for storage and permeability for efficiency of injection. The following suite of logs, where available, was used to indicate suitable properties (see Figure 5):

natural gamma – in clastic rocks, lower gamma is typically associated with sand and higher gamma with more clay content. The standard 100 API units is typical of a North American Pennsylvanian black shale. Quartz sand will have low natural gamma, possibly less than 10 API units. The DMG rocks are fairly fine-grained, with high natural gamma. Intervals with lower natural gamma were preferred, and an artificial filter of 70 API units was used to identify preferred intervals.

acoustic travel time – acoustic travel time is related to the density and lithification of the

rock. High density, well lithified rocks such as anhydrite and dolomite, have high velocity and short travel times. Well compacted sandstone has slightly lower velocities and longer travel times. Shale or siltstones, common components of these formations, have quite variable travel times (see Figure 5). The acoustic or sonic log is very useful as a lithologic indicator and for stratigraphic correlation; in combination with other logs, it can be used for porosity estimates.

neutron – the neutron log responds to hydrogen (H) in the rock; lower neutron returns to the sensor indicate more H, although the form (e.g., water, oil, gas, mineral form such as hydrated minerals or clays) is not indicated by this log. High neutron intervals are avoided here because they are likely cemented, with little available porosity.

density – density is particularly useful in diagnosing lithology, especially in evaporites where halite is present. Here, high density rocks such as limestones are generally not selected as they tend to exhibit other characteristics not expected to be suitable.

resistivity – several kinds of "electric" logs measure resistivity. Here the laterolog is the most common. Resistivity is an important characteristic as it is related strongly to the permeability and porosity of the rock. Fluid type (e.g., brine vs fresh water) affect resistivity, but this analysis focuses more simply on lower resistivity in general, with the general assumption that water at these depths is unlikely to be fresh.

other – the log files include many other types of logs, and these were generally not examined because of the presence of more suitable log types.

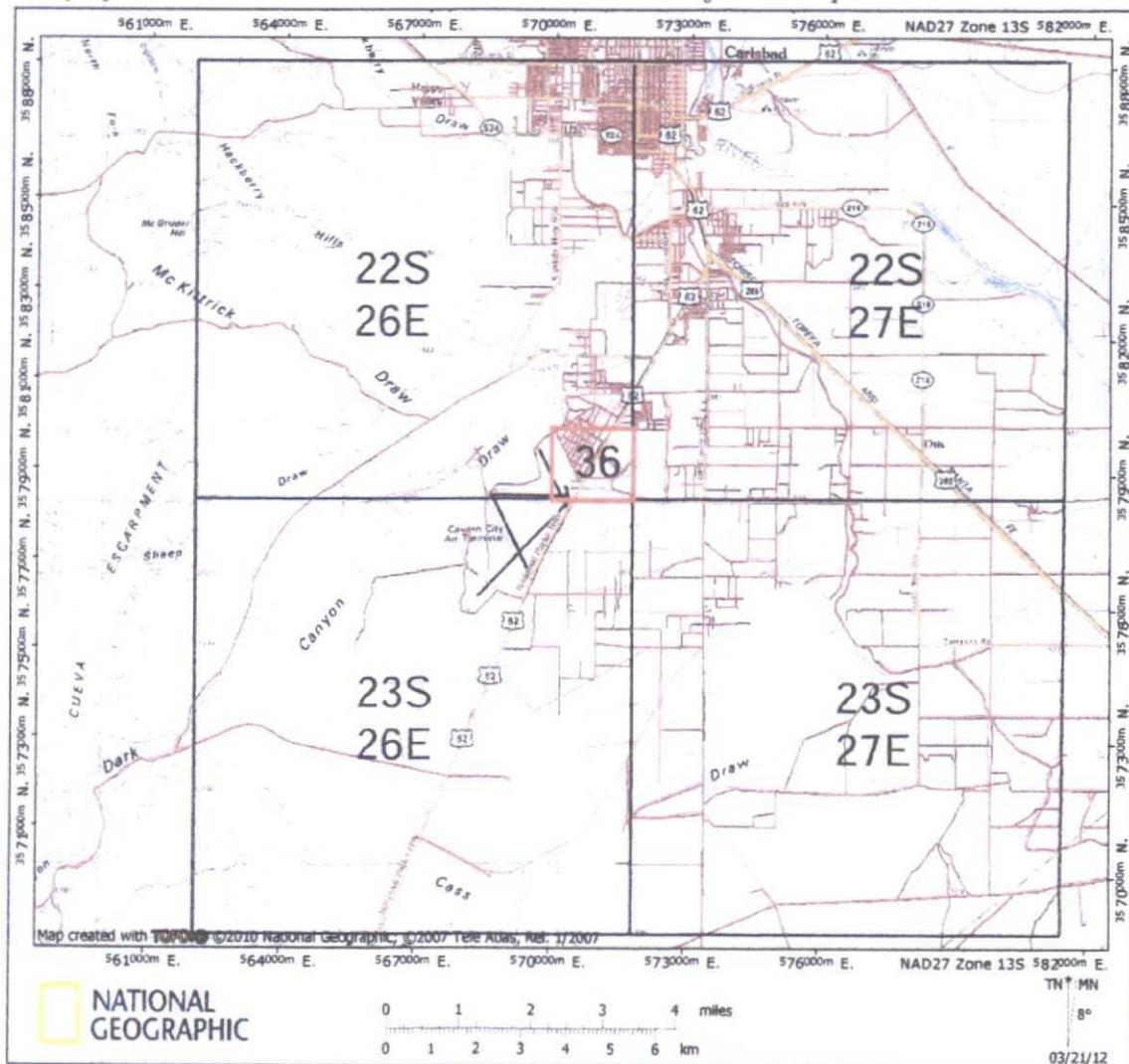
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Data Sources

Geophysical logs are publically available through the OCD website (<http://ocdimage.emnrd.state.nm.us/imaging/>). Because some logs were not available from this source or the log images were poor, a few logs were purchased by me from TGS-NOPEC. These are available to anyone who has a membership. All logs used in illustrations in this report are from public sources.

The literature on the DMG and related rocks is voluminous. A few references are cited here. The New Mexico Bureau of Geology & Mineral Resources (formerly New Mexico Bureau of Mines and Mineral Resources) produces publications and staff reports that are relevant to this and other aspects of New Mexico geology (<http://geoinfo.nmt.edu/>).

Figure 1. General location map with topography. Stratigraphic data were obtained mainly from these townships and immediately west to determine continuity and properties of DMG rocks. The proposed SWD well location is in section 36, marked by the red square.



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BACKGROUND GEOLOGY

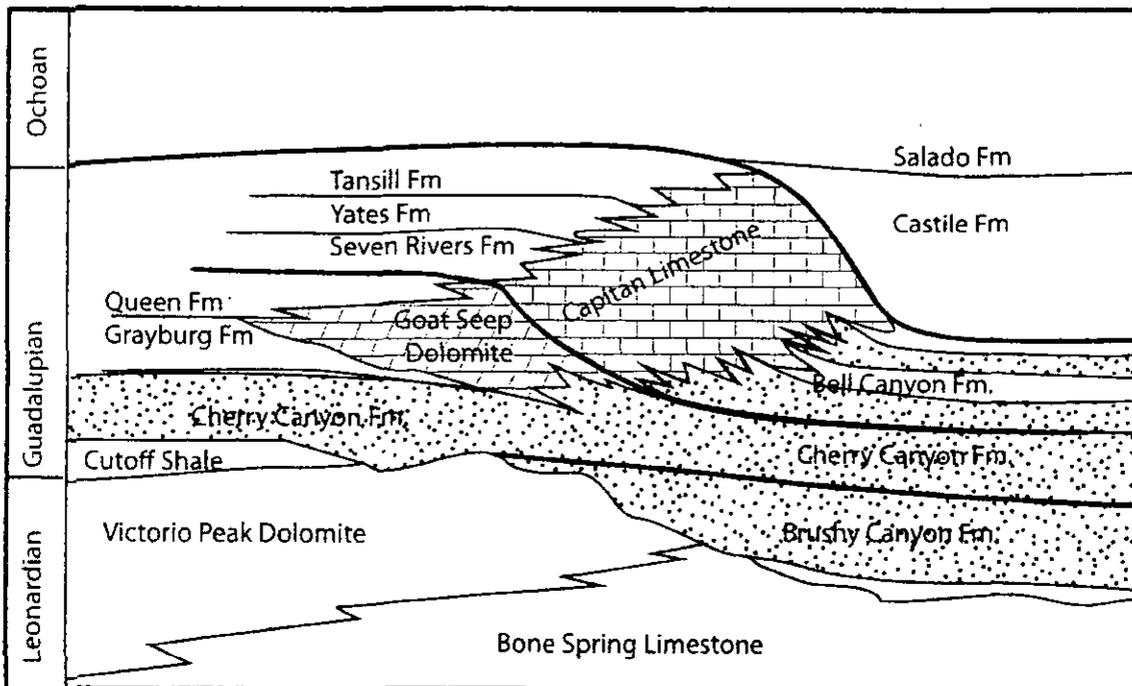
Stratigraphic Units

The three formations of the DMG (Figure 2) are basin facies of shelf, reef, and backreef rocks of the Guadalupe Mountains. Their physical and stratigraphic relationships are complex and have been studied in great detail in outcrops and subsurface (e.g., King, 1948; Newell et al., 1972; Dunham, 1972). They were deposited mainly as slide and debris flow sediments driven by density currents along the sediment-water interface. They exhibit some erosive channeling with coarser deposits as well as lateral and distal fining as the density currents wane with distance into the deeper Delaware Basin. As a consequence, these deposits tend to be more elongate as sands and have finer "overbank" deposits. Delaware

Basin drilling patterns since the mid to late 1980s for DMG exploration and development tend to show these channels very well.

The underlying unit to the DMG is the Bone Spring Limestone. It is persistent well beyond northwestern limits of the Delaware Basin. Broadhead and Gillard (2005) developed structure contours (elevation) on the top of the formation across southeastern New Mexico, with some data in the vicinity of the proposed SWD well location. For the geophysical log interpretation, the top was picked as closely as practical to the same signatures as Broadhead and Gillard used. They report (op cit., p. 7) that "in most places within the Delaware Basin, the top of the Bone Spring is marked by the boundary between the dark micritic limestones of the upper Bone Spring and the sandstone, siltstone, and shales of the overlying Brushy

Figure 2. Stratigraphic units in the area around the proposed SWD location. Delaware Mountain Group units (Brushy Canyon, Cherry Canyon, and Bell Canyon are mainly Delaware Basin equivalents to reef and earlier rocks in the Guadalupe Mountains).



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Canyon Formation of the Delaware Mountain Group." In many logs, there is a short section of high natural gamma at or near the top of the high density limestones that may be called the Cutoff Shale or Formation. It is not distinguished here from Brushy Canyon. The natural gamma and acoustic travel time log from Airport Grace No. 1 (API 30-015-20829) located 1980' fsl, 2164' fwl, section 36, T22S, R26E is taken as a reference log (Figure 3) in section 36 in view of the variable information from other wells. It displays the sharp increase in acoustic velocity of the dense limestones below the contact compared to the lower velocities in the overlying Brushy Canyon (and Cutoff).

The Brushy Canyon is about 1148 ft thick at the reference well (5230 ft - 4082 ft). The natural gamma shows generally shorter segments of lower values (less than ~70 API units) indicating sands. Some of these segments are overlain by intervals of increasing natural gamma upward that indicate upward fining (e.g. 4900-4700 ft). Higher acoustic travel times (lower velocity) coincident with some of the lower natural gamma may be indicating somewhat limited cements and greater porosity/permeability (e.g., 4540-4500 ft). These alternating signatures are consistent with the origin of the formation by deep-water density currents (Harms, 1974).

The Cherry Canyon is ~1276 ft thick (4082-2806 ft) as interpreted here. The basal contact with the Brushy Canyon is commonly marked by a large increase in natural gamma above the main body of the Brushy Canyon. At the reference well, there is an increase in the acoustic velocity (lower travel time), followed upward by a decrease in gamma and decrease in velocity. This contact was not clearly defined in several wells interpreted within the area around the proposed site. The upper

contact of Cherry Canyon with Bell Canyon is placed at the base of a small sandstone (lower natural gamma) that is associated with a marked increase in acoustic velocity as well as changes in neutron, density, and resistivity. The Cherry Canyon displays much increased natural gamma in the lower half (compared to the underlying Brushy Canyon), a zone of relatively uniform natural gamma ~400 ft thick, and another zone of increased and variable natural gamma toward the top of the formation. It formed similarly to Brushy Canyon, but in general appears to be finer-grained.

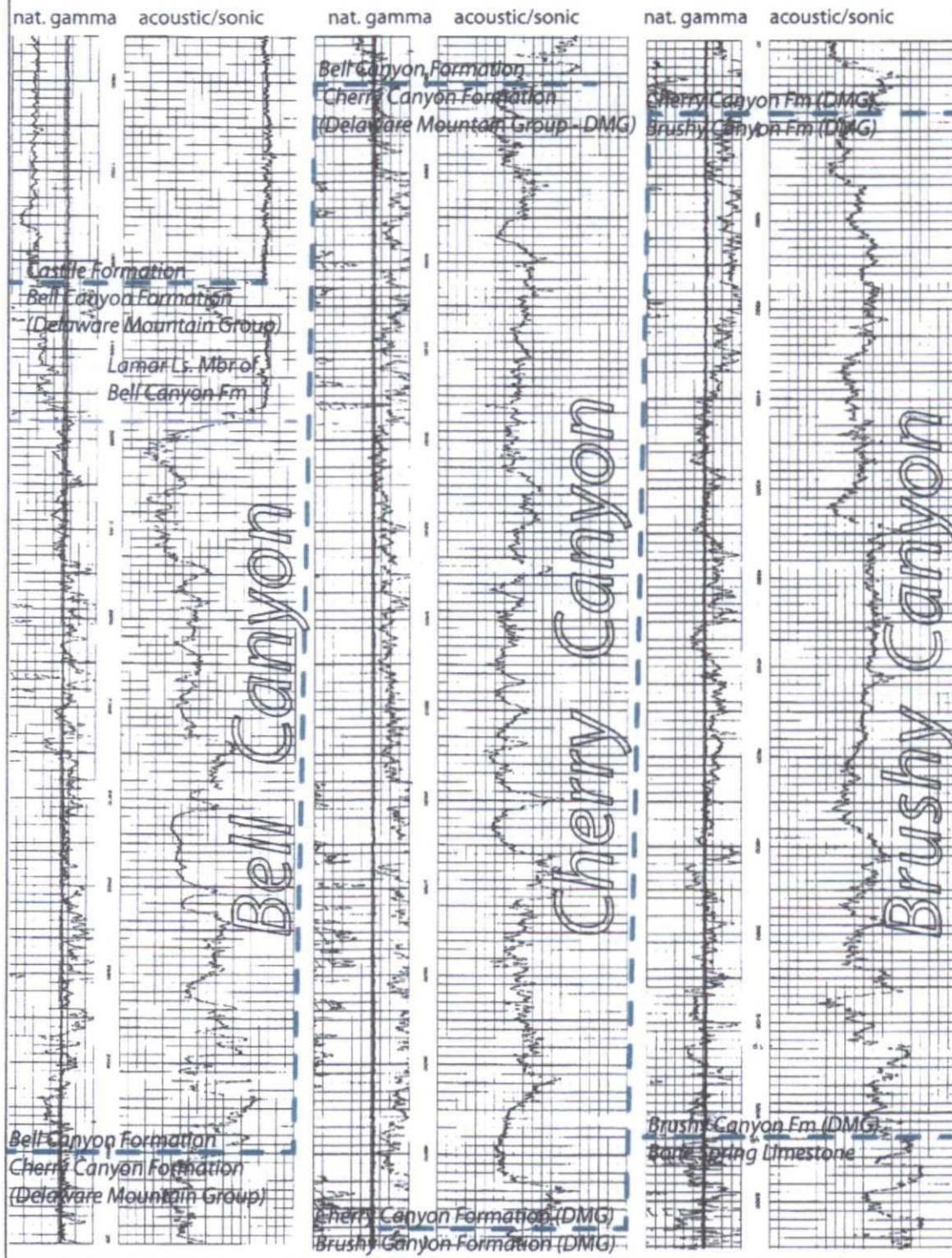
The Bell Canyon is 981 ft thick (2806-1825 ft) as interpreted at the reference well. The upper contact with the base of Castile Formation is marked by a sharp upward decrease in natural gamma to a very low baseline level and a high acoustic velocity or density above the contact. The Bell Canyon displays characteristics between that of Brushy Canyon and Cherry Canyon. The natural gamma tends to be lower than Cherry Canyon and somewhat more uniform. The acoustic log displays considerable variation between low and moderate velocities. From 1980-1870 ft, a low natural gamma and high acoustic velocity zone is here called the Lamar Limestone, a member of the Brushy Canyon. This unit is persistent in the area. Well files from OCD for the Salty Bill SWD well in section 36 indicate the equivalent zone is anhydrite. The velocity signature is consistent with either lithology, but the natural gamma is slightly high for most anhydrites in the basin.

Basin Structure and Alleged Faulting

The margin of the Delaware Basin is complex stratigraphically, with facies changes for the DMG that also reflect considerable difference in elevation for equivalent beds over short distances. To evaluate the local structure and

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Figure 3 Delaware Mountain Group Stratigraphy
in Section 35, T22S, R26E, Airport Grace #1 (API 30-015-20829)



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potential for faults, the contacts at top of Bone Spring, top of Brushy Canyon, top of Cherry Canyon, and base of Lamar Limestone were mapped as elevations and contoured (Figure 4; at end of report due to dimensions). The Bone Spring map was extended to the west to evaluate the alleged Carlsbad fault along the edge of the escarpment west of the proposed SWD location.

The Bone Spring contour map shows two important features: general eastward dip and no apparent displacements along the trend of the alleged Carlsbad fault (Kelley, 1971). This is consistent also with the findings of Hayes and Bachman (1979), in which they concluded (p. 9) "a careful field examination of the area of the Carlsbad Fault as described by Kelley failed to reveal any fault planes or fault scarps." The Carlsbad fault was located in section 6, T23S, R26E by Kelley and trended northeast across T22S, R26E.

The top of Brushy Canyon indicates an east to east-northeast dip and some possible channeling on the top of the formation by the overlying Cherry Canyon. There is uncertainty associated with interpreting this contact, as noted earlier, that make the channeling somewhat less certain, but it is not a feature that requires resolving for this project. There is some possible increase in dip to the west.

The top of Cherry Canyon is similar to top of Brushy Canyon. Data are sparse along the trend of the alleged Carlsbad fault.

The base of Lamar Limestone Member also displays general eastward dip. There are variations in the south central part of T22S, R26E, along the trend of the alleged fault, but these are much more likely due to facies changes along the reef front, part of which is equivalent to the Lamar.

PROPOSED INJECTION INTERVALS

Criteria

The main inferences that can be drawn from geophysical logs relate to basic lithology and the potential for favorable properties (porosity and permeability). In the vicinity of the proposed SWD well location, each of the formations of the DMG was examined for several logs (Figure 5), and favorable zones were noted for each log. Intervals exceeding ~20 ft thickness and with favorable characteristics for several log properties were chosen and prioritized by quality, thickness, and depth.

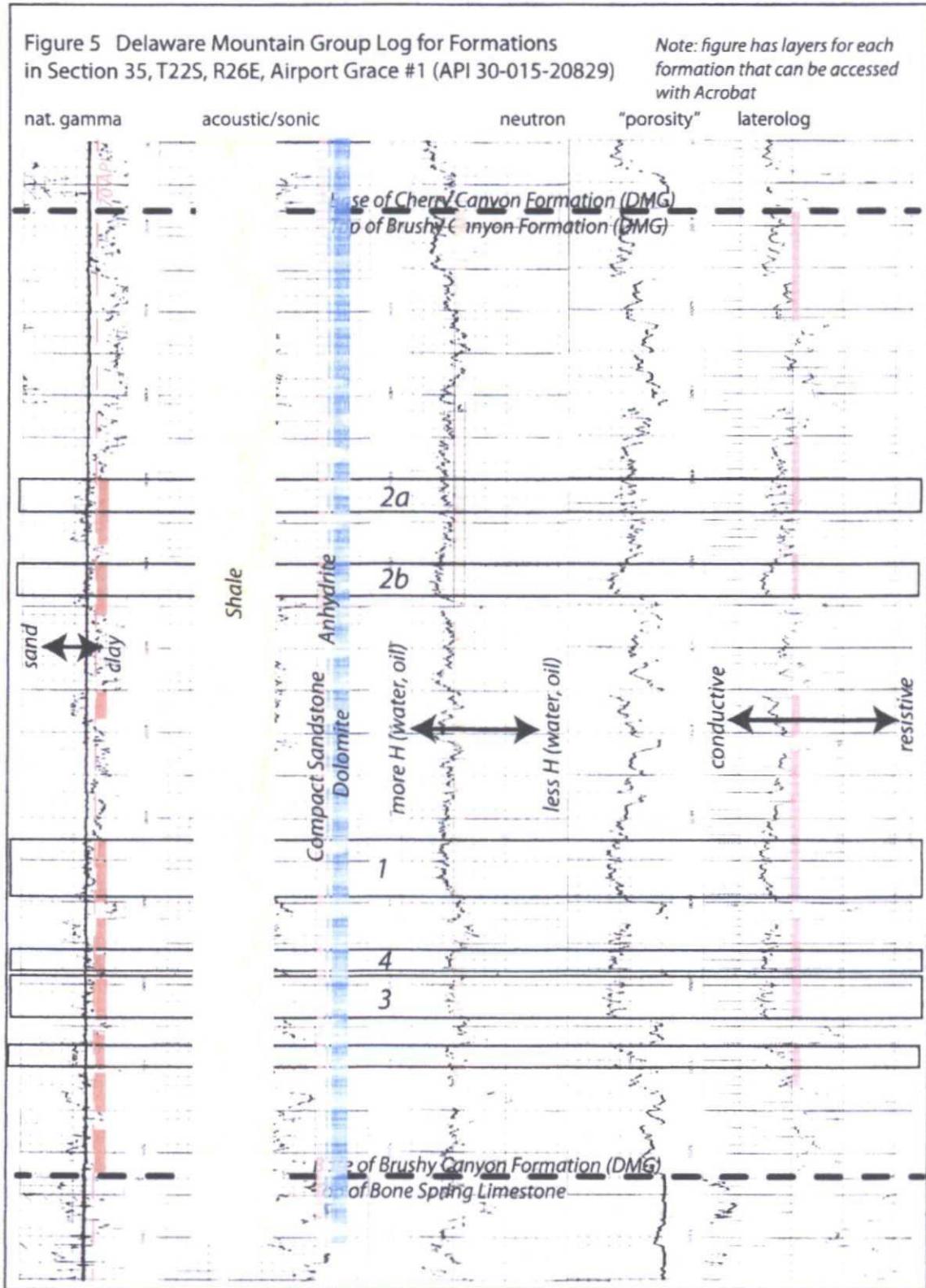
The main criteria, as described previously, were for low (or lower) gamma (sandier), low neutron (presence of H), low resistivity (fluid and connectivity) and general range of acoustic travel times.

An overlay layer in Figure 5 includes the following:
labelled red dashed line on the left log to mark 70 API units, and
colored zones on the acoustic log indicating common ranges for some important lithologies.

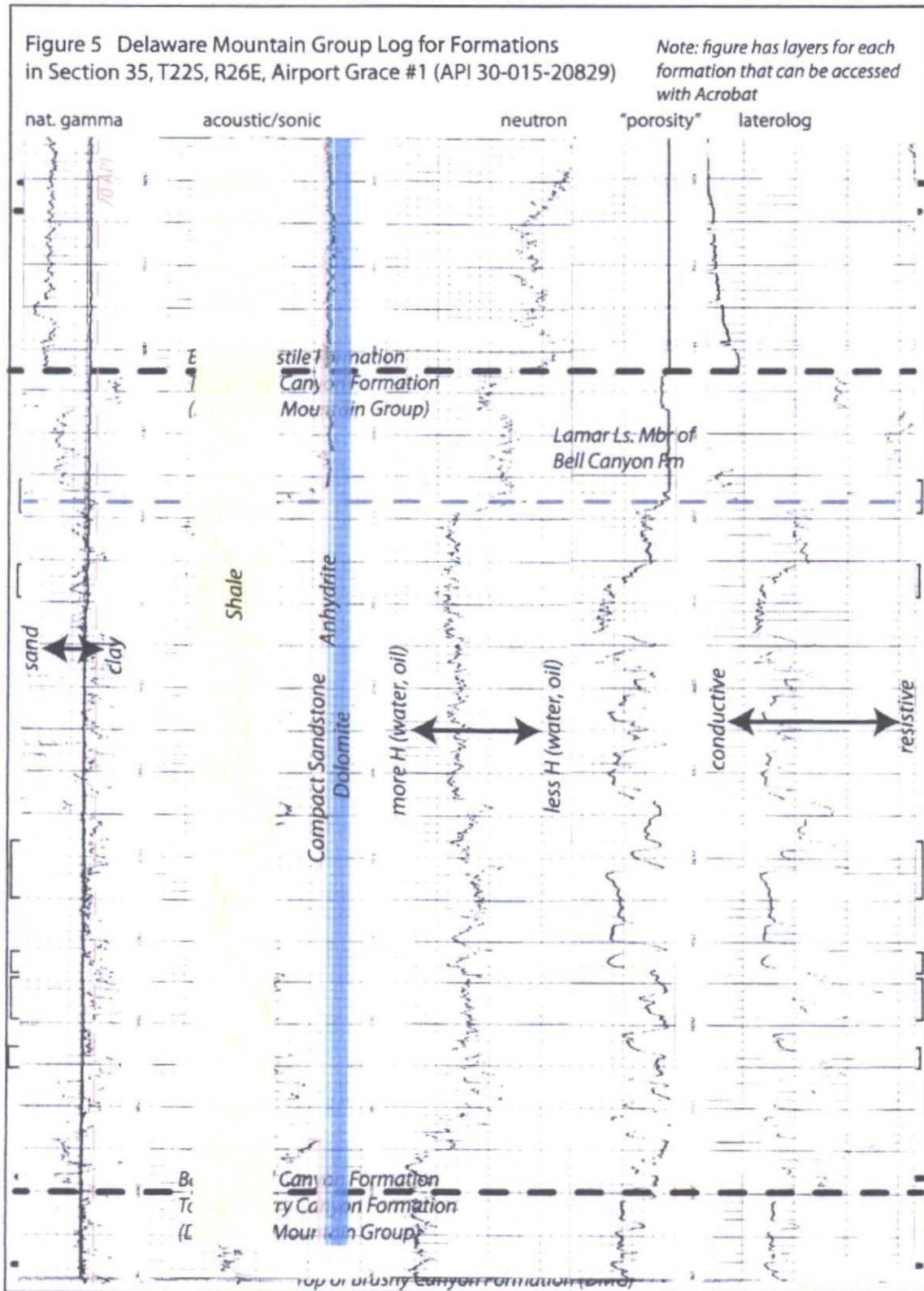
The natural gamma log for each formation shows reddish rectangles opposite zones of gamma < 70 API units. The neutron log for each formation shows some orange rectangles for low neutron zones. The resistivity log for each formation shows pink rectangles for low resistivity. For each formation, the criteria were the same.

The results are simple to summarize. The Brushy Canyon shows thicker and more numerous zones with common more favorable properties for each log type. The Cherry Canyon shows little that is favorable, compared to the Brushy Canyon. The Bell

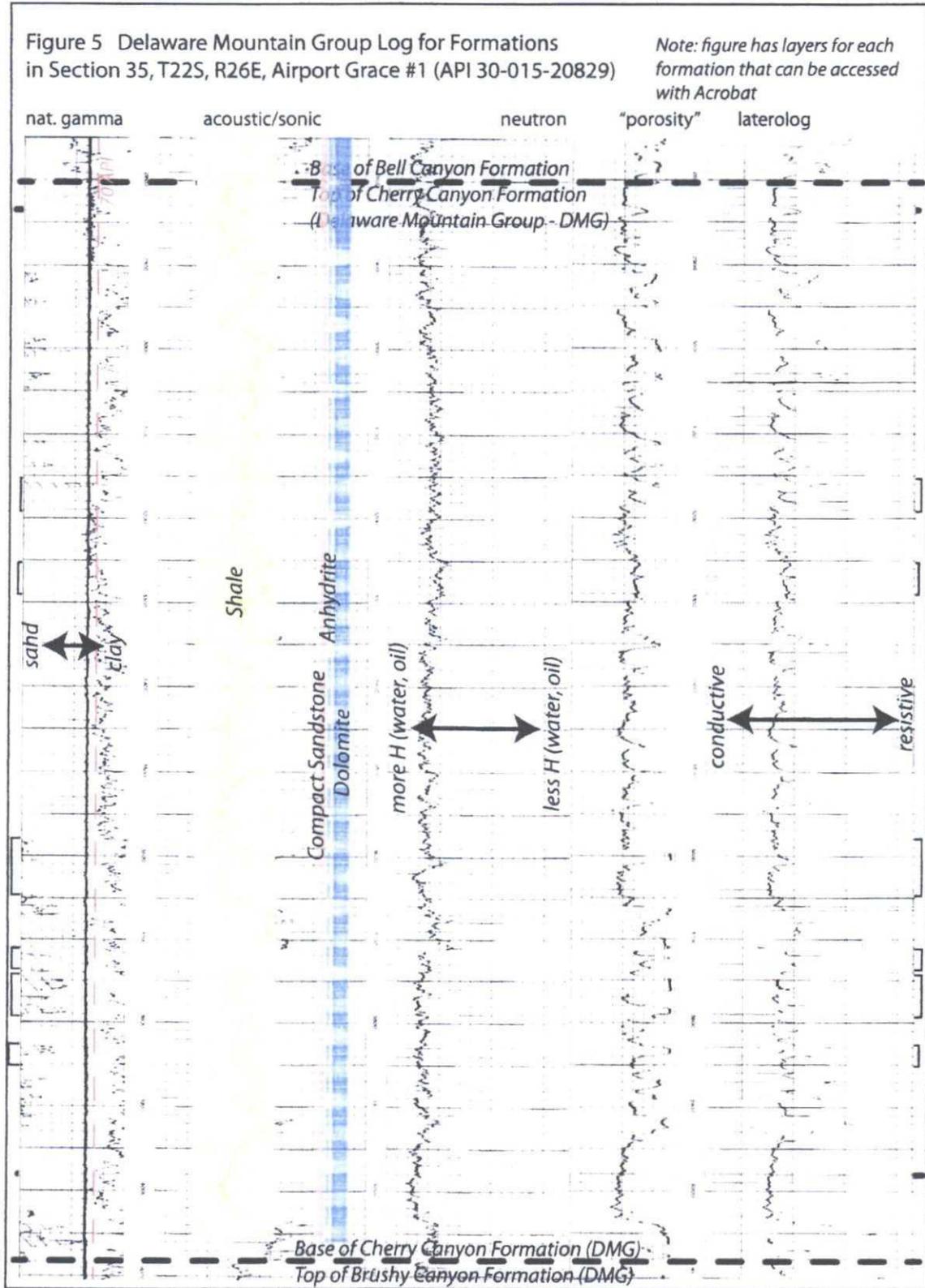
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Canyon is somewhat more promising than Cherry Canyon but mainly lacks thicker intervals.

The Brushy Canyon is also a preferred interval because it lacks direct stratigraphic connection to the Capitan reef, a significant local source of water. Other formations that are higher and closer to the Capitan have been used as injection wells without apparent issue, but first priority is for a different unit without direct connection.

Short log cross-sections (Figure 6; E-W, N-S) across the proposed location indicate both continuity and lateral heterogeneity of the rocks of the Brushy Canyon. Some of the sand units are correlated, while others appear to truncate or pinch out laterally. Some correlations suggest potential channeling. More detailed cross-sections with shorter spaces can better discriminate such channeling. There is apparent significant continuity with some of the intervals to indicate larger areas for the injection unit, while the heterogeneity indicate lateral limits to migration of the injected fluid.

Lateral heterogeneity of the formation also indicates that specific intervals at the proposed location may differ somewhat from the reference well, requiring some adjustment based on geophysical logging of the well.

Priorities

Only intervals within the Brushy Canyon are given priority for testing.

Interval 1 is ~65 ft thick (4890-4825 ft). It is the thickest interval without combining short intervals of less favorable characteristics.

Interval 2a and 2b may offer ~80 ft combined if perforated separately. These two intervals are ~300 ft higher than interval 1.

Intervals 3 and 4, if combined, offer ~70-75 ft with preferred characteristics. These two intervals might be combined with interval 1 for ~150 ft.

Recommendations

As many of the suitable intervals 1-4 as are practical should be tested. Interval 1 is top priority as a single interval, but combining 1, 3, and 4 would be better. Intervals 2a and 2b, even if combined, would be lower priority although 2b has possibly the best characteristics overall.

A good range of open hole logs are recommended, to include natural gamma (spectral if possible), borehole compensated (BHC) neutron and BHC density, and multi-depth electrical logs (e.g., dual laterolog or better). I also recommend monitoring cuttings closely for hydrocarbon shows.

Resource Conflicts

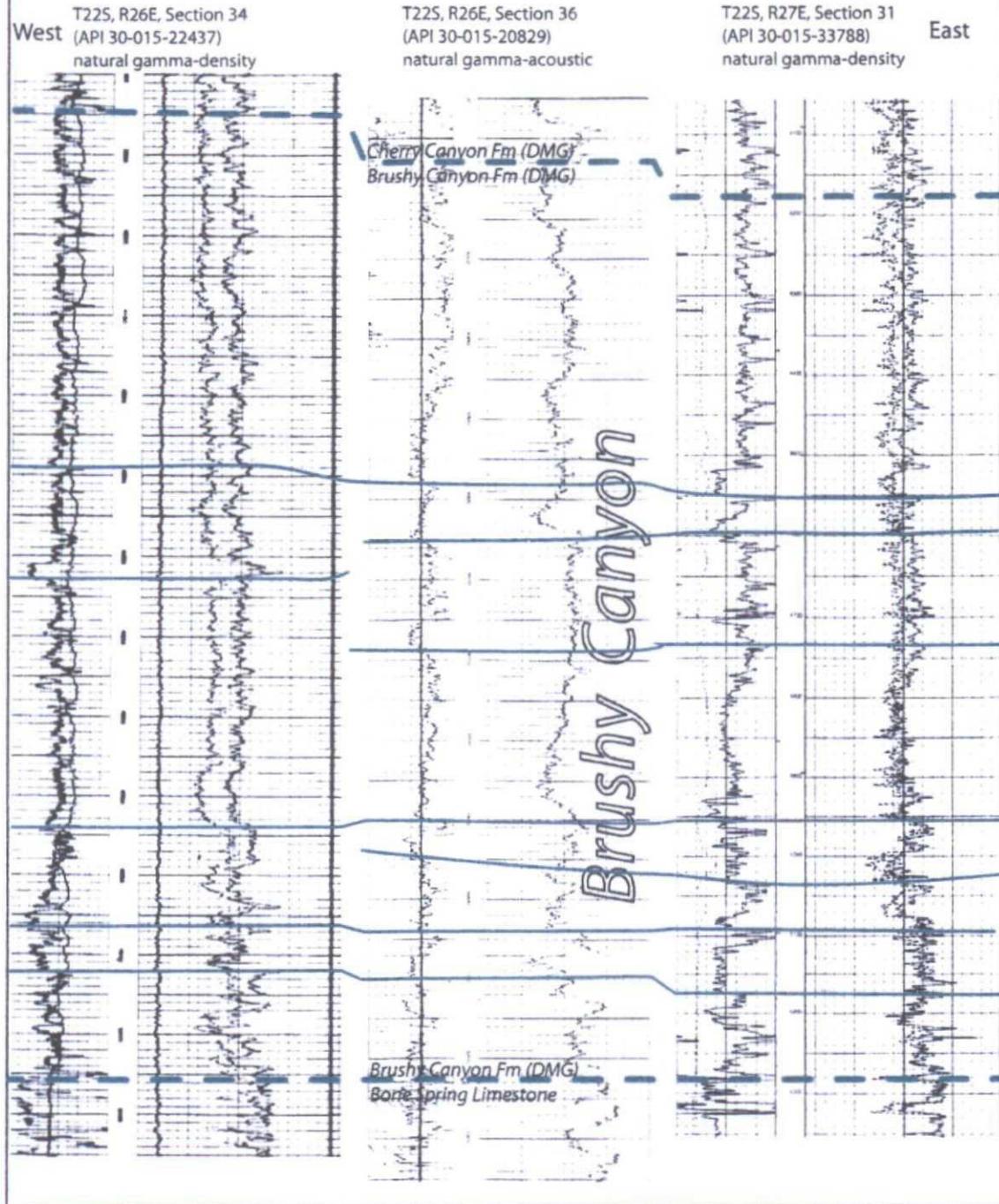
There is some potential for conflict with resources in these formation, but they appear to be avoidable. Broadhead and Justman (undated) describe production from the lower Brushy Canyon sandstones south of the proposed location. This production may require additional examination to determine if there is conflict with some of the preferred lower intervals. There is also some production in the area from upper Cherry Canyon, but not immediately adjacent to the site.

These formations all produce in different parts of the basin.

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Figure 6 North-South and East-West Log Cross-sections of Brushy Canyon Formation Through T22S, R26E, Section 36

Note: figure has layers for each formation that can be accessed with Acrobat



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REFERENCES CITED

- Broadhead, R.F., and Gillard, L., 2005.
Structure contours on Bone Spring Formation
(Lower Permian). Delaware Basin: Open file
report 488, New Mexico Bureau of Geology
and Mineral Resources, Socorro, NM.
- Dunham, R.J., 1972. Capitan reef, New
Mexico and Texas: facts and questions to
aid interpretation and group discussion:
Permian Basin Section, Society of Economic
Paleontologists and Mineralogists, 310 p.
- Harms, J.C., 1974. Brushy Canyon Formation,
Texas: A deep-water density current deposit:
Geological Society of America Bulletin, v.
85, p. 1763-1784.
- Kelley, V.C., 1971. Geology of the Pecos
country, southeastern New Mexico: New
Mexico Bureau of Mines and Mineral
Resources, Memoir 24. 75 p.
- King, P.B., 1948. Geology of the southern
Guadalupe Mountains, Texas: U.S. Geological
Survey Professional Paper 251. 183 p.
- Newell, N.D., Rigby, J.K., Fischer, A.G.,
Whiteman, A.J., Hickox, J.E., and Bradley,
J.S., 1972. The Permian reef complex of the
Guadalupe Mountains region, Texas and New
Mexico: A study in Paleogeology: Hafner
Publishing Company, New York, 236 p.