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Albuquerque, New Mexico 87185-0750

date: March 12, 1998

to: Distribution

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subject: Carthage Cotton Valley Five-Level Extracted Data Results And Effect of Velocity Structure

The Carthage diagnostic experiment was an industry consortium test of microseismic fracture diagnostics in the Cotton Valley formation. Three fracture experiments were conducted between 8000 and 10,000 ft using diagnostic information obtained from two monitoring wells. In 1997, the Taylor Sand fracture experiment was re-analyzed using the polarization information and found to differ considerably from the original interpretation. In 1998, the focus was on using the microseismic data obtained in the shallowest experiment to extract a 5-level data set from which comparisons could be made with the full data set to evaluate the accuracy of a reduced receiver array.

Extraction Of Five-Level Data

It was originally intended that 5-level data be extracted from each of the three injections at Carthage. However, because many of the receivers had failed (particularly the deep ones), the only injection from which quality 5-level data could be extracted was the last injection. The deeper injections had no good tri-axial receivers below the fracture interval to constrain the height of the fracture. As a result, extraction analyses were only performed on the final injection.

To process the information, it was necessary to write two codes to convert the data. Since GRI data is fully taken and processed on PC platforms, the SEG2 disk data format is used for all GRI software. ARCO, however, wrote the data in SEGD format (a tape format), and this needed to be converted to SEG2 for further processing. Once in SEG2 format, a second code was written to extract appropriate 5-level data from the complete microseismic data set. This was rather complicated because ARCO's format did not have channels in sequence, but rather scattered throughout the data set.

All of the event files detected by ARCO were processed in this manner and 5-level SEG2 format event files were written for each of them. These events were then checked for events that had reasonable P and S waves on most channels. Events without P waves or those without S waves were not used.

Extracted Five-Level Receiver Geometry

A reasonable 5-level system was found by examining the data from the various operating channels in the upper section of the monitor well. This system consisted of receivers at 8271, 8471, 8773, 8923 and 9173 ft., as shown in Figure 1. In these tests, the monitor well (CGU-22-9) was about 1400 ft from the treatment well (CGU-21-10). The perforated interval for injection consisted of selected zones between 8580 and 8844 ft.

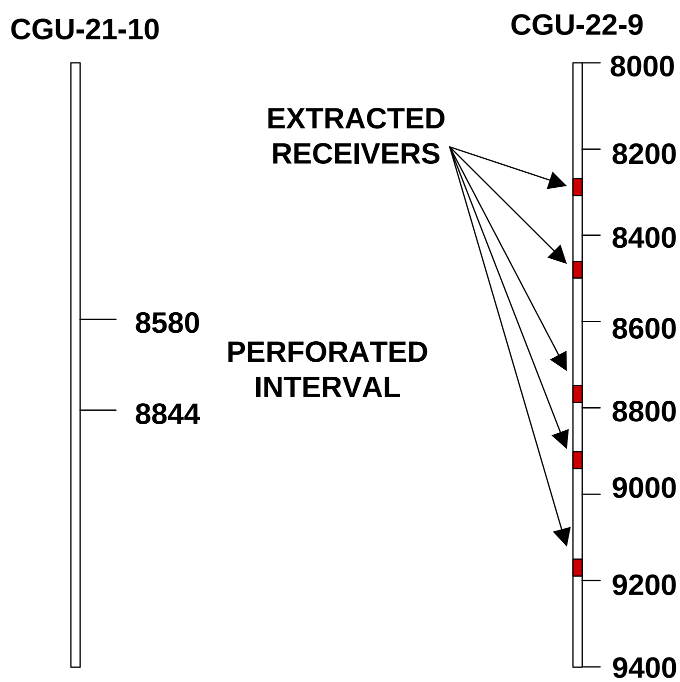

Figure 1. Receiver configuration for extracted 5-level system for upper Cotton Valley test.

Results

After extracting the 5-level data from all of the ARCO-detected events, the resultant data files were analyzed using the SMART5 code to process P and S arrivals and receiver hodograms. Because of the poor P waves on many of the events, considerable hand editing was required to accurately pick the required information and many of the events were discarded. Since the waveforms from the events have been published by ARCO, none of the raw data is shown here. Additionally, orientations of the receivers were given in the earlier report on the re-analysis of the Taylor sand fracture and are not repeated.

After processing, 254 microseisms were found and analyzed for their locations. Figure 2 shows the plan view and side view maps of those microseisms. It can be seen that the microseisms align tightly along a ENE azimuth with an east wing length of 1300-1400 ft. It is thought that the farthest point on the east is probably spurious (e.g., it may be related to other things such as production). There is very little height growth out of the perforated intervals, even though there are only supposed to be small stress contrasts in this zone. The microseisms do not perfectly intersect the treatment well, suggesting that there are some errors in the velocity information or deviation of the treatment well. This could easily be corrected by changing the velocities, but we would rather show the data as actually analyzed.

There are few points on the west wing, but this is an artifact of the method ARCO used in their data acquisition. The event detector triggered on the large S waves, using a pre-event buffer in which to store a selected amount of prior data. Unfortunately, the selected pre-event buffer size was insufficient to capture the P waves from the west wing (the arrival time differences between the P and

S waves at these distances were larger than the buffer allowed). We believe that there are many events on this wing, but the event files only have the S waves and high-quality analyses could not be performed on these data.

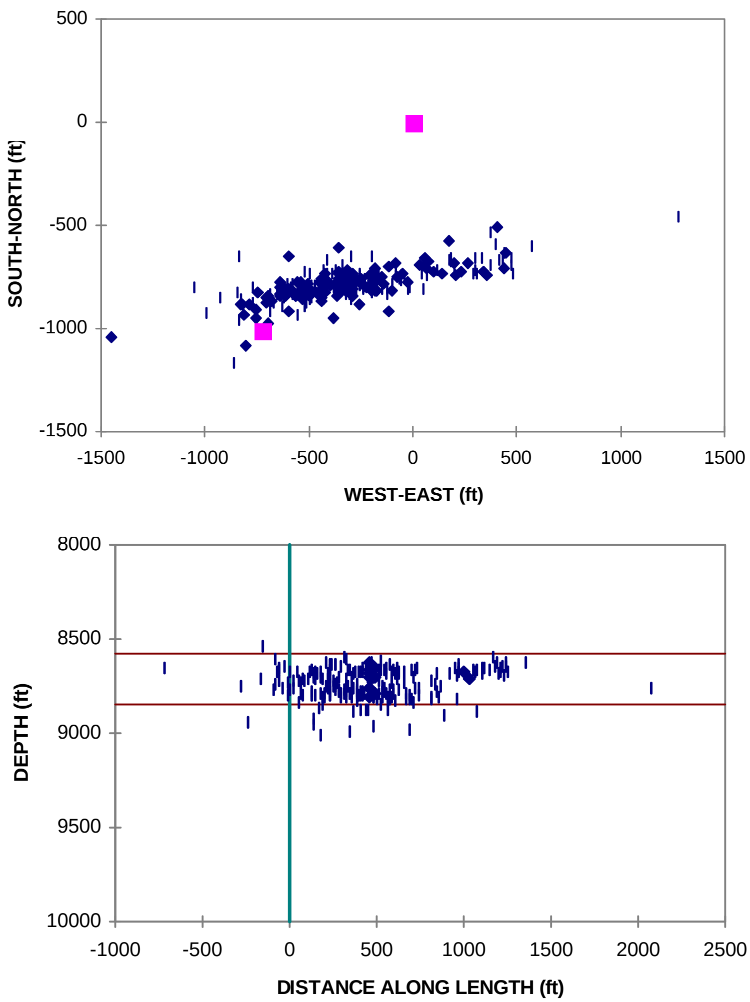

Figure 2. Plan view and side view maps of Stage 3 (upper) Cotton Valley fracture test.

Results With Velocity Structure Effects

Since there is considerable velocity structure throughout the Cotton Valley formation, an attempt was made to determine the effect of this structure on the locations. Figure 3 shows the velocity structure of the Cotton Valley section as deduced from logs and a crosswell tomogram. It shows that velocities vary widely over this interval, particularly in the 8,200-9,200 ft range of interest.

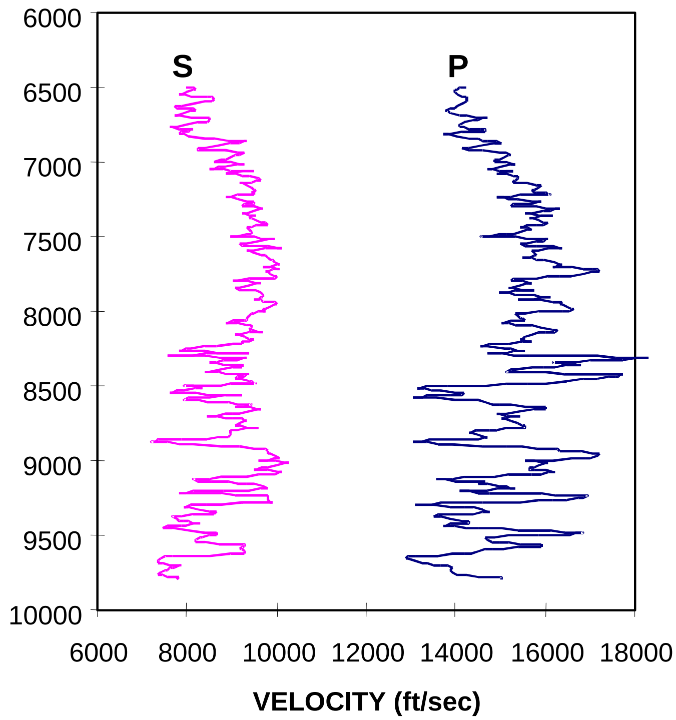

Figure 3. Velocity logs of Cotton Valley section.

The data from Figure 3 were used to construct a layered velocity model for the 8,200-9,200 depth range that could be used for detailed velocity-structure analyses. Figure 4 shows the resultant layered model.

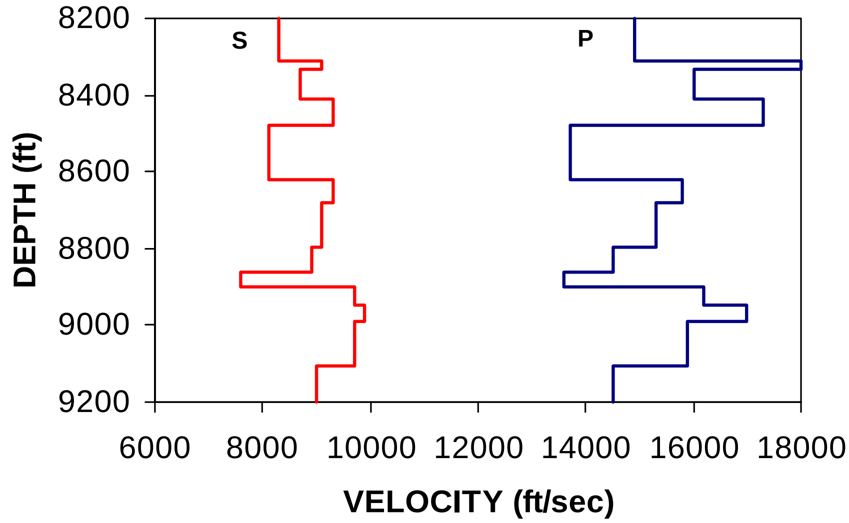

Figure 4. Layered velocity structure for advanced analyses.

Using the Vidale and Nelson algorithms,[1,2] the microseisms were relocated taking into account the major velocity structure to yield the maps shown in Figure 5. The microseism distribution tightens up somewhat, but there is no significant change in the overall size and shape of the fracture. The most significant difference is the reduction in downward growth when the microseisms are located using full velocity data. The microseisms still do not interesect the treatment well adequately, suggesting that there is some other systematic error involved (e.g., fault between wells, production or injection induced velocity changes, or other effects)

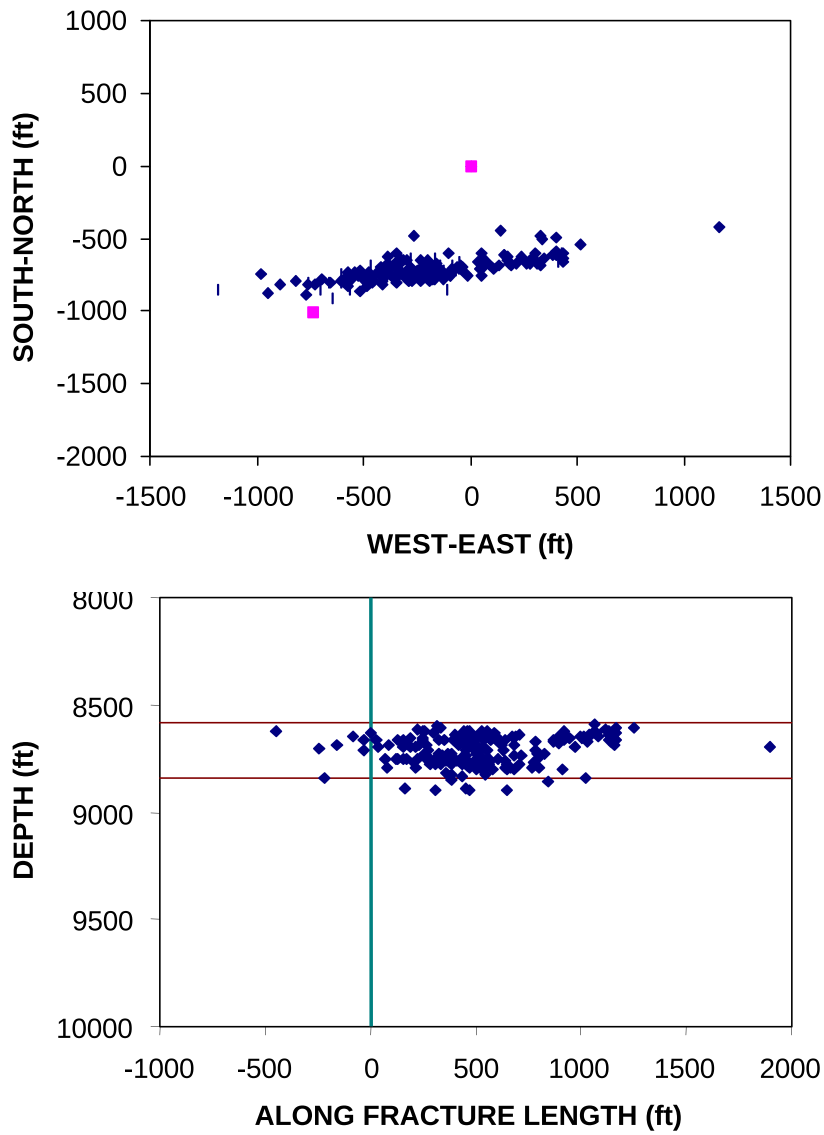

Figure 5. Plan view and side view maps of upper Cotton Valley stimulation using velocity structure.

While these analyses in no way alter the main results from the Carthage Cotton Valley experiments, they show very clearly that a 5-level system is perfectly adequate to map the fractures from this type of reservoir at these interwell spacings. Important factors are the total aperture of the array relative to the distance from the monitor well to the fracture and the accuracy of velocity information.

References

1. Nelson, G.D. and Vidale, J.E., “Earthquake Locations by 3D Finite Difference Travel Times,” *Bull. of the Seismological Society of America*, **80**, April 1990, 395.
2. Vidale, J.E., “Finite Difference Calculation of Travel Times,” *Bull. of the. Seismological Society of America*, **78**, 1988, 2062.