THE USE of the SHEAR WAVE and the DUAL SPACED NEUTRON to DETECT HYDROCARBON ZONES

Lee Sanders
Halliburton Logging Services

ABSTRACT
A new log analysis technique is being used to evaluate sandstones in the Permian Basin for hydrocarbons. This technique is a crossplot on a well log format of the neutron porosity and the shear wave travel time with respect to depth. In this technique the zones that are hydrocarbon productive will exhibit a greater shear travel time value than would be predicted from the neutron porosity. Those zones that are water productive or "wet" exhibit a smaller shear travel time value than would be predicted from the neutron porosity. The technique can be applied in the cased hole and open hole environments. Several field examples demonstrate the manner in which the technique is successfully applied.

INTRODUCTION
The technique for detecting hydrocarbons was originally intended to identify gas production behind pipe using the Di-Pole Shear Wave Tool. The specific zones of interest were the Canyon age sandstones of Edwards County in the Val Verde Basin of Texas. The Di-Pole Shear Wave Tool was particularly suited for this area because the clays within the shales associated with the Canyon sands precluded obtaining acoustic measurements normally acquired with the conventional monopole source acoustic tools. In comparing the shear wave travel time with the neutron porosity, the data indicated that zones that were gas productive exhibit a greater shear travel time value than would be predicted from the neutron porosity. Zones that were "wet" exhibit a smaller shear travel time value than would be predicted from the neutron porosity.

The technique was extended to other areas in the Permian Basin where the Di-Pole Shear Tool was run in the open hole analyzing sandstone zones with low GOR's. In logging wells in the Delaware Basin, the clays do not adversely affect the monopole source so both the Di-Pole and Full Wave Sonic Tools were used to record the shear wave. The technique is most effective in the Delaware Basin where the "Delaware effect" complicates conventional log analysis. In addition, the technique identifies sands to be "wet" where conventional log analysis would classify the sand as productive.

CONCEPT

Shear waves can be generated by the Di-Pole Shear Tool and in most cases in the Permian Basin, the Full Wave Sonic Tool can generate shear waves. The shear wave travel time is a function of the shear modulus and bulk density of the formation. Therefore, shear waves are affected by formation fluids only to the extent that fluids can effect the bulk density. The neutron porosity is a function of the hydrogen content of the formation and the formation fluids.

By crossplotting the shear travel time to the neutron porosity, when the sandstone is hydrocarbon productive, the shear travel time is unaffected; however, the neutron will respond to a lower hydrogen content reflecting a smaller value than would be predicted. When the sand is non-productive or "wet", the crossplot of the data shows a smaller shear travel time value than would be predicted from the neutron porosity response to a higher hydrogen content in the "water zone".

CASED HOLE - DI-POLE SHEAR WAVE - DELAWARE SANDS

This example illustrates how the technique was applied in a well where a conventional open hole logging program could not be run because of "hole problems". The well was cased, cemented and the operator wanted to define the hydrocarbon bearing zone and the oil-water contract.

Figure 1 shows the waveforms generated by the Di-Pole Shear wave tool. The first wave arrivals on the waveform are the shear waves. For each sampled depth, the wave arrivals occur within a time frame of 500 to 16,000 microseconds. The arrivals times are then transformed into shear travels time and plotted with the neutron porosity values for comparison. Figure 2 shows the crossplot of the neutron porosity and the shear travel times. The base of the evaporite section occurs at X040 feet. The zone from X040 to X074 is a non-productive shaley sand exhibiting a high neutron porosity because of the bound water within the shales. The zone from X074 to X118 is the productive interval showing the crossover of the shear travel time with respect to the neutron porosity. The increase in the neutron porosity at X0118 represents the oil-water contact.

CASED HOLE - DI-POLE SHEAR WAVE - CISCO SANDSTONE

This example shows how the technique was applied on a cased hole re-entry prospect. The well was abandoned from a lower productive interval. The Dual Spaced Neutron and Di-Pole Shear Tool were run in the cased hole. Figure 3 shows the waveform plot of the shear arrivals. Figure 4 shows shear travel time and neutron porosity crossplot. The zone of interest from X028 to X060 was perforated in the top 20 feet. The well is producing 150 BOPD, 5 BWPD, with a GOR of 500 : 1.

OPEN HOLE - FULL WAVE SONIC - DELAWARE SANDS

This example shows how the technique was applied in an open hole well where conventional water saturation calculations are of dubious value because of the "Delaware effect". The "Delaware effect" is an electrical phenomena causing the deep resistivity measurement on the Dual Laterolog to yield erroneously high readings. The deep resistivity exhibits erroneously high values when a low resistivity formation (Delaware sands) is overlain by a highly resistive formation (Castile anhydrite).

Figure 5 shows the Dual Laterolog - Microspherically Focused Log and the "Delaware effect". The base of the evaporite zone occurs at X256 feet. The increasing Deep Laterolog values from X358 to X256 are the results of the "Delaware effect" and not to higest resistive formation fluids. Figure 6 shows the Dual Spaced Neutron and Spectral Density Log for the subject well. There are 3 sand packages identifiable: X276 to X303, X325 to X378, and X408 to X450. Figure 7 shows the crossplot of the shear travel time and neutron porosity. The only zone that is productive is the sand from X325 to X378. The other two sands were non-productive.

CASED HOLE - DI-POLE SHEAR WAVE - CANYON SANDS

This example illustrates that the technique can differentiate between productive zones and "wet zones" even though conventional logs indicate potential production. Figure 8 shows the shear waveform arrivals. Figure 9 shows the original open hole density and neutron porosity values compared to the current day cased hole shear travel time. The common practice on re-entry work has been to perforate all sand zones where the density porosity is greater than the predicted neutron porosity. The technique of comparing the neutron porosity to the shear travel time shows most of the sands to be "wet". The only exception is the sand at X286 to X293. Notice that the productive zone extends through a shale interval. This well was perforated in the zone from X236 to X293 and producing 100 mcfd with no water.

CONCLUSIONS

The technique for identifying hydrocarbons with the shear wave travel time and neutron porosity crossplot was originally intended for the cased hole applications. The technique has presently been extended specifically to the Delaware age sandstones in both the open and cased holes. The technique is effective in gas producing sandstone reservoirs and sandstone reservoirs with low gas to oil ratios.

REFERENCES

The Neutron Log, Halliburton Logging Services, internal publication, 1980.

Paillet, F.L., Chuen, H.C.; Acoustic Waves in Boreholes, CRC Press, 1991.

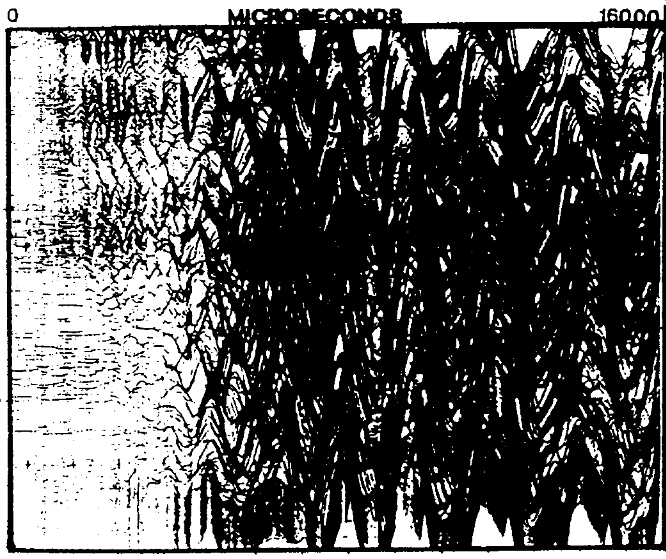

Figure 1 - Shear waveform plot

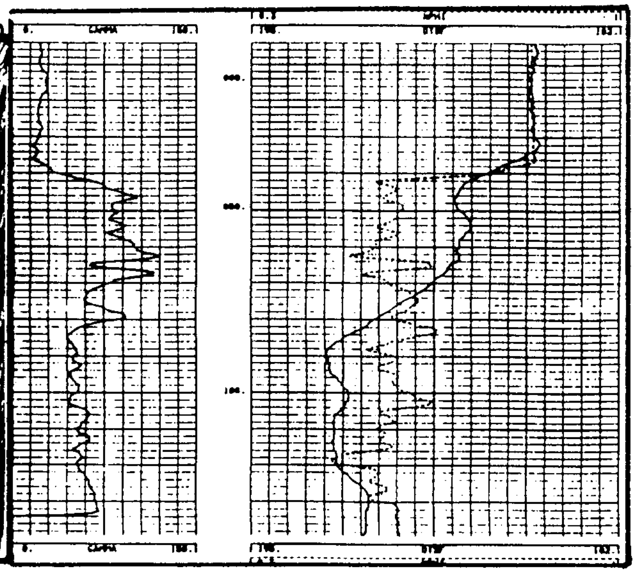

Figure 2 - Shear travel time and neutron porosity crossplot

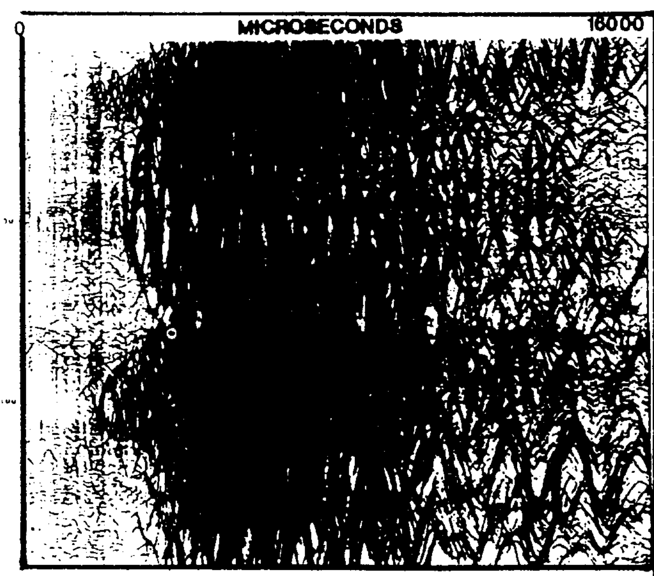

Figure 3 - Shear waveform plot

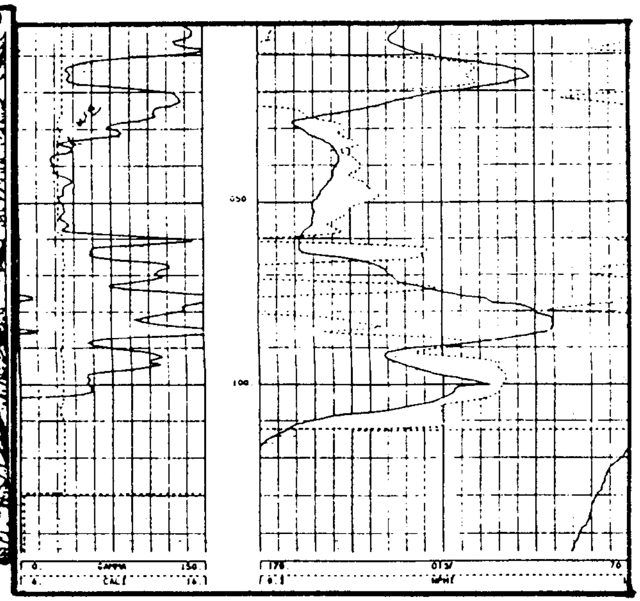

Figure 4 - Shear travel time and neutron porosity crossplot

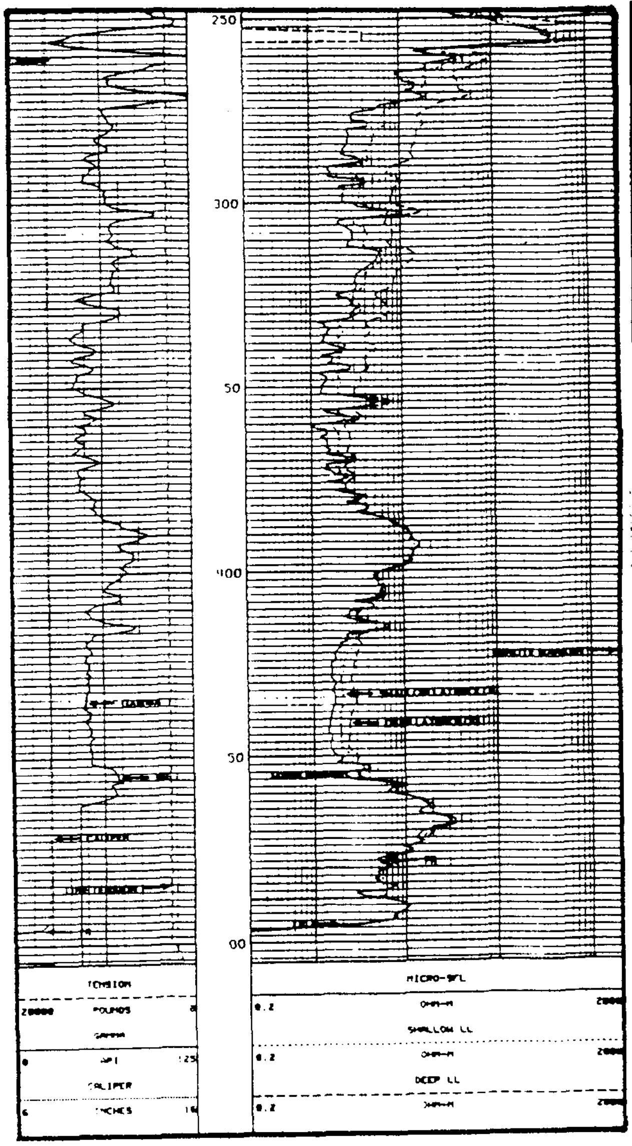

Figure 5 - Dual Laterolog MSFL

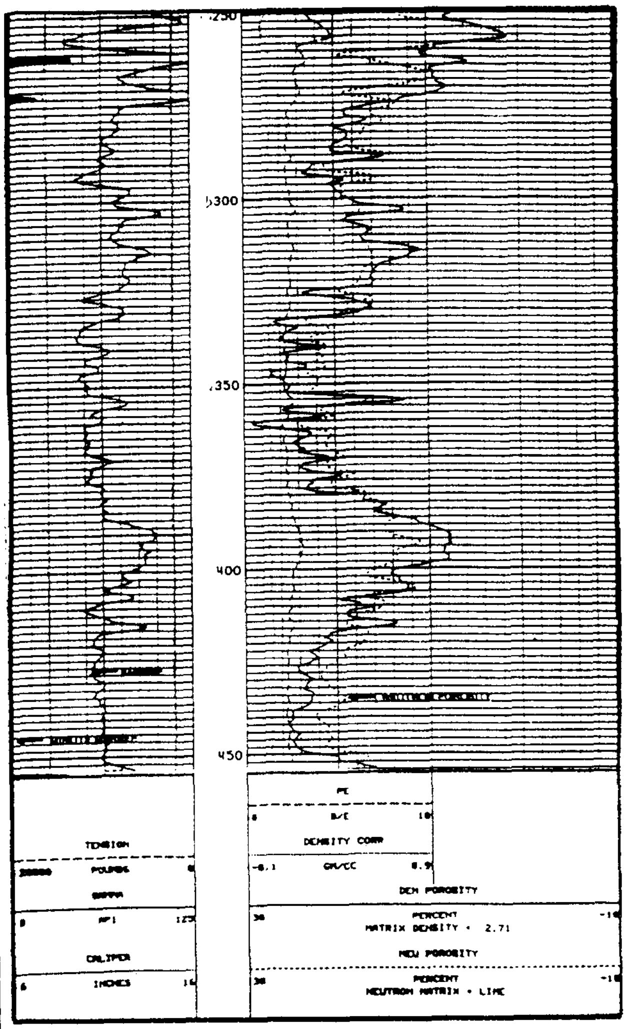

Figure 6 - Porosity log

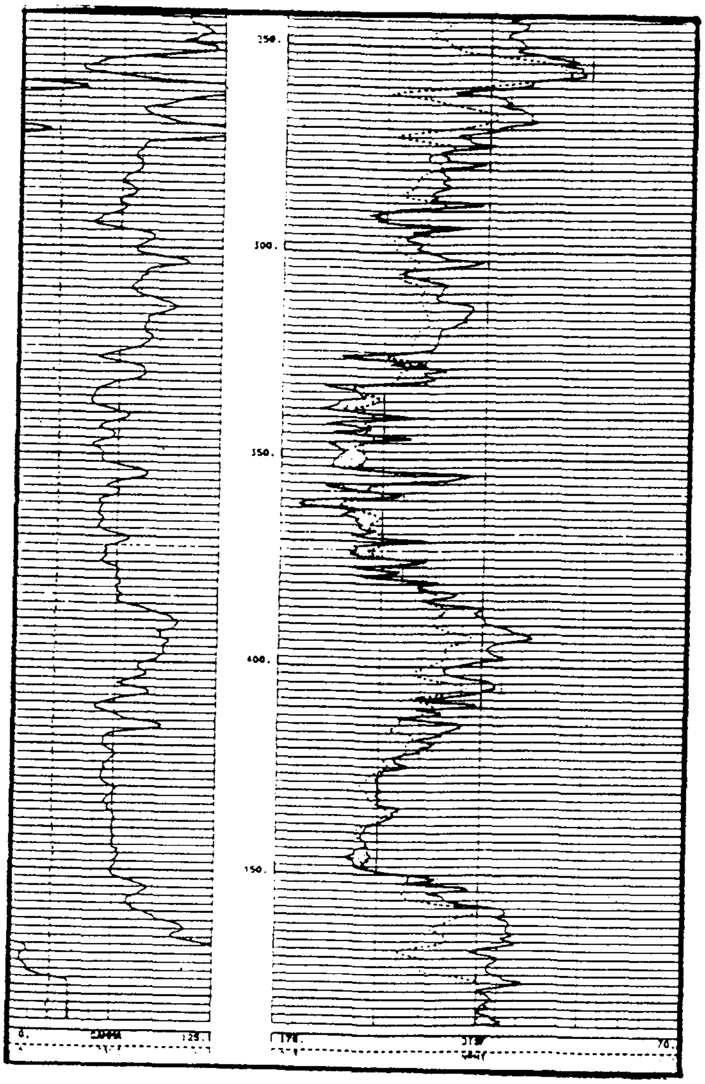

Figure 7 - Shear travel time and neutron porosity crossplot

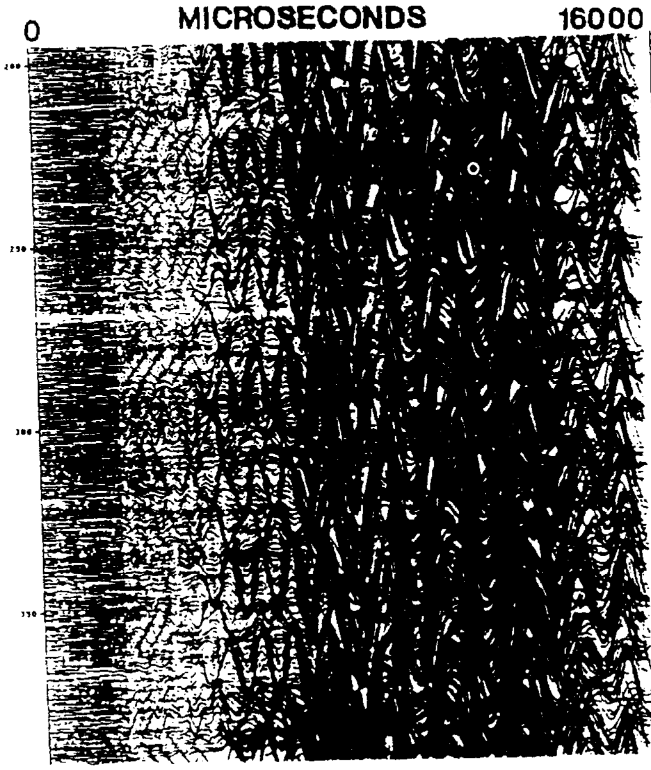

Figure 8 - Shear waveform plot

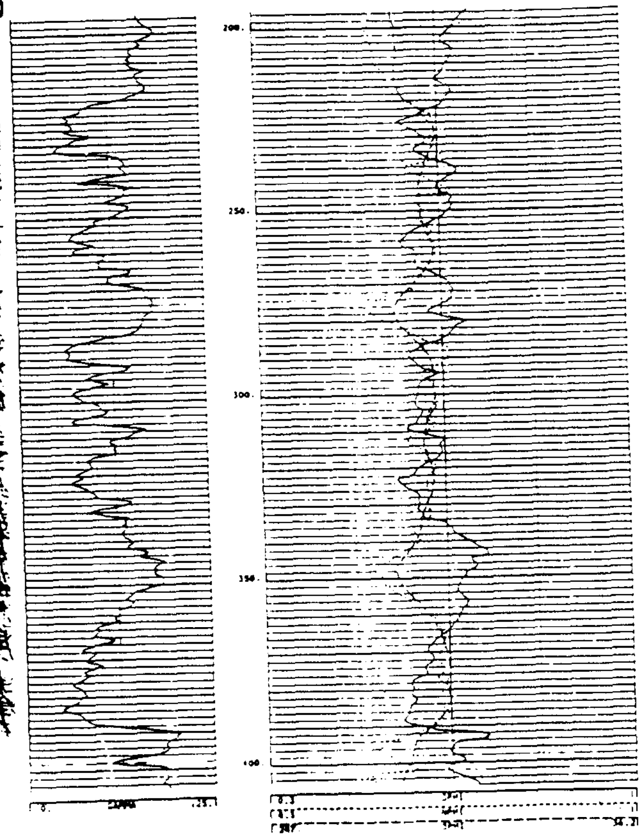

Figure 9 - Shear travel time, neutron and density crossplot