TECHNIQUES FOR HYDROCARBON DETECTION USING DATA FROM THE FULL WAVE SONIC

Lee Sanders and Calvin Kessler
Halliburton Logging Services

ABSTRACT

Recent advances in the design of sonic logging tools and in the development of computer software have provided methods for the detection of hydrocarbons in porous formations. The detection of hydrocarbons is based on changes in the acoustical properties of the formation, such as compressive wave travel time, Tc, shear wave travèl time, Ts, attenuation of the acoustic energy, and changes in the frequency of the acoustic signal. The compressive and shear wave travel time to the compressive wave travel time is termed the velocity ratio.

Extensive prior research has demonstrated that each rock type has a fairly specific velocity ratio. However, when compressible fluids occupy a portion of the pore space in the rock, the compressive wave travel time increases, which results in a lower than expected velocity ratio for a given lithology.

One of the limitations of using the velocity ratio as a method for detection of compressible hydrocarbons is that the lithology must be known. Interpretation methods have been developed which combine the velocity ratio and Photoelectric absorption index, Pe. This technique enables the velocity ratio to be used for the detection of hydrocarbons in formations where there may be changes in the lithology. The velocity ratio has been compared to a synthetic velocity ratio which is calculated from the volumetric fractions of the various lithologies present in the formation. This method has been used successfully in formations composed of a mixture of many lithologies. Several log examples will be presented that show these techniques have been successful for the detection of hydrocarbons.

INTRODUCTION

Research has shown the correlation between velocity anomalies and the occurrence of hydrocarbons. The velocity of the compressive wave is sensitive to the compressibility of fluids saturating a formation. As gas saturation increases the compressive wave velocity is reduced. This reduction in the velocity is due to the absorption of the acoustic energy by the gas saturated zones. The shear wave does not appear to be influenced by the gas saturated zones. The ratio of the compressive wave velocity to the shear wave velocity is defined as the Vp/Vs ratio.

Each rock type has a fairly specific Vp/Vs ratio.

Rock Type		Vp/Vs Ratio
· Limestone	-	1.9
· Dolomite	-	1.8
· Sandstone	-	1.7

In a hydrocarbon bearing zone the formation will have a lower than expected velocity ratio for each of the given rock types. Figure 1 shows a limestone. Because of hole problems, casing was set and a a Full Wave Sonic was run to evaluate the zone. Low Vp/Vs ratios for the limestone were perforated for production. Although the well in Figure 1 was successful, it illustrates the fundamental limitation to using only the Vp/Vs ratio. The limitation is that the rock type must be known and it will be presumed that the rock type remains homogeneous over the interval of the Vp/Vs ratio evaluation.

The following examples show how to resolve these limitations by coupling the Vp/Vs with well log defined lithologies.

TEXT

Example 1. Velocity Ratio/Pe Curve Overlay
This technique uses a velocity ratio overlay with the photoelectric values to show that Vp/Vs ratio anomalies are due to either hydrocarbons or lithology changes. Photo electric absorption values measured by the SDL provide a direct indication of the lithology and these values are unaffected by hydrocarbon bearing zones. By overlaying the velocity ratio to the Pe curve, the corresponding reduction in Vp/Vs can be attributed to either hydrocarbons or lithologic variations.

Figure 2 is a section of Permian aged dolomite. The formation in this area produces from natural fractures. This particular well had no hydrocarbon shows or drilling breaks through the section. However, by overlaying the Vp/Vs ratio to the Pe curve there are several zones of interest. Casing was set and the well was perforated at the Vp/Vs anomalies for the production noted on the Figure 2.

Example 2. FWS Vp/Vs and Synthetic Vp/Vs
This technique compares two sets of data for the detection of hydrocarbons. First, a synthetic Vp/Vs is compared to the Vp/Vs generated from the Full Wave Sonic. The synthetic Vp/Vs is calculated from the volumetric fractions of the various lithologies present in the formation. If lower FWS Vp/Vs are measured compared to the synthetic Vp/Vs, this zone is of potential interest.

A second set of data is an overlay of the neutron-density porosity and the neutron-acoustic porosity. Since the neutron-acoustic porosity is sensitive to the shale in the formation, the neutron-acoustic porosity will have a larger porosity value than the neutron-density porosity if the zone is shaly. If the neutron-acoustic porosity is less than the neutron-density porosity, then either secondary porosity, or gas or both are present.

Therefore, if a zone shows

1) a FWS Vp/Vs value is less than the Synthetic Vp/Vs **value and**

2) neutron-acoustic porosity is less than neutron-density porosity then the zone becomes a target for the production of hydrocarbons.

Figure 3 shows an interval of Devonian dolomite. Although the conventional Lithcal log did not show much promise (nor did sample shows) a zone of interest was detected from 8445' to 8459'. This zone was perforated in the interval for the production noted on the Figure 3.

Example 3. Vp/Vs Ratio and Compensated Spectral Natural Gamma

In the cased hole environment a comparison of Vp/Vs ratio to the components of the CSNG log provides a technique for the detection of hydrocarbons. This technique distinguishes between anonomously low Vp/Vs ratios associated with shaly formations from anonomously low Vp/Vs ratios associated with radioactive carbonates. A low Vp/Vs ratio associated with a high thorium zone would mean that Vp/Vs is reflecting a shaly zone. On the other hand, a low Vp/Vs ratio corresponding to a high uranium value would indicate a zone of interest.

Figure 4 shows an interval of Permian aged dolomites and shales in a cased hole. The low Vp/Vs ratio and higher uranium enriched zones were perforated. The production results are noted on the Figure 4.

Risks Using Techniques

The main risk in using the techniques involves missing a productive interval because of the insensitivity of Vp/Vs to a gas saturated zone. The one case reported to be productive but showed no Vp/Vs anomaly was the Bone Springs limestone. The reason for this absence of the hydrocarbon effect may be due to the pore aspect ratio. The pore aspect ratio describes the geometric configuration of pore spaces by comparing the width of an ellipsoidal pore to the length of the pore. Round or spherical pores would have large aspect ratios (i.e. 1) while thin pores would have small aspect ratios. Laboratory tests show that pores with ratio of .1 or less show the greatest sensitivity to gas saturation meaning that Vp/Vs would be more sensitive gas saturation with pores of small aspect ratios. In addition, the presence of microfractures in the rock should contribute to a more sensitive Vp/Vs response to gas saturation.

CONCLUSIONS

The tools and techniques can be applied

1) open hole or cased holes,

2) new wells or old wells

3) Vp/Vs can be used as a single parameter for evaluation or can be run in addition to other porosity tools, and

4) these techniques offer a means to evaluate rocks for hydrocarbons independent of conventional water saturation analysis.

REFERENCES

Pickett, G.R., "Acoustic Character Logs and Their Application in Formation Evaluation", J. Petroleum Technology, p. 659-667, 1963.

Kithas, W.A., "Lithology, Gas Detection and Rock Properties from Acoustic Logging Systems", Paper R, SPWLA, 1976.

Eastwood, R.L. and Castagna, J.P.", Basis for Interpretation of Vp/Vs Ratios in Complex Lithologies", Paper G, SPWLA, 1983.

Kessler, C., and Sanders, R.L., "Cased Hole Hydrocarbon Detection in the Permian Basin using the Full Wave Sonic Tool", paper 19610, SPE, 1989.

Georgi, D.T., Heavysege, R.G., Chen S.T., Eriksen, E.A., "Application of Shear and Compressional Transit-Time Data to Cased Hole Carbonate Reservoir Evaluation", Paper L, CWLS, 1989.

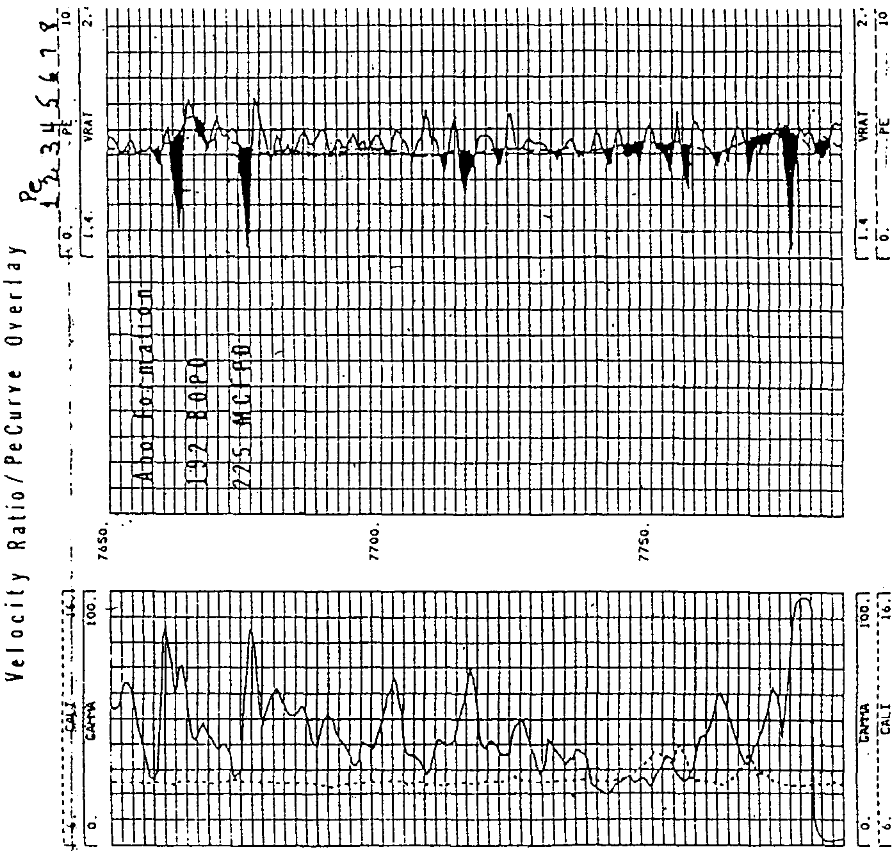

Figure 2

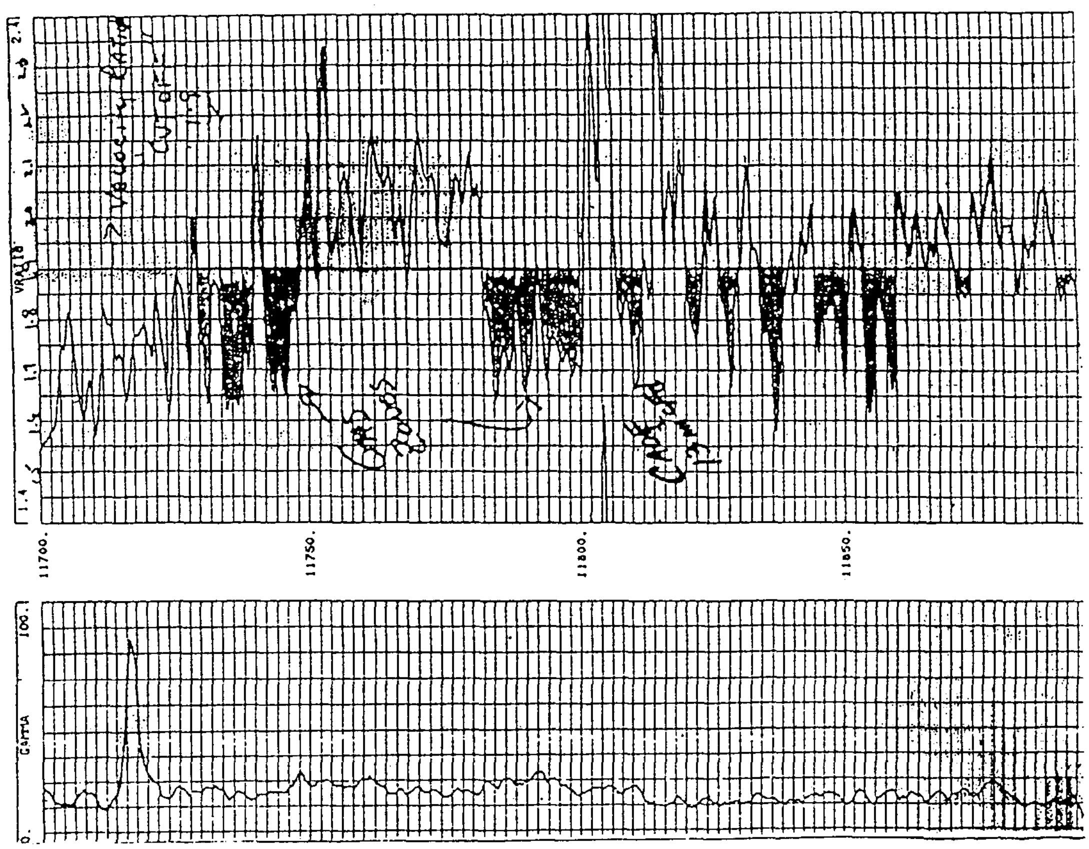

Figure 1

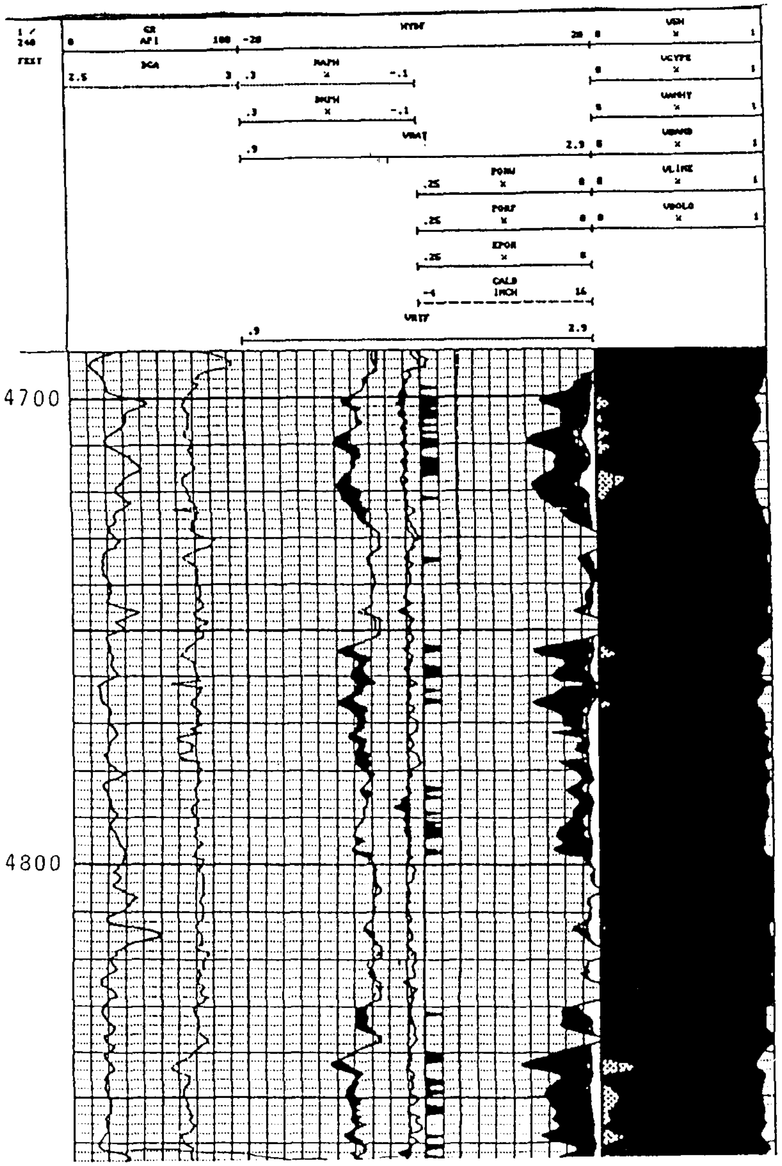

Figure 3

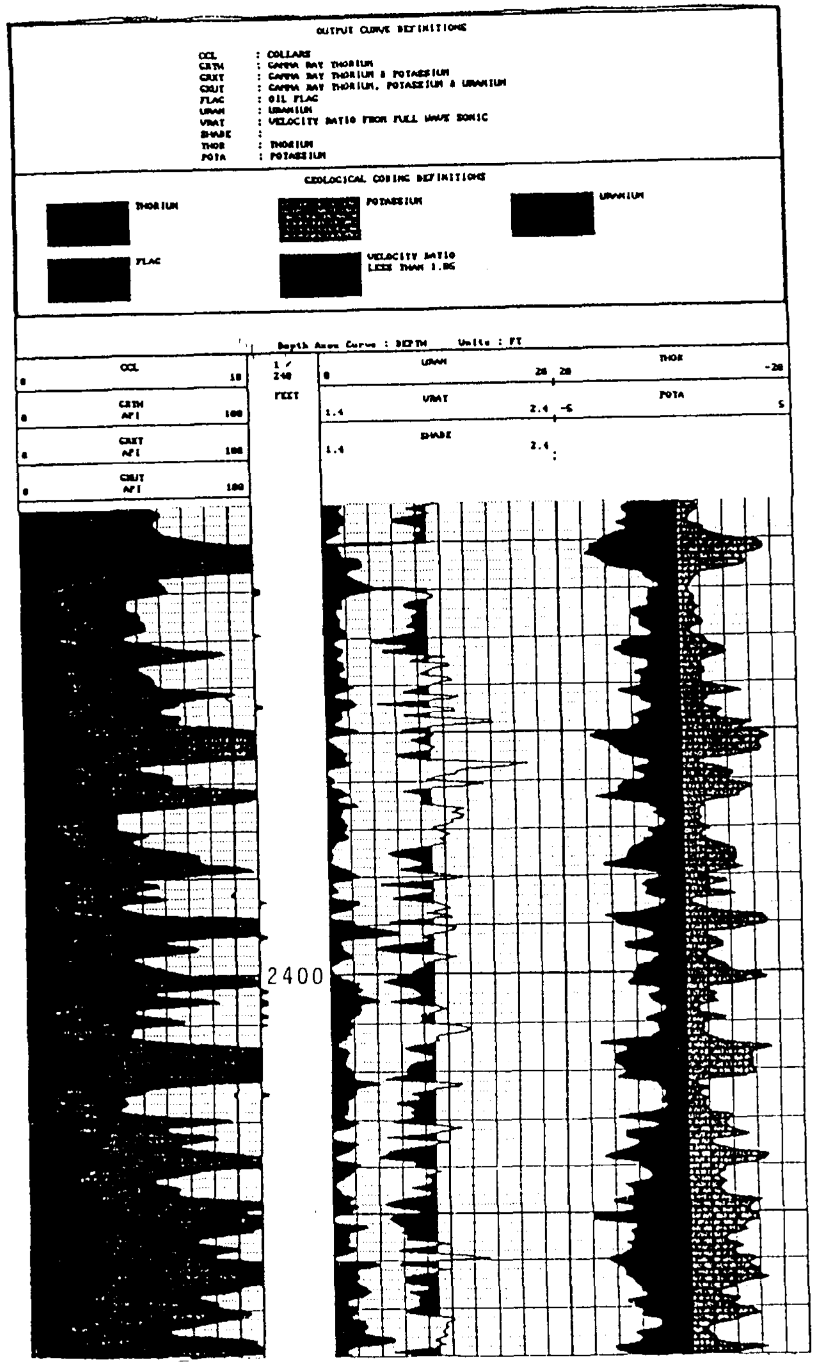

Figure 4