SONIC LOG APPLICATIONS
- EASTERN VENEZUELA

W.F. Clarke

Summary

A large amount of work has recently been done on the measurement of acoustic velocities in porous media and the various factors affecting these velocities. The results of these studies have been applied to actual field sonic measurements with good results. A greater amount of field data is still needed, however, to evaluate the sonic log as a porosity and/or hydrocarbon indicator.

The following discussion presents the general theory based on published works on acoustic measurements in the laboratory. Applications of the above are then given to specific sonic borehole measurements in Eastern Venezuela.

Introduction and General Theory

Acoustic velocities through a lithologic medium adjacent to the borehole are dependent on the properties of the rock, its permeating fluid, and the differential pressure to which the rock is subjected.

Rock System - The theory of wave propagation through an heterogeneous elastic medium is a complex one which involves the elastic constants both of the rock matrix and its saturating fluid. However, as the rock system comes under pressure, it is possible to apply a ray path relationship and arrive at a time-average equation which gives satisfactory results at the lower porosities.

\[
\Delta T_{\text{system}} = \phi \Delta T_{\text{liquid}} + (1 - \phi) \Delta T_{\text{matrix}}
\]  

(Equation 1)

The time-average equation by-passes the elastic constants of the system and a complex system of non-linear equations. Thus, the variable incremental-time varies linearly within limits. These empiric limits, although not well defined, are generally that, (a) the porosity factor, \( \phi \), should be low (<30%), and (b) the system should be subjected to moderate to high pressures. Within these limits, Equation 1 satisfactorily defines the porosity-incremental-time relationship for heterogeneous sandstones and shales.

The rock matrix term, \( \Delta T_{\text{m}} \), accounts for the elastic properties of the individual grains and the arrangement of the grains in the rock. Thus, for a particular lithologic unit (e.g., a clean quartz sandstone, \( \Delta T_{d_0} = 50 \mu s \)) the \((1 - \phi) \Delta T_{m}\) term is dependent on the porosity factor, \((1 - \phi)\). This presupposes, of course, that there is no significant change in rock structure, \( \Delta T_{m} \), with porosity change.

Shaliness, which gives an increase in \( \Delta T_{m} \), must be adjusted before a true porosity can be determined from \( \Delta T_{\text{log}} \). This is accomplished by the application of a correction based on the SP of the sand under investigation (Equation 2).

\[
\text{True Porosity} = \phi \log \left( \frac{2}{2 - \alpha} \right)
\]  

(Equation 2)

The effect of the permeating fluid in the rock \( \Delta T_{L} \), is dependent on the overburden pressure. At shallow depths, where overburden pressure is not great, and at moderate to high porosities, a distinct velocity change in \( \Delta T_{L} \), is discernible on the sonic log in sandstones saturated with hydrocarbons (Figure 2). The fluid incremental-time change would be from 200 (\( \Delta T_{H2O} \)) to 230 microseconds (\( \Delta T_{oil} \)). A more pronounced incremental-time change, sometimes accompanied by signal attenuation (i.e., skipped cycles) would occur in gas sands (\( \Delta T_{methane} = 650 \mu s\)-atmospheric conditions). However, care must be used in the interpretation of high incremental times, as lignites...