A Method for Calculating Pseudo Sonics from E-Logs in a Clastic Geologic Setting

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ABSTRACT

Sonic (DT) logs used for synthetic seismogram (SS) calculation are often not available when needed. The interpreter must rely on a pseudo-sonic (DTP) derived from other log curves to generate the SS. It is the purpose of this study to identify methods and practices that are accessible to working geoscientists for solving this problem.

A cross-plot analysis of Gulf Coast onshore logs was performed in order to examine the relationship between the DT log and resistivity curves (RS) and to identify the proper choice of RS curve to use for creating a DTP. A method to quantify the DT/RS relationship for a geologically similar area was established which may be applied to wells that do not have DT curves or to fill gaps in partial DT logs.

It was shown that the DT/RS relationship varies with RS log type, location, depth, lithology and formation age. With this relationship determined, an accurate DTP from RS log can be computed using a depth and lithology dependent scale function.

INTRODUCTION

Several methods for creating pseudo-sonic (DTP) logs have been proposed. The technique derived by Faust et al. (1951) is available in most exploration software systems and is suitable for many areas.

Investigations by Rudman et al. (1975) and Kim (1964) explore the cross-plot method and offer suggestions for improvement. Wyllie et al. (1958) developed several algorithms that are useful.

Integration (summing the sonic [DT] values) of the sonic log is fundamental to the calculation of the synthetic seismogram (SS); therefore, it is essential that the sonic log be accurate. The integrated sonic log (DT or DTP) determines the time/depth relationship of the SS and the character of the synthetic reflections. The density log is also used in calculating the SS but makes a much smaller contribution (Hilterman, 2001).

Integration errors in the sonic are cumulative. An improper reflection phase will result from an inaccurate velocity calculation causing poor correlation between the SS and seismic data.

The determination of which resistivity (RS) curve (SFL or ILD) is appropriate for DTP calculation is currently an unresolved issue. One view is that the RS measurements in shallow investigation logs (SN, SFL) are susceptible to distortion due to formation invasion by drilling fluids. Faust et al. (1951) and Rudman et al. (1975) use the short normal log (SN) as the source data. Burch (2002) uses the ILD as a conductivity log.

Log 1 is a Gulf Coast onshore sonic log recorded in 1983. The log is a Dual Induction-SFL-Sonic. Curves of interest are: DT, SFL, ILD and SP. The interval from 9200-10,000 ft is a porous, wet sand with shale laminae. By inspection, it is noted that the SFL curve is in close correlation to the DT curve. The ILD, by contrast, diverges from the SFL and DT in wet sands.

The depth of investigation of the ILD is such that it measures the conductivity of a large volume of salt water in the porous sand causing a sharp decrease in the resistivity value recorded. The SFL measures a much smaller formation interval similar to that measured by the DT (16 inch SFL / 24 inch DT). This accounts for the good

Smith, J. H., 2007, A method for calculating pseudo sonics from e-logs in a clastic geologic setting: Gulf Coast Association of Geological Societies Transactions, v. 57, p. ##-##.

character correlation between these curves. Even in shale zones, the SFL curve character is more similar to the DT than is the ILD.

This phenomenon is widely observed in Tertiary zones of the Gulf Coast region and is the basis for using the SFL log for DTP computation in this area.

CROSS-PLOT TECHNIQUE

Cross-plots between RS and DT in a pilot well will determine a depth varying scale function between the two logs. This scale function may then be applied to wells where no DT is present to calculate a DTP from RS.

The cross-plot is the average resistivity value associated with each DT value that occurs in a specified depth interval. The data points are displayed on a semi-log graph resulting in a statistical view of the DT/RS relationship in the depth interval.

A least mean square (LMS) fit to the distribution of values will define a scale function relating the RS to DT.

By using a depth window of approximately 500 ft and moving the window down the pilot log, a depth varying view of the DT/RS relationship can be observed and scale functions calculated at appropriate intervals. These scale functions can be applied to other RS logs to calculate the DTP.

It is also informative to differentiate the cross-plot by referencing a lithology log at each DT/RS data point to indicate if the value is from sand or shale. In this manner, scale function differences due to lithology may be considered.

Figures 1 and 2 illustrate cross-plots between DT to SFL, and DT to ILD, respectively.

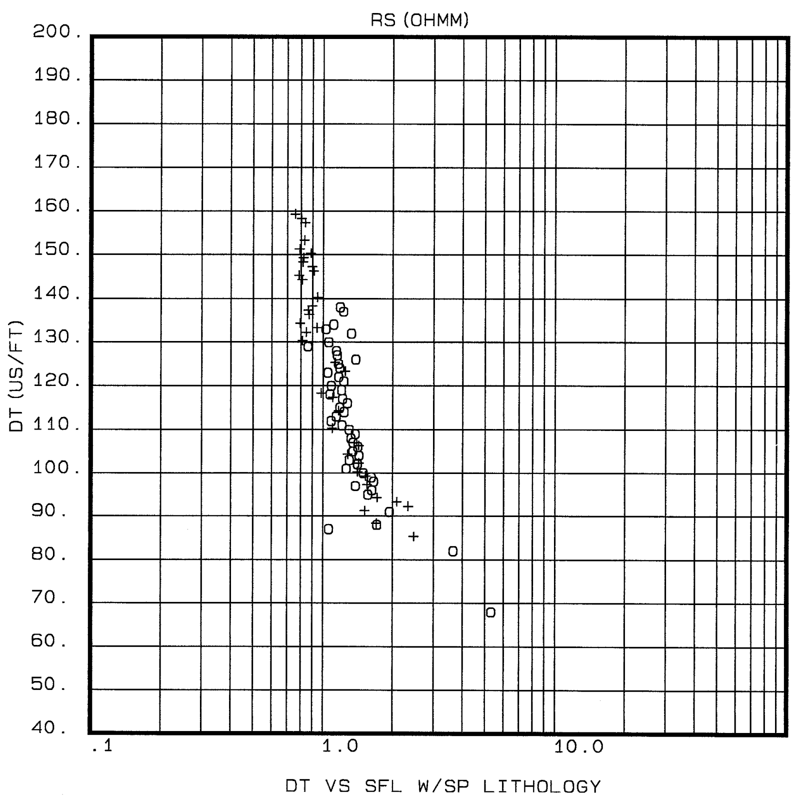

Figure 1. Cross-plot of DT to SFL over 1,000 ft of Miocene sand/shale section in Matagorda County, Texas. Circles (o) represent values in sand, plus (+) are values in shale. This type of distribution can be converted into an accurate scale function.

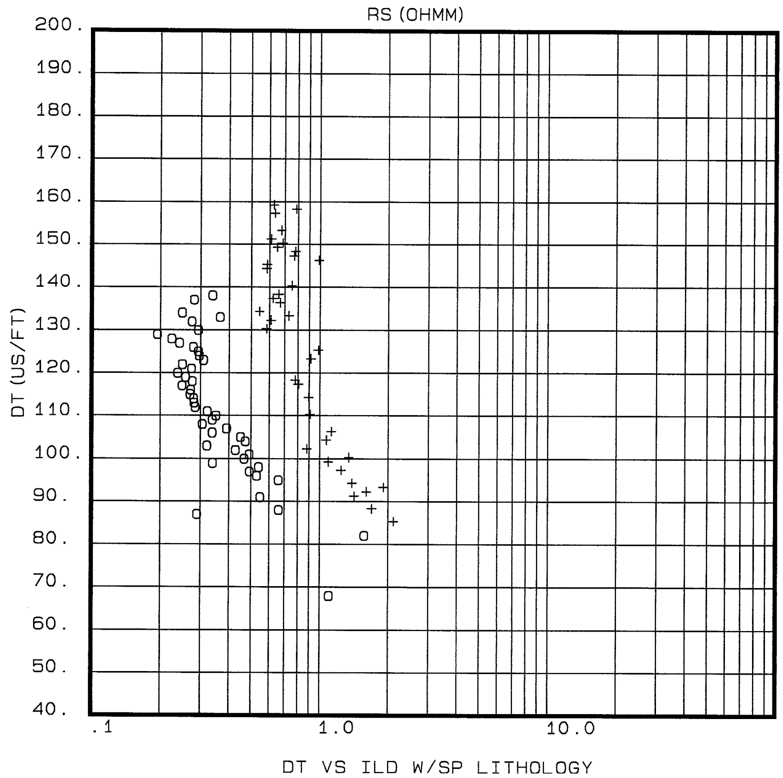

Figure 2. Cross-plot of DT to ILD over the same interval as Figure 1. Circles (o) represent values in sand, plus (+) are values in shale. The bifurcation of the sand values from shale values indicate that a single scale function cannot be derived from these data.

DATA ANALYSIS

For this study DTP logs were generated for each well using three methods: Faust algorithm, LMS depth varying, and LMS depth varying with lithology reference.

In the Faust cases, SFL and ILD logs were used and the results compared to the actual DT.

In the LMS cases, SFL logs were used and were compared to Faust and the actual DT.

Comparisons of the results were made by calculating a SS with each DTP log and plotting the resulting time/depth function (T/D) with that yielded by the DT log for the same well.

The results were further evaluated by applying an LMS scale function from a pilot well to a nearby well using the SFL to calculate a DTP. The DTP calculated was compared to the DT for the well.

SUMMARY AND CONCULSIONS

A comparison of the DTP derived from the LMS technique was made with that obtained from the Faust algorithm and to actual DT logs. Shallow (SFL) and deep (ILD) resistivity logs were compared for accuracy in DTP computation for several wells in the Gulf Coast region.

It was observed that the Faust algorithm using the SFL yielded good results in all areas considered. Faust using SFL was within 0.5-2.0% of the actual DT in most cases. Faust using the ILD yielded 7.0-9.0% error. Using the ILD log also caused reflection polarity errors at sand boundaries. The ILD curve should not be used for DTP calculation in areas with a significant presence of high porosity sand.

For all methods considered error ranges were from –2.0% to +9.0% varying with RS log type, depth and type of section.

The LMS method was more accurate in geologic settings where velocity change with depth may be abrupt such as Miocene and Frio sand intervals or the Wilcox. This method was typically within 1.0% of the actual DT.

The LMS method with lithology detection was superior to the others tested and yielded results that are within 0.5% of the actual DT log. If modeling or amplitude versus offset (AVO) analysis is a planned use of the DTP this method should be considered.

All cases examined were non-hydrocarbon bearing. Pay sand velocities may be computed manually, typically by applying the Wyllie algorithm (Wyllie et al., 1958) to a nearby wet sand.

ACKNOWLEDGMENTS

Texas logs were acquired from the University of Texas/BEG Geophysical Log Facility, University Station, Box X, Austin, Texas 78713-8924.

Louisiana logs were acquired from the Louisiana Department of Conservation, SONRIS Database Facility, 617 N. Third Street, Baton Rouge, Louisiana 70802.

Cross-plot, synthetic seismogram and other log analysis software used are proprietary products of Petrophysics, Inc., and may not be duplicated without permission.

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