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TALANG AKAR (OLIGOCENE)SOURCE ROCK IDENTIFICATION FROM WIRELINE LOGS - APPLICATIONS IN THE DEEP ARDJUNA BASIN, OFFSHORE NORTHWEST JAVA

B.Sukamto*
B.Siboro*
T.D.Lawrence*
S.W.Sinclair**

*** ARCO Indonesia, Jakarta**
**** AIOGC, Plano, Texas**

ABSTRACT

Coal and organic rich shale of the Talang Akar Formation in the Deep Ardjuna Basin of Indonesia can be identified using a conventional suite of wireline logs. The method employed in this study is based on the calibration of well log data with core data from several wells in order to estimate the amount of Total Organic Carbon (TOC) along with the corresponding Hydrogen Index (HI) values. Based on the TOC and HI values, which are estimated from well logs, it is possible to indicate the presence or absence of good quality source rocks, to differentiate oil prone from gas prone shales or coals, and to calculate the respective thicknesses of each.

This technique involves a special multivariate non-linear statistical regression method developed internally using density, sonic, neutron, and resistivity log measurements versus core data. The current computer programs are written in FORTRAN as user programs that run on the PETCOM PC log analysis system but can easily be ported to other computer platforms. Coefficients of independent variables have been determined that allow the TOC and HI values to be estimated on other wells in the Ardjuna Basin.

Source rock identification in approximately 61 wells in the Ardjuna basin and the surrounding area have been obtained by using these programs. The results of this work, such as : net source rock thicknesses of shales or coals maps, oil or gas prone shale/coal maps, initial TOC, initial HI maps of each source interval, etc. can be used to better evaluate charge analyses and to improve prospect appraisals.

INTRODUCTION

Source rocks are commonly shales and lime-mudstones that contain significant amounts of organic matter. Non-source rocks also contain organic matter, but the amount is generally not significant (i.e. less than 1 wt. %).

Organic-rich rocks are assumed to be composed of three components: (1) the rock matrix, (2) the solid organic matter, and (3) the fluids filling the pore space. Non-source rocks are composed primarily of only two components: the matrix and the fluids filling the pore space (Figure 1A). In immature source rocks, solid organic matter and rock matrix comprise the solid fraction, and formation water fills the pore space (Figure 1B). As the source rock matures, a portion of the solid organic matter is transformed to liquid hydrocarbons which move into the pore space, displacing the formation water (Figure 1C). This is the general model used by Meyer and Nederlof (1984).

The log response of a source rock can normally be predicted from its petrophysical properties, such as its natural radioactivity, resistivity, bulk density, neutron hydrogen index and acoustic travel time. For example, organic rich sediments can be relatively high in radioactive content, and thus can have higher gamma ray readings than ordinary shales. As organic carbon is electrically less conductive, high TOC contents can increase the resistivity of the host rock compared to the same rock deficient of TOC. The presence of hydrocarbon in the rocks usually yields higher readings on resistivity logs. The travel times of acoustic waves may be increased by kerogen, depending on the composition and nature of the organic matter. Cross plotting density versus TOC indicates that organic rich sediments generally have lower density than lean sediments. Density readings alone, however, may not be a reliable indication of organic matter in the presence of rugose or bad hole conditions. In these cases, acoustic travel times of sonic logs may be more reliable and were used instead of density readings. The neutron log of course is highly affected by the hydrogen index. By using a combination of several log types, it was possible to improve the estimation of both TOC and HI.

The source rocks in ONWJ area can be grouped into four stratigraphic intervals which from top to bottom are : the marine Talang Akar (MTAF), the deltaic Talang Akar (DTAF), the continental Talang Akar (CTAF), and the Jatibarang (JTB). These intervals have been chosen both on the basis of their interval context and also on their ease of recognition from seismic data for later mapping and volumetric calculation.

REGIONAL SETTING

The Ardjuna basin is located within the central part of the ONWJ PSC area (Figure 2), approximately 90 km northeast of Jakarta. This basin is one of a series of basins (Palembang, Sunda, Asri, etc.) on the southern edge of the Sunda craton that originated during a major Eocene-Oligocene period of extension.

The Ardjuna basin is a large sag basin located over on older rift containing three sub-basins (Northern, Central and Southern)(Figure 3). The Ardjuna basin, offshore covers an area of approximately 3000 km2 (100 km by 30 km or 740,000 acres). The sub-basins average 700 km2 and are composed of at least one half-graben system. The large half-graben of southern Ardjuna is the deepest, while the central Ardjuna is the widest and consists of numerous, smaller half-grabens. The northern sub-basin is primarily a single graben.

The stratigraphic succession in this basin ranges in age from Latest Eocene/Earliest Oligocene to the Holocene (Figure 4). Thickness of this interval ranges from 7700' in the southern rift to 0' on the flanking central Ardjuna shelf.

DATA BASE

The data base used in this project contains measurements of pyrolysis, TOC and visual kerogen description of Talang Akar formation from 28 wells and included 902 data points. A total of eight exploration wells (SH-1, OC-2, TY-1, XYZ-1, SF-1, SC-4, SD-1, and LS-1) with available core and sidewall data were initially selected for calibrating geochemical parameters such as total organic carbon (TOC) and hydrogen index (HI) as functions of petrophysical measurements. In order to do the calibration, the log and core data from the eight wells were combined together into one composite pseudo well. These original data formed the basis for calibration using 193 data points for TOC and 158 data points for HI. The relationships between TOC or HI with the log data were determined by a special non-linear multivariant regression method using computer programs developed in-house that run on the PETCOM computer log analysis system.

Following the original calibration and program results, additional data were obtained. The amount of TOC data points were increased from 193 to 409 while the number of HI data points were increased from 158 to 349. In order to do the subsequent calibration, the log and core data from the original eight wells were combined together with the additional data into another subsequent composite pseudo well. The relationships between TOC and HI with the log data were again determined by the same methods as described above (Figure 5).

LOG RESPONSES

Prior to incorporating multiple log responses into a calibration method for delineating source rocks, the individual log petrophysical characteristics of organic rich sediments within the Talang Akar formation were studied using standard cross plot techniques. The standard cross plots were initially used to determine the relationship between TOC & HI and individual log responses using standard linear regression equations. The logging measurements tested included gamma ray, resistivity, density, neutron and sonic logs. Figure 6 shows TOC cross-plotted against a.gamma ray, b.resistivity, c.neutron, d. density, and e.sonic while cross-plots HI against a. gamma ray, b. resistivity, c.neutron, d. density, and e.sonic can be seen in figure 7.

CALIBRATION PROGRAM METHOD

The computer method that was used to calibrate the source rock indicators to the log data was originally developed to automatically edit well logs, fill in missing data and to generate pseudo curves. This method uses two steps in the overall process. The first computer program, ACECAL (Automatic Curve Editing and Calibration), was used to perform the calibration while a second program , ACEGEN (Automatic Curve Editing and Generation), was used to apply the calibration coefficients to generate TOC and HI.

Step 1: ACECAL (Automatic Curve Editing and Calibration)

The ACECAL program calibrates three input curves to a fourth input reference curve such as TOC or HI to determine coefficients that can be applied to the three input curves for generating a pseudo curve equivalent to TOC or HI using step 2. A core data reference curve, either TOC or HI, was selected for calibration. Three other log curves that were expected to have some reasonable correlation to the reference curve were then chosen for calibration to the reference curve. The program ACECAL calculated the coefficients that best fit the correlation curves to the reference curve using a special non linear multiple regression technique.

Step 2: ACEGEN (Automatic Curve Editing and Generation)

The ACEGEN program applies the coefficients previously determined from ACECAL to the three input curves to create pseudo curve of TOC or HI.

CALIBRATION RESULTS

Based on the correlation coefficients of each logging device. the gamma ray was eliminated (correlation coefficient 0,38) and resistivity (RT), density (RHOB) and neutron (NPHIDEC in decimal) were chosen as the main three indicators with the sonic (DT) being substituted for the density in bad hole or washed out intervals. The logarithm of RT (LOGRT) was later selected in lieu of RT in order to yield a better correlation.

Four sets of calibration coefficients were obtained. The first two sets used the LOGRT, RHOB and NPHIDEC curves to estimate TOC and HI respectively, while the last two optional sets substituted DT for RHOB in cases where bad hole conditions caused problems with the density log.

Figure 8 shows the pseudo well with the comparison between the actual TOC and HI data versus the values calculated from the LOGRT, RHOB and NPHIDEC well log curves. The computed TOC curve is labeled TOCRDNT (for TOC computed from the resistivity, density and neutron using the total data), while the computed HI curve is named HIRDNT. The results obtained using the LOGRT, SONIC and NPHIDEC log curves is also shown in figure 8 for comparison. TOCRSNT is the TOC computed from the resistivity, sonic and neutron logs, while the corresponding computed HI curve is labeled HIRSNT. Figure 9 and 10 show the core TOC and HI values, respectively, compared to the log generated estimates using the resistivity, density and neutron along with histograms and averages of each.

SOURCE ROCK COMPUTER PROGRAM

After obtaining the original calibration coefficients, a program was developed to apply those coefficients to other wells and to identify source rock potential using the calculated TOC and HI values. The program is called SOURCET and has been written as a PETCOM PC user program. In order to correct the present-day calculated TOC and HI values to the initial values, a program called KINETICT has also been developed along with a source rock quality grade indicator.

SOURCE ROCK PROGRAM PARAMETERS

The organic rich shale is identified as fine grain sediment clastics that have a TOC greater than two percent, an HI greater than 100 and clay volumes greater than fifty percent. Gas prone shales are distinguished from oil prone shales by selecting organic rich shales with an HI less than 300.

Source rock coal is identified as coals that had a TOC greater than 20 and an HI greater than 100. Gas prone coals are distinguished from oil prone coals by selecting source rock coals with an HI less than 300.

The caliper is used as a discriminator curve to substitute the sonic for the density in bad hole areas.

SOURCE ROCK PROGRAM EXAMPLE PLOTS & MAPS

Typical source rock logs display for wells SH-1, and KLS-1 can be seen in figures 11, and 12. Coal prone source and shale prone source rock flags are located in the left side and right side of the depth track, respectively. The flags determined from present-day TOC and HI values are shown on the right hand side portion of each, while the flags determined from the initial TOC and HI values are plotted on the left hand portion.

Track 1 consists of lithology types, porosity, water volume and a bad hole indicator, while the resistivity curve is in track 2. The neutron porosity (in decimal), rhob, and sonic curves are in the track 3. Transformation ratio, formation temperature, source rock quality grade, initial TOC & HI, present-day TOC & HI are displayed in track 4.

Oil-prone coal isopach and initial TOC coal maps from R4-R5 interval in the Ardjuna basin can be seen in figure 13 and 14, respectively.

CONCLUSIONS

The application of multivariate non-linear regression analysis by using an in-house program "SOURCET" and "KINETICT" has lead to the following conclusions :

1. Resistivity, Density, Neutron porosity, and Sonic Transit Time rather than gamma ray have better correlations with TOC and HI. These petrophysical measurements were therefore chosen for calibration.

2. These programs are able to indicate the presence or absence of good source rock potential. The programs are also able to determine quantitatively the richness of the source rocks at the present day level (Present-day TOC) and

initial level (Initial TOC), to differentiate oil prone source rocks from gas prone source rocks.

3. More work is needed to fully take advantage of the possible benefits from this source rock identification method.

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