Linking Petrography And Petrophysical Analysis In Carbonate Reservoir Characterization: Case Study In Baturaja Formation Offshore Northwest Java

Nanda Natasia, Muhammad Kurnawan Alfadli, Kurnia Arfiansyah, Adi Hardiyono, Mohamad Nursiyam Barkah, Iyan Haryanto

Faculty of Engineering Geology – Padjadjaran University
Correspondence email : nanda.natasia@unpad.ac.id

Abstract

Linking geological analysis with petrophysical characterization in complex carbonate reservoir is a chalangging task. Many previous researcher has proofed that depositional facies in carbonate reservoir has very little advantages in reservoir quality due to overprinted with diagenetic facies. The difficulties in characterized the carbonate may rise because one does not include some genetic, geometrical and petrophysical character of the pore space, both geometry and distribution. The aim of this study is to evaluate the reservoir rock typing in carbonate reservoir by comparing rock-fabric descriptions analyzed in thin section with laboratory measurements of porosity, permeability, capillarity, and Archie m values. Methodology employed for this study involved the examination of thin sections and the integration of routine analysis data following lucia's pore classification scheme. The first step in characterized the petrophysical class is the determination of interparticle porosity by substracting the separate vug porosity from total porosity. The separate vug porosity is estimated in petrographic analysis in 325 thin section samples. Than estimating the value for un cored interval by determining the relationships between total porosity, separate vug porosity and sonic interval transit time. The petrographic analysis to estimating the separate vug porosity is a qualitative way, and so the value is not quantitative, but the trend is still implies the value so the relationships between porosity and sonic log can be quantified. Calibration of pore types to acoustic log response is accomplished by making a detailed log of porosity types described from thin sections and constructing Z-plots of total porosity and transit time from logs and separate-vug porosity from thin sections . The "m" value (lithology exponent or cementation factor) is different from the other terms in the Archie equation in that it is related to rock fabrics, specifically to vuggy porosity. Reservoir characterization by using this scheme has proofed that geological analysis made in detailed thin section can be a helpfull tool since the validation in tested and produced interval shows a verry good relationships.

Keywords : *Reservoir Characterization, Baturaja Fm., Carbonate, Petrophysics.*

INTRODUCTION

The Rock characterization of carbonate reservoir in this study was done by using the carbonate reservoir characterization purposed by Lucia F.J. (1995). The petrophysical classification of carbonate porosity presented by Lucia (1995) emphasized petrophysical aspects of carbonate pore space, as does the Archie classification. However, by comparing rock-fabric descriptions with laboratory measurements of porosity, permeability, capillarity, and Archie m values, Lucia (1995) showed

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that the most useful division of pore types for petrophysical purposes was of pore space between grains or crystals, called interparticle porosity, and all other pore space, called vuggy porosity. Three rock fabric groups define the three petrophysical classes. Figure 1 illustrates the relationship between rock fabric and petrophysical classes. Grainstones, dolograinstones, and large crystalline dolostones all have similar petrophysical properties that are characterized by petrophysical class 1. Grain-dominated packstones, fine and medium crystalline grain-dominated dolopackstones, and medium crystalline mud-dominated dolostones all have similar petrophysical properties that are characterized by petrophysical class 2. Mud-dominated limestones (mud-dominated packstone, wackestone, and mudstone) and fine crystalline mud-dominated dolostones all have similar petrophysical properties that are characterized by petrophysical class 3. The methodology that used in petrophysical class classification is based on the method purposed by Lucia. F.J. presented in his own book "carbonate reservoir characterization, second edition" Lucia (1995).

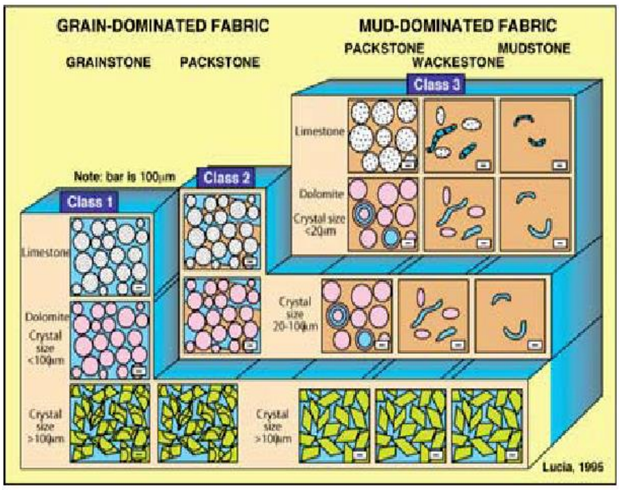
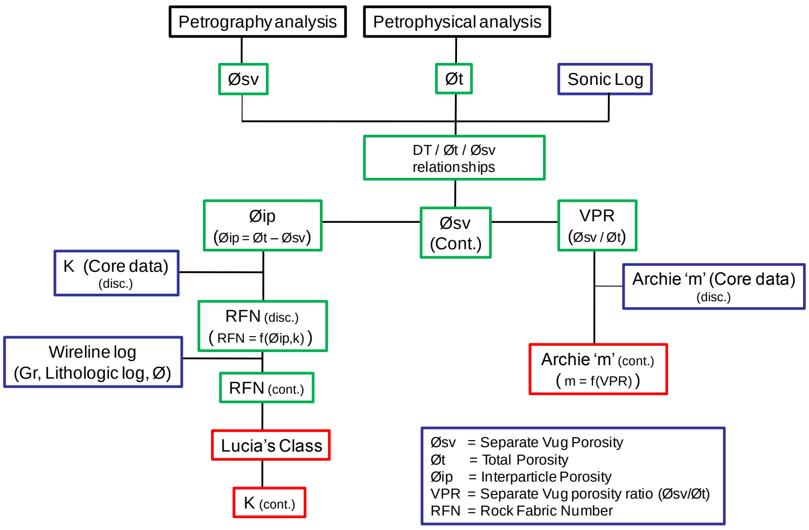


Figure 1. Petrophysical and rock fabric classes based on similar capillary properties and interparticle porosity/permeability transforms. Lucia (1995, 1999)

Diagram 1. Reservoir characterization flowchart, modified from Lucia (1995).



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Interparticle porosity determination

The first step in characterized the petrophysical class is the determination of interparticle porosity by substracting the separate vug porosity from total porosity. The separate vug porosity is estimated in petrographic analysis in 325 thin section samples. Than estimating the value for un cored interval by determining the relationships between total porosity, separate vug porosity and sonic interval transit time. The petrographic analysis to estimating the separate vug porosity is a qualitative way, and so the value is not quantitative, but the trend is still implies the value so the relationships between porosity and sonic log can be quatified.

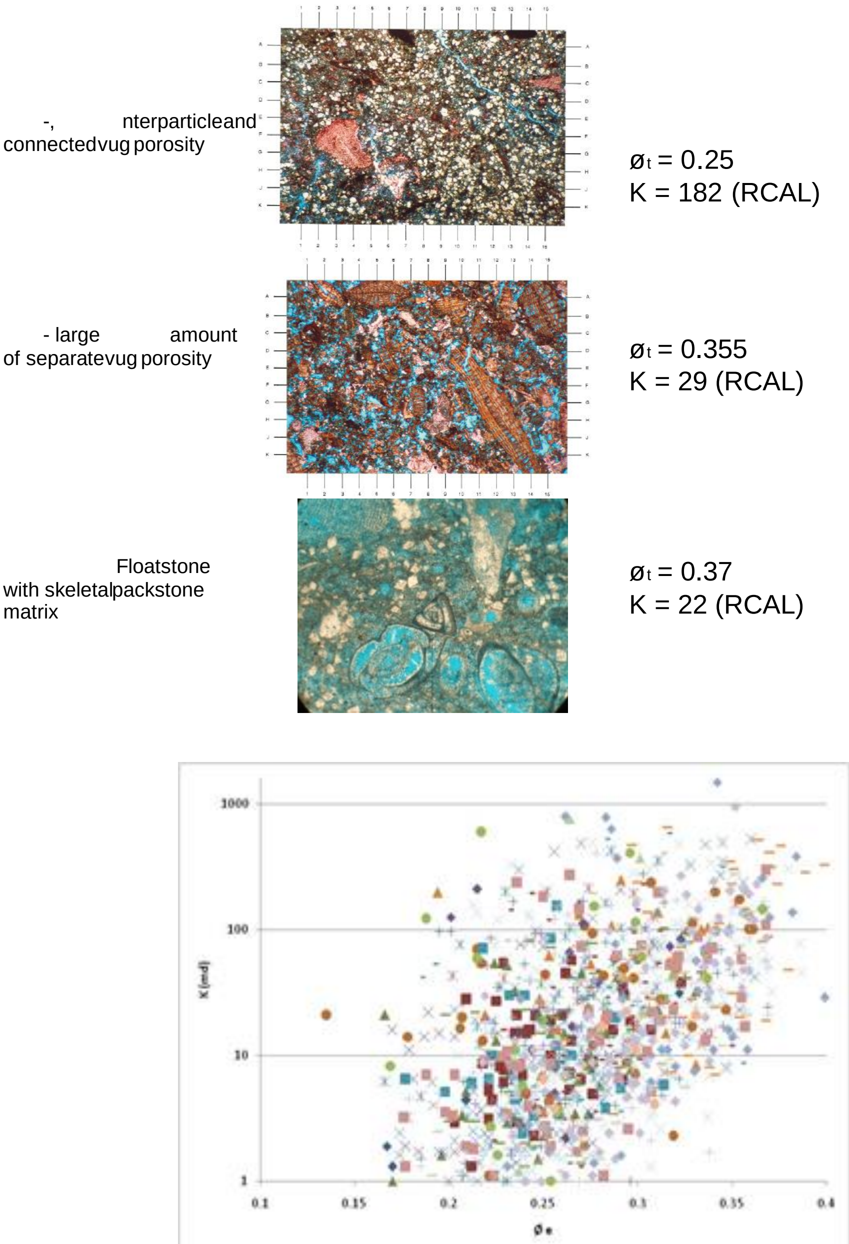

Figure.2 The porosity and permeability from several samples shows non correlative relationships due to the separate voug porosity.

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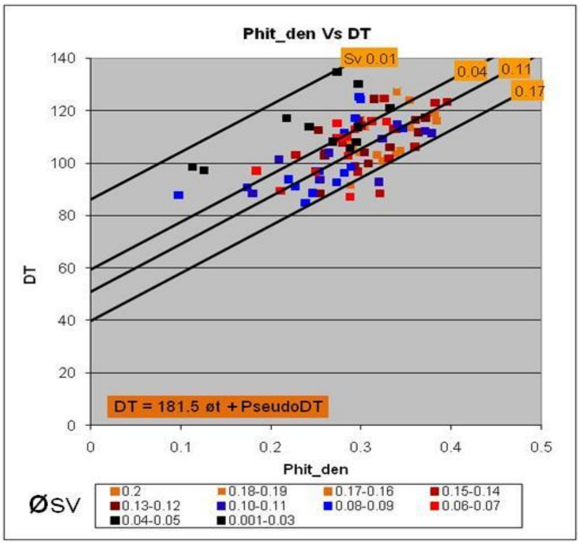
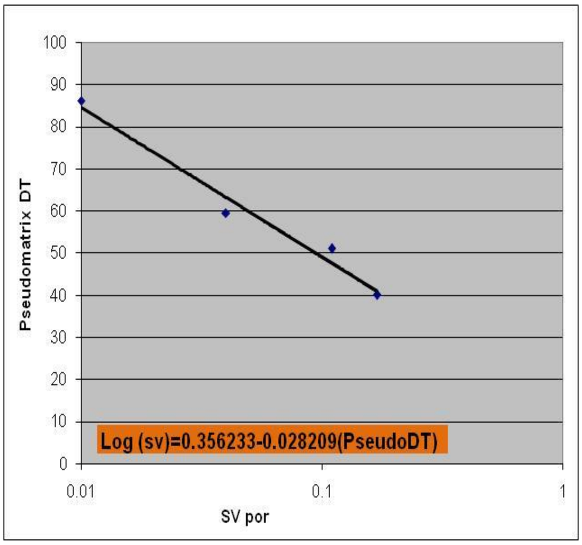


Figure 3. Crossplot off total porosity vs acoustic travel time. The lines distinguish separate vug porosity is drawn based on petrography analysis

Calibration of pore types to acoustic log response is accomplished by making a detailed log of porosity types described from thin sections and constructing Z-plots of total porosity and transit time from logs and separate-vug porosity from thin sections (Fig. 3). It is assumed that for constant separate-vug porosity a plot of transit time and porosity will have the same slope as the Wyllie time average plot. Lines of constant separate vug porosity can be constructed that are parallel to the Wyllie curve and extended to intersect the transit-time axis at zero porosity. The value at the intersection is normally the matrix transit time but here it is referred to as the pseudomatrix transit time.



Gambar 4. Plot of pseudomatrix DT vs Separate vug porosity shows that separate vug porosity has a Log linear relationships with pseudomatriks DT

The pseudomatrix transit time is plotted against the log of separate-vug porosity (Fig. 4). The pseudomatrix transit time can be expressed in terms of Dt and porosity resulting in a relationship between total porosity, transit time, and separate-vug porosity. After separate Vug porosity was estimated, the intrparticle porosity can be calculated by subtracting total porosity with separate vug porosity.

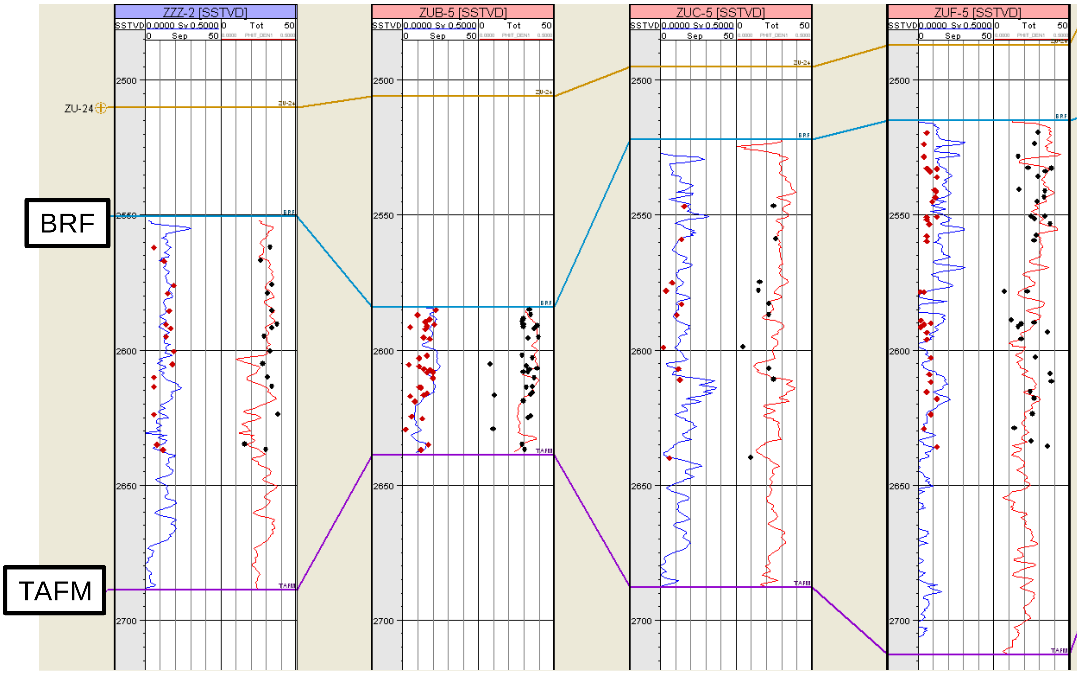
DT = 181.5 øt + PseudoDT ,

PseudoDT = DT - 181.5 øt , ------------------------- (Fig. 2)

Log(sv)=0.356233 -0.028209(PseudoDT) --- --------(Fig.3)

Log (sv)=0.356233 - 0.028209(DT – 181.5ø)

$$\boxed{Ø\ sv = 10^{0.356 - (0.028*(DT - 181.5\ ø))}}$$



Øsv From thin section analysis

Øsv Calculated from log

Øt From thin section analysis

Øt Calculated from log

Figure 5. Comparison between calculated Øsv Vs Thin section Analysis

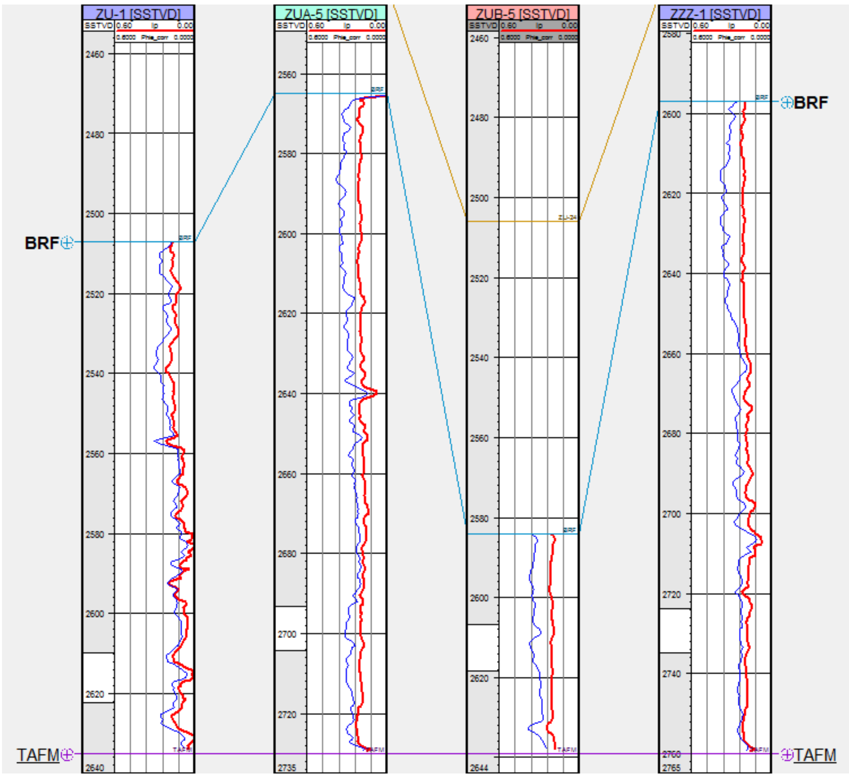
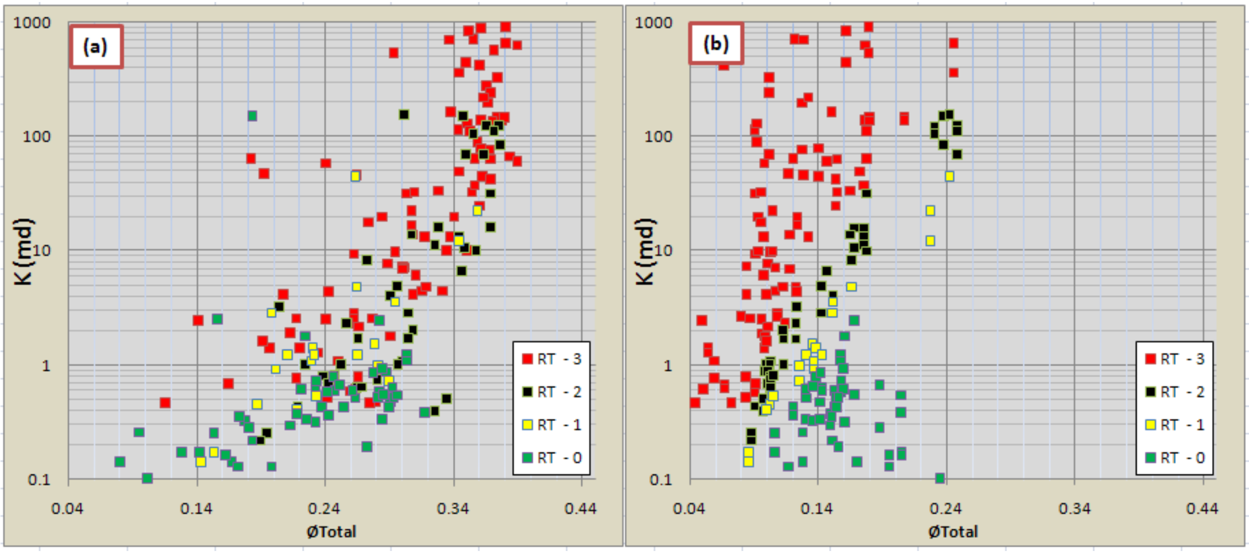


Figure 6. Comparison between total porosity with interparticle porosity

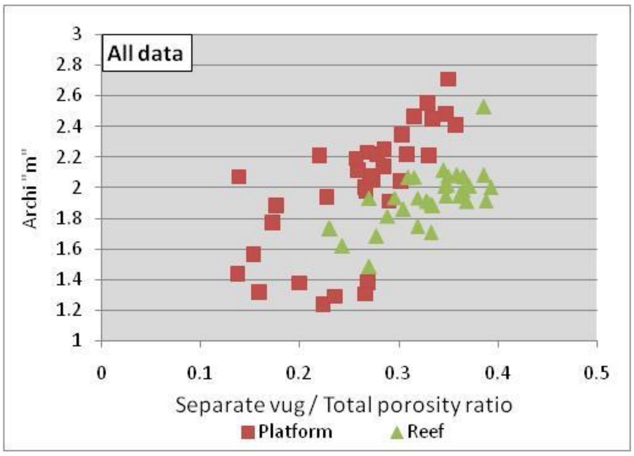


Gambar 7. Porosity – permeability cross plot from ZUF-5 limestone compared with three permeability fields purposed by lucia (1995). (a) using total porosity and permeability from RCAL data. (b) using interparticle porosity by subtracting total porosity with separate vug porosity calculated from acoustic travel time – total porosity relationships

Archie "m" value determination

The "m" value (lithology exponent or cementation factor) is different from the other terms in the Archie equation in that it is related to rock fabrics, specifically to vuggy porosity. Laboratory (Lucia, 1983) and borehole (Lucia and Conti, 1987) data have demonstrated that the "m" value is a function of the ratio of separate-vug porosity to total porosity, a ratio referred to as the vug porosity ratio (VPR). This ratio can be calculated using separate-vug porosity estimated from acoustic logs, and total porosity calculated from neutron and density logs.

SCAL data from eight wells shows the variation in archie 'm' factor in several well related to its depositional environment (reef and platform). This differentiation can be caused by the different process and cementation intensity between two environment. Conceptually, cementation will happen more intense at platformal area compared with reef.



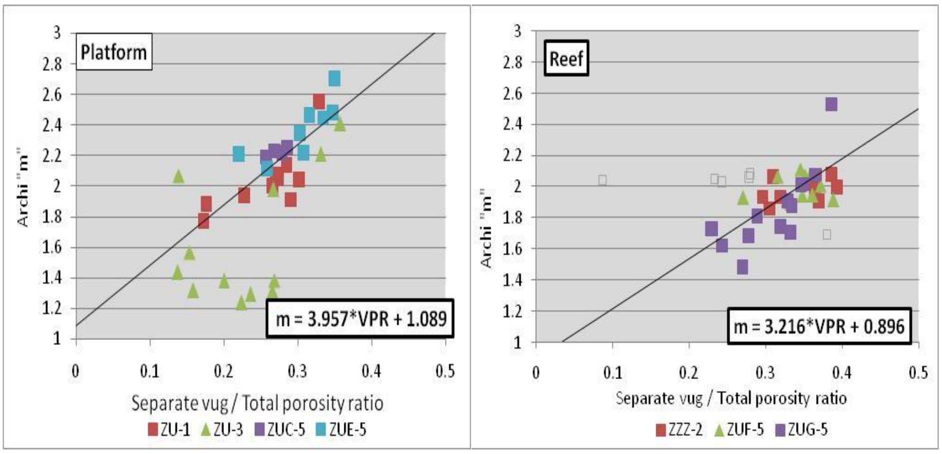


figure 8. Crossplot VPR Vs Archie 'm'

Figure 8 shows a good relationships between Archie "m" and VPR varies based on laboratory measurements and log calculations, which is defined by the following equation:

Reef :

Cementation Factor (m) = 3.216 (VPR) + 0.896

Platform:

Cementation Factor (m) = 3.957 (VPR) + 1.089

[VPR = Vug porosity ratio (separate vug porosity / Total porosity)]

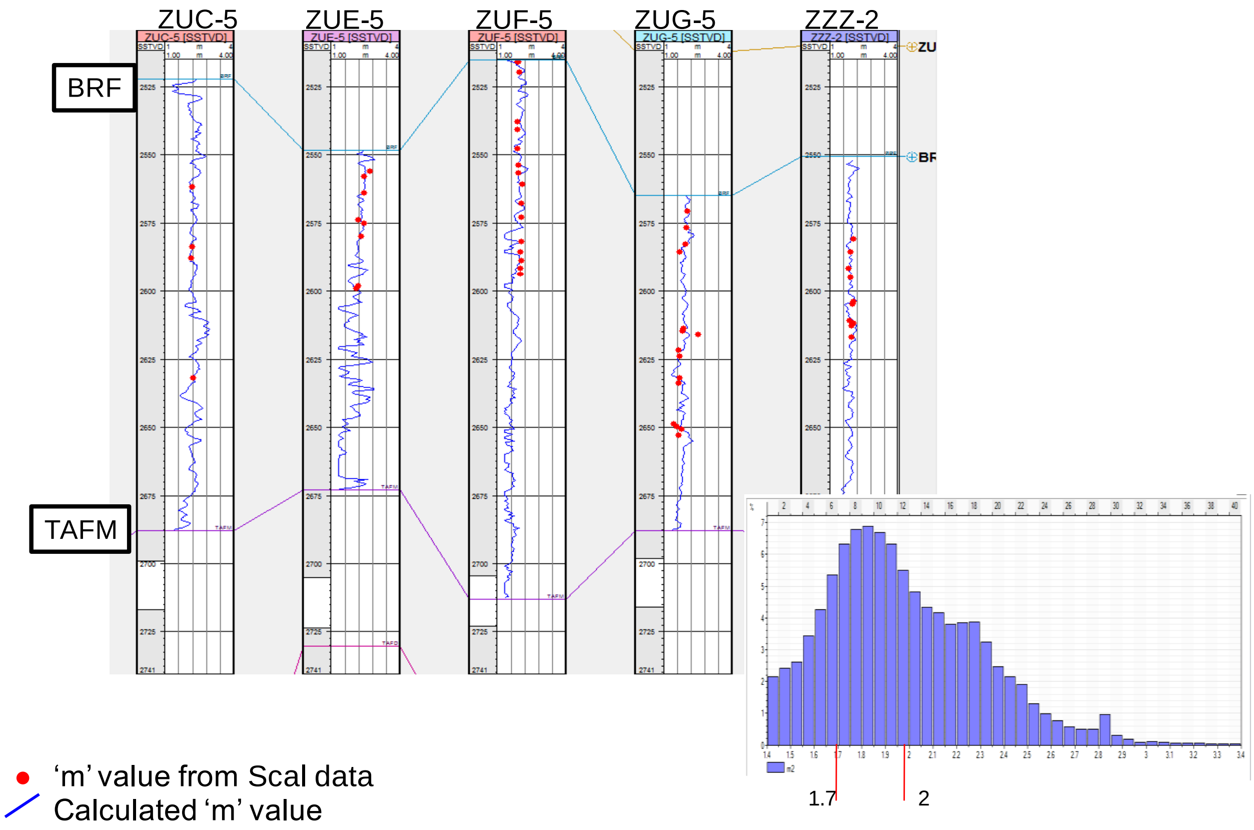


Figure 9. Comparison between calculated 'm' Vs Scal data

Rock Fabric Number (RFN) And Petrophysical Class Determination

Rock fabrics are divided into three petrophysical classes, in nature there is no sharp boundary between the rock fabrics. Instead, there is a continuum of grain size and sorting from mudstone to grainstone, as reflected in the proportion of mud to grains and in grain size .Similarly, there is a continuum of dolomite crystal size from 5 ηm to 500 ηm in mud-dominated dolostones . Therefore, there is also a complete continuum of porosity-permeability transforms within the petrophysical class fields. To model such a continuum the boundaries of each petrophysical class are assigned a value (0.5, 1.5, 2.5, and 4) and porosity-permeability transforms generated. These transforms, together with the three petrophysical-class transforms, were used to develop an equation relating permeability and interparticle porosity to a continuum of petrophysical classes using multiple linear regressions. The continuum of petrophysical classes is called rock-fabric numbers (rfn)

Lucia (1995) purposed that RFN is a function of initial water saturation and porosity.

$$Log(rfn) = \left[A + B\log(\phi) + \log(S_{wi})\right] / \left[C + D\log(\phi)\right],$$

Where:

rfn = rock-fabric number ranging from 0.5 to 4 (petrophysical class may also be used),

Swi = initial water saturation above the transition zone,

Ø = porosity,

A = 3.1107, B = 1.8834, C = 3.0634, D = 1.4045.

But here, we prefer to make the transformation of RFN falue by using porosity – permeability relationships.

Log(rfn) = (a+c log(Øip) – log(k)) / (b + d log (Øip)

where :

rfn = rock-fabric number (petrophysical class can also be used)

Øip = Interparticle porosity,

a = 9.7982, b = 12.0838, c = 8.6711 and d = 8.2965.

By using the relationships above, the RFN value in cored samples can be determined. The next step is estimating the RFN for whole interval. For this purpose, gammaray, PEF, porosity, and sonic log are used by using neural network application. The correlation value from several parameters is quite good and can be use for the RFN estimation.

Table 1. Correlation valuefor CGR, PEF, DT, and Øsv with RFN

	CGR	PEF	DT	PHI_Sv	RFN_SCAL
CGR	1.0000	0.2946	0.0496	0.2057	0.4585
PEF	0.2946	1.0000	0.6977	0.0426	0.2927
DT	0.0496	0.6977	1.0000	0.2199	0.4176
PHI_Sv	0.2057	0.0426	0.2199	1.0000	0.6571
Total	0.5504	0.7951	0.7877	0.4214	0.8068

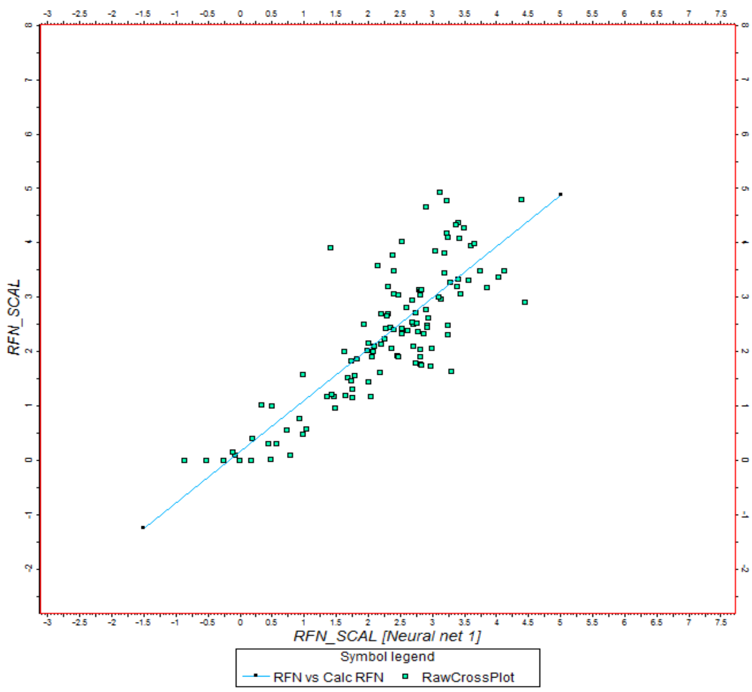


Figure 9. Crossplot RFN core data Vs Calculated RFN

RFN value is used to categorized the petrophysical class, where RFN <2 is Class 1; RFN 2- 2.5 is Class 2 ; RFN 2.5 - 3 class 3; and RFN >3 is non reservoir.

The Class value is used for transform porosity to permeability by using transform :

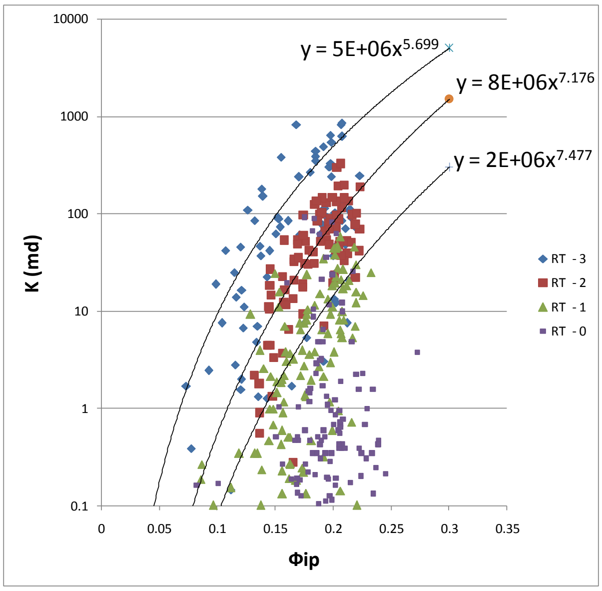


Figure 10. Crossplot Φip Vs K

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