# INTEGRATION OF GEOLOGY AND PETROLEUM ENGINEERING ASPECTS FOR CARBONATES ROCK TYPING

**Andy Setyo Wibowo**
"LEMIGAS" R&D Centre for Oil and Gas Technology
Jl. Ciledug Raya, Kav. 109, Cipulir, Kebayoran Lama, P.O. Box 1089/JKT, Jakarta Selatan 12230 INDONESIA
Tromol Pos: 6022/KBYB-Jakarta 12120, Telephone: 62-21-7394422, Facsimile: 62-21-7228414
Email: Andy5w@hotmail.com

First Registered on April 4th 2013; Received after Corection on April 25th 2013
Publication Approval on : April 30th 2013

**ABSTRAK**

Tingkat heterogenitas batuan karbonat yang tinggi menyebabkan penentuan rock typing batuan reservoir karbonat tidak mudah untuk dilakukan walaupun dengan mengintegrasikan sifat statik dan dinamik batuan. Sesuai dengan definisi rock type yang umum digunakan, yaitu batuan atau bagian-bagian batuan yang telah diendapkan pada lingkungan yang sama dan telah mengalami proses diagenesa yang serupa (similar) memiliki kemiripan karakter fisik seperti tekstur butiran atau rock fabric, geometri pori-pori dan struktur pori-pori, maka selanjutnya karakter-karakter ini yang akan dijadikan landasan untuk menentukan rock types. Penggunaan rock fabric sudah dilakukan oleh banyak peneliti sebelumnya. Sementara pemakaian atribut pori-pori dalam rock typing masih terbatas dan lebih ditekankan pada keperluan engineering. Penelitian ini ditujukan untuk mengintegrasikan ketiga karakteristik tersebut di dalam penentuan rock typing. Landasan teori yang akan digunakan untuk mencirikan geometri poripori dan struktur pori-pori adalah teori-teori yang sudah mapan dan terkait dengan aliran fluida didalam media kapiler dan media berpori. Selanjutnya, pembuktian secara karakteristik geologi akan dilakukan dengan menggunakan data deskripsi percontoh batuan inti, petrografi dan data lainnya untuk mendapatkan hubungan antara aspek engineering dengan aspek geologi sesuai konsep atau definisi rock type dimaksud. Dalam rock typing, permeabilitas dan porositas mencirikan geometri pori-pori dan struktur pori-pori. Penelitian ini membuktikan bahwa adanya hubungan yang kuat antara karakterisitik detail geologi dengan arsitektur pori-pori batuan. Dengan demikian, metodologi rock typing yang dihasilkan dapat bersifat universal dengan memperhatikan aspek geologi dan teknik perminyakan.

**Kata kunci:** batuan inti, geologi, geometri pori-pori, karbonat, permeabilitas, petrografi, porositas, rock fabric, rock type, struktur pori-pori, teknik perminyakan

***ABSTRACT***

*Carbonate rocks are highly heterogeneous. That which leads to rock typing of carbonate rocks is not easy to do even by integrating static and dynamic properties of rocks. In accordance with the definition of rock types that are commonly used, rocks or parts of rocks that have been deposited in the same environment and experienced similar diagenetic process have similar physical characteristics, such as grain or rock fabric texture, pore geometry and structure pores, then the characters that will be used as the basis for determining rock types. The use of rock fabric has been performed by many previous researchers. While the use of attributes in the rock pores typing is still limited and more emphasis on engineering purposes. The objective of this study is to integrate all three of these characteristics in the determination of rock typing. Theories that have been established and related to fluid flow in capillaries and porous media that will be used to characterize the pore geometry and pore structure. Furthermore, the characteristics of the geological evidence will be conducted using core description, petrography and other data to obtain the relationship between aspects engineering and aspects geology in accordance with concept or definition of rock type in question. In rock typing, permeability and* *porosity characterize the pore geometry and pore structure. This study proves that there is a strong relationship between the characteristics of the detail geological and architecture pores. Thus, the resulting methodologies rock typing can be universal with respect to aspects of geology and petroleum engineering.*

*Keywords: core, geology, pore geometry, carbonate, permeability, petrography, porosity, rock fabric, rock type, pore structure, petroleum engineering*

## I. INTRODUCTION

Understanding of rock typing can vary from one researcher to another researcher. In general, all of researchers lead to the same destination, the grouping of parts or similar rock formations based on the attributes of a geological and physical attributes (petrophysical). The emphasis on the attributes used for rock typing is a difference in the method of approach. (Folk (1959), Dunham (1961) Ham and Pray (1962)) place more emphasis on geology. While Leverret (1940), Amaefule *et al*. (1993), El-Khatib (1995), Gunter *et al*. (1997) and Corbett *et al*. (2003)) place more emphasis on its engineering.

Several previous studies, generally indicates that reservoir characterization including rock typing, especially carbonate reservoir should be done by integrating geological and petroleum engineering information. Lucia *et al*. (2003) stated that the carbonate rocks, rock groupings based rock fabric (grain size, sorting, interparticles porosity ($\phi$ip) and vuggy porosity variations) tend to be consistent both vertical and lateral directions with a special relationship between the porosity ($\phi$) and permeability (k) for each group of rocks. Skalinski et al. (2005) succeeded in improving the accuracy of dynamic simulation models by applying carbonate reservoir rock typing methods were established based on the relationship between the data presented mercury injection capillary pressure (MICP) and depositional facies and stratigraphy of the cores. Permadi et al (2009) showed that the model equation characterizing the capillary tubes can provide geometry and pore structure, although the results of this study have shown the relationship between attributes of pore geometries and pore structure attributes for example natural rock but rock samples were used too little to be concluded.

In fact, rock typing carbonate rocks parameter by integrating geology and petroleum engineering is not easy. Research conducted by Rushing *et al*. (2008) stated that the reservoir rock typing in tight gas sand deposition factor approach, petrographic and petrophysical hydraulic or will face problems in classifying rock types at the rock consistently undergo significant diagenetic. Al-Farisi *et al*. (2009) stated that the heterogeneity of carbonate rocks causing difficulties for petroleum geoscience expert in forming a universal method for typing rock carbonate rocks, although by integrating static and dynamic properties of rocks. Diagenetic process can modify the texture, mineral composition, pore geometry, pore structure and other physical properties of rocks. This can result in porosity and permeability does not correlate well and are not easily correlate the geological parameters and petroleum engineering parameters to distinguish rock type identification using flow unit, Leverret JFunction, grouping petrophysical properties (pore size, pore types, porosity, permeability) and classification of rock texture caused by the deposition process (depositional) (Skalinski *et al*., 2010).

The study purposed to deeply understand the meaning of rock typing of the geological and engineering side. Both sides should be aligned so that meaningful physical geology (rock fabric or microscopic geological features) of a rock type has a certain relationship between physical properties. This relationship is different from one rock type to another rock type.

The objective of this study is to produce a method of rock typing carbonate rocks by integrating Archie's definitions and rules regarding rock type with the basic laws of porous media.

Noting that there is a carbonate rock has fractures (fractures), this study is restricted to carbonate rocks where fracture not dominate permeability and rock samples (core plug) carbonate can be used for the measurement of porosity, permeability and water saturation is normal or standard.

Consideration of carbonate rocks become the object of this study because of carbonate rocks have physical properties and petrophysical highly heterogeneous (Chilingarian *et al*., 1992) and its potential as a hydrocarbon reservoir is very large. More than 60% of oil reserves and 40% of world gas reserves are in carbonate reservoir rocks (Akbar *et al*, 2001).

## II. BASIC THEORY

Fundamentals science associated with the reservoir rock has actually valid (well established). In relation to the problems of rock typing, deep understanding of the science is question as well as integration is a solution.

Refer from the definition of Archie (1950) on the rock type that was adopted in the world of petroleum, rocks or parts of rocks that have been deposited in the same environment and have similar diagenetic process. Archie also said, though not in the form of mathematical correlation, that parts of rock which the same rock type tend to have a certain correlation (definite) between the physical properties of and the other physical properties. Pore size distribution of rocks control the porosity and permeability and saturation correlates with water. Rock type tends to have a certain pore size distribution and shape of the curve will have the unique capillary pressure. Nevertheless, the pore size distribution does not necessarily define or characterize rock type, some rock types have the pore size distribution is generally the same. Integration aspects of geology and petroleum engineering are necessary to define or characterize the rock type.

Understanding what has been stated by Chilingarian *et al*. in 1992, it can be stated that all geological events during the deposition process and diagenetic played a role in the establishment of the physical character of the rock. Each depositional environment and diagenetic forming rocks with special geological features that characterize the physical. Detailed description of the geological core descriptions, thin section analysis / petrographic and SEM and XRD describing geological features microscopically as physical characteristics of rocks.

It has been generally understood that the physical characteristics or distinguishing petrophysics highly heterogeneous carbonate rocks of other reservoir rock. Grouping of carbonate rocks in the reservoir characterization of carbonate rocks should not only be based on common characteristics of the composition and texture of the grain-matrix. In terms of bafflestone, framestone and bindstone is very difficult to be applied in small samples carbonate rocks. Jones and Lucia (2004) stated that the fabric (grain size, sorting), pore types, lithology and crystal size is an important component in the description of the reservoir characteristics of carbonate rocks. In another sense, the description into a detailed geological information that can not be ignored in the classification and characterization of reservoir rocks including carbonate rock typing.

Purcell (1949) suggested a link between aspects of geological and petrophysical aspects in the form of the equation as a function of the permeability of the capillary pressure curve and lithology factors. It suggests also that the Pc curve is controlled by the pore size distribution and reflects the structure of the pores.

Leverett (1940) suggests that the Pc curves can be normalized by using the similarity of the pore geometry. Normalization is then known as the Leverett's J-function. By applying the concept of J-function in the carbonate rocks (Edward formation), Brown (1951) identified four groups of curves J-function based on the texture of the grain. Long after this, El-Khatib (1995) proved mathematically that specific tortuosity ($\tau$) is a function of Leverett's J-function and reflect the specific character of geologically.

## III. METHODOLOGY

This study begins with understanding the basic theory and formulation of the relationship between aspects of the geological characteristics of the rock typing and physical properties of reservoir rocks. In accordance with what was raised by Archie empirically, researchers found that the geological processes in the formation of the rocks and their parts will result in the character of the physical properties (petrophysical) is unique according to geological processes.

Rock grouping based on the similarity physical characteristics of rocks are the result of detailed microscopic observation (microscopic geological features) that describes all the geological events that occurred during the forming of rocks. That is including the granular material, shape and size of grains (rock texture), grain to grain relationships, sorting, cementation, pore type, composition of mineral impurities.

Darcy's law is the basis for determining permeability of rock. However, this law does not recognize the geometry and structure of the pores. Mathematically, Poiseuille's law which is commonly used for the idealization of porous media to accommodate the geometry and pore structure. Combinations of these equations obtain the pore geometry and pore structure.

Furthermore, geological and petrophysical data collection with a variety of carbonate rocks that represent the fabric and texture of natural events that commonly occur in the formation of carbonate reservoir rocks, oil and gas field. Include data analysis of sedimentology (core descriptions, petrographic (thin section) and data analysis core (routine core and SCAL). At the end of investigation (investigation) to prove the existence of a strong relationship between the microscopic geological features, geometry and pore structure as the basis for the development of new methods for carbonate rock reservoir rock typing. Flowchart rock typing study outlined on Figure 1.

## IV. DATA USED

This study was supported by data from the geological and petrophysical analysis of the two data sets carbonate reservoir rock core with fabric and texture variations that represent natural events that commonly occur in the formation of carbonate reservoir rocks of oil and gas field. Data analysis includes the analysis of petrography (thin section),

Table 1
Data Used

| Analysis | Number of sample | Unit |
|---|---|---|
| **Sedimentology** | | |
| Petrographic (thin section) | 70 | Sampels |
| SEM & XRD | 60 | Sampels |
| Core Log description | 300 | ft |
| **Routine Core** | | |
| Permeability | 233 | Sampels |
| Porosity | 233 | Sampels |
| Core plug description | 233 | Sampels |
| **SCAL** | | |
| Capillary pressure (Centrifuge) | 32 | Sampels |

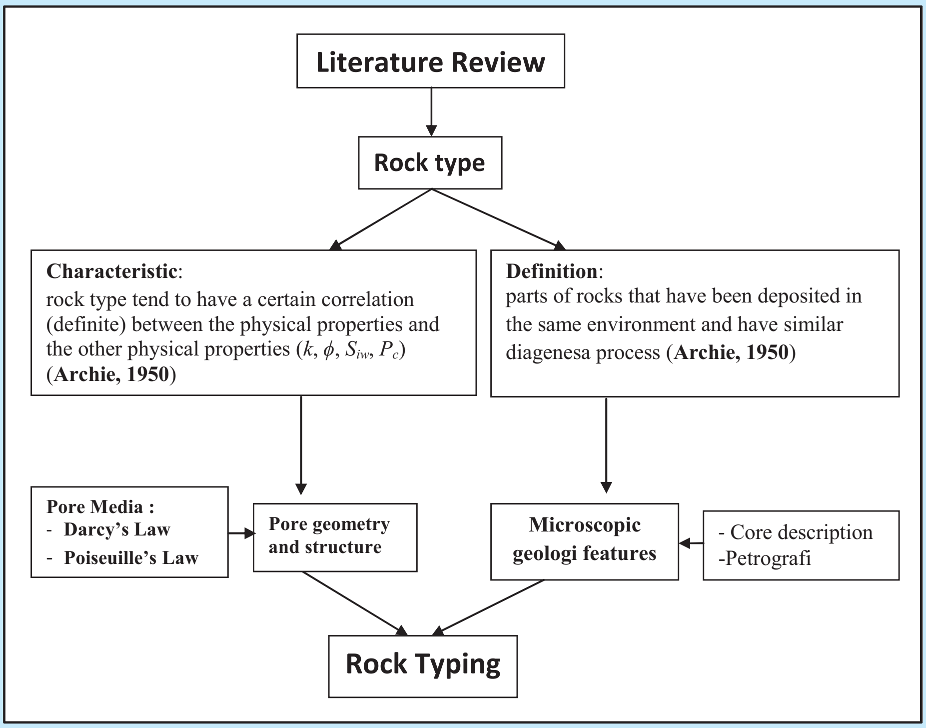



Figure 1
Research Methodology

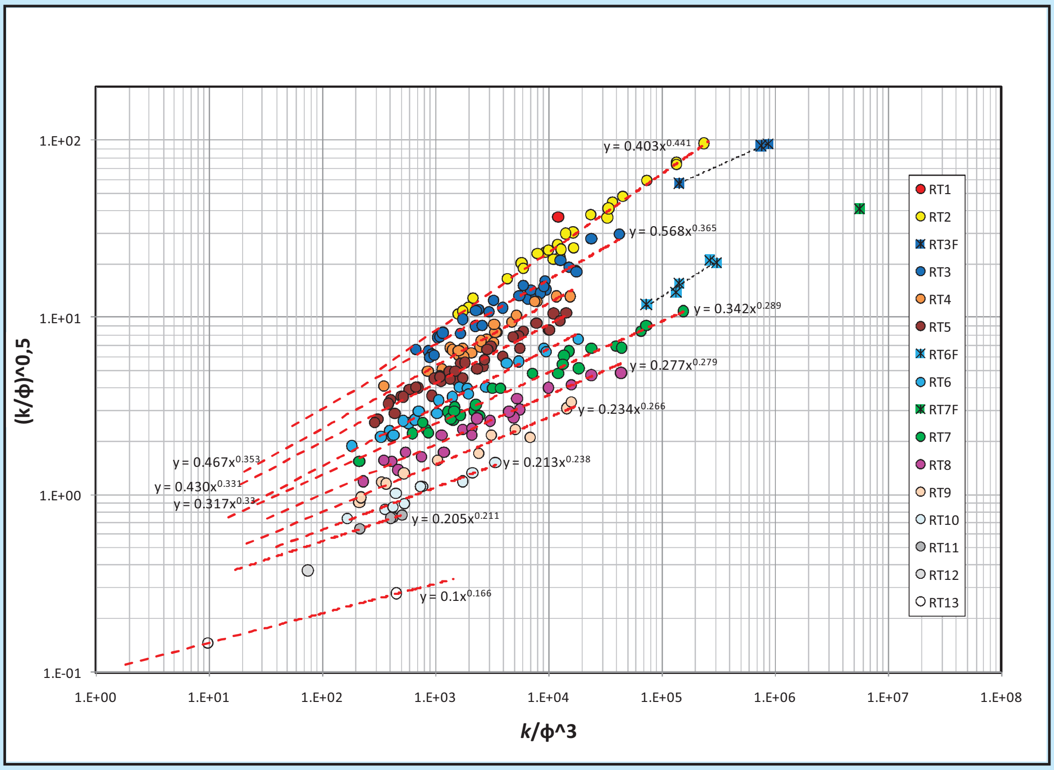



**Figure 2**
**Plot of pore geometry and pore structure core samples**

SEM and XRD, whole core description, core plug description, routine core, SCAL core samples reservoir carbonates A. The research data outline on Table 1.

## V. RESULTS

Core samples reservoir A taken from the formation X from the beginning to the middle miocene formed in marine environments (marginal marine to deep) with a variation of the flow regime. This formation is dominated by limestone-type framework is very complex due to the changes in precipitation and flow regimes and diagenetic.

Grouping the data geometry and pore structure of the rock sample for samples that have similar features are microscopic geology. Plot the pore geometry to the pore structure $\left(\left(\frac{k}{\emptyset}\right)^{0,5} vs. \left(\frac{k}{\emptyset^3}\right)\right)$ on the graph scale Log - Log (PGS) shows the trend line with a particular slope for each group (Figure 2).

The first group is the skeletal limestone with fragmental skeletal grains (packstone, grainstone, rudstone, floatstone) formed in the shallow marine tidal flat and dead corral accumulation. Relatively intense rocks undergo weathering, dissolution, evaporation due to fresh water and sunlight. Dissolution component reactive rocks form fresh water vug and moldic reach 7mm diameter. Secondary porosity formed by vugs, moldic pore system dominated rock beside the primary porosity (interparticle, intrapartikel) (Figure 3). The particles consist of rocks that form the skeleton of coral, algae, bryozoans (0.06 - 4 mm) will form the primary porosity (interparticles and intraparticles) very well. It forms an effective pore diameter to larger than 100 μm, but that dominates is an effective pore diameter of 10-100 μm. The ratio of the component grains (grains) and mud (micrite), the framework play a role in the rock pore size distribution of rocks especially effective when diagenetic not happen either. Distribution of pore size and pore geometry describes the pores relation (pore structure) that control the porosity and correlated with permeability and water saturation. Rocks are dominated by the large effective pores will make it easier for fluid to flow. Thus, it is not surprising that the rock has a very good quality with an average permeability of 333 mD and porosity ranging from 20-30%. The group is located at the top of PGS curve with slope 0.441.

The next group is characterized by the emergence of intercalation coralline and bioclastic wackestone to packstone and reduced the intensity of secondary porosity. The difference in the physical characteristic

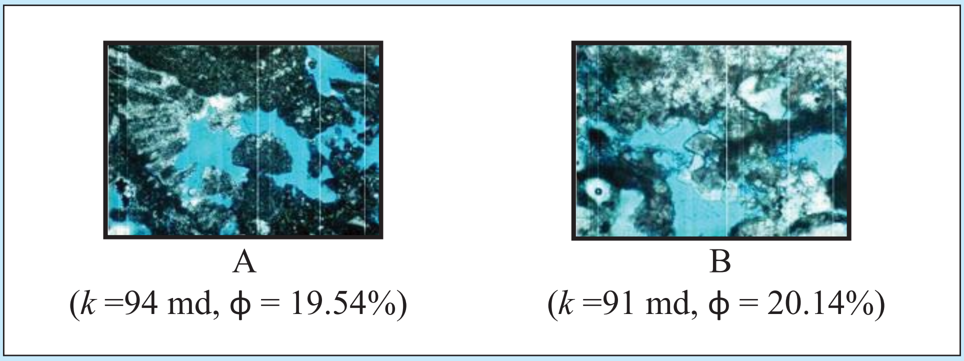



**Figure 3**
**Microscopic geological features of rock type 2:**
**A. LM , PackStn, Wht-ltbrn, med hd-hd, conglomeratic, coral, algae, L.foram, moldic, vugs up to 7 mm, intra particle.**
**B. LM , PckStn, ltgy-wht, med hd-hd, coral, L.foram, algae, moldic, mott vugs, intra particle, calcite x-Ln**

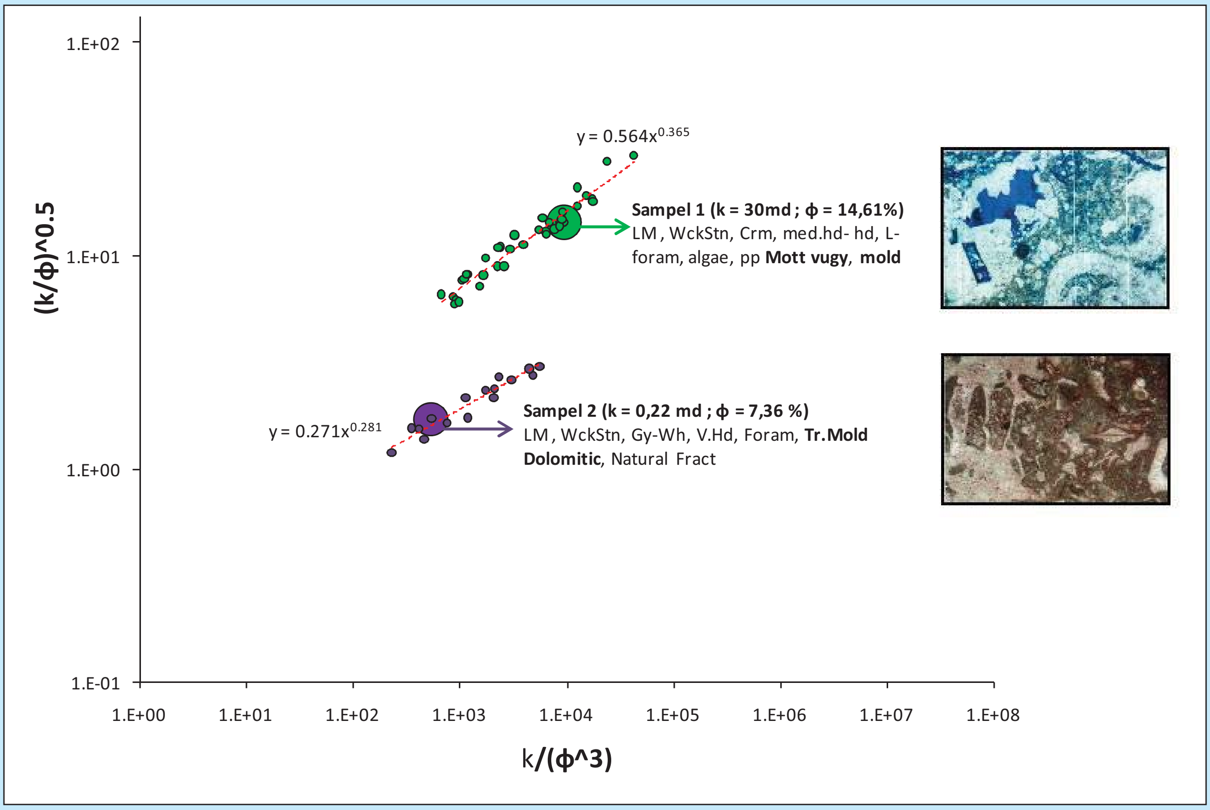



**Figure 4**
**Vuggy wackestone dan moldic wackestone on PGS graph**

is influenced by changes in depositional environment and flow regimes during the process of its formation. Environment slope to shallow marine reef lagoon back into place bioclastic accumulated particles (coral, algae, mollusks, foraminifera, etc.). Quiet flow regimes tend to form a rock-textured wackstone - packstone with relatively smaller grain size depends on the size of the grains in the surrounding environment. Thus, these rocks tend to be structured laminates result of the influence of changes in flow regime and or erosion. In general, the physical characteristic of the rock does not have a significant difference from the previous group. Pore system is still dominated by vugs, moldic, intraparticles, interparticles, but its intensity is reduced. In quality, the rock was worse than the previous group with permeability and average porosity is 91 mD and 19%. It is coinfluenced by the texture and structure of the rock. Small grain size distribution will form pores smaller effectively with the complexity of the relationship between higher pore. However, that does not mean grain size distributions can define the quality of the rock, some samples showed the same grain size distribution of rocks of different quality depending on diagenetic process. Several rock samples show that vuggy wackstone has better quality than moldic wackstone and be at the top of the charts over PGS (Figure 4). Genesis geological rock formation at the end of the process should at least play a role in defining the quality of the rock. The slope of the trend line is on the graph PGS group is smaller than the previous group is 0.365.

In this case, the rock type skeletal limestone (floatstone) formed the rear area of coral reef buildup close to the energy flow is large enough group that has a slope of a line (trend line) at small and located at the very bottom of the chart PGS. This group is very fine grained to fine and have no vuggy and moldic pore system which is likely caused by the crystallization process and or recrystallization that occurs during diagenetic. It contributed to the formation of a small pore size, pore shape and the complexity of the relationship between pore high permeability and porosity so very small.

Physical characteristics of rocks of each group changes systematically and demonstrated by a systematic change in the slope of the line. The quality is getting worse by the rock group the decreasing slope of the trend line on the chart PGS. Diagenetic process results mainly vuggy and moldic significant effect on the shape and size of the pores and the pores relationship. Nevertheless, rock texture (grain shape, grain size and relation) the results of the deposition process and the minerals in rocks can not be ignored when performing grouping of rocks. This shows that the physical characteristics of rock that is formed by all geological events during the formation process during deposition and diagenetic participate in the formation of pore geometry and structure.

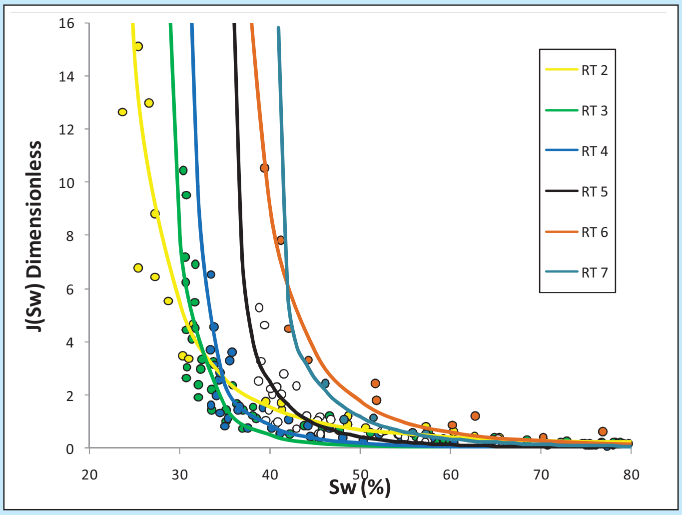



**Figure 5**
**J-Function (J(Sw)) curves of core samples**

Rock group has the form J-curve function is unique, meaning that there are similarities geometry and structure of the pores in the rock groups (Figure 5). Regularity of geological processes that occur in nature during the formation of rocks and diagenetic generate a regularity architecture pores. Thus, the geometry and pore structure is closely associated with all the geological events that occurred since the beginning to the end of the rock formation. Rock Typing reservoir A outlined on Table 2.

## VI. DISCUSSION

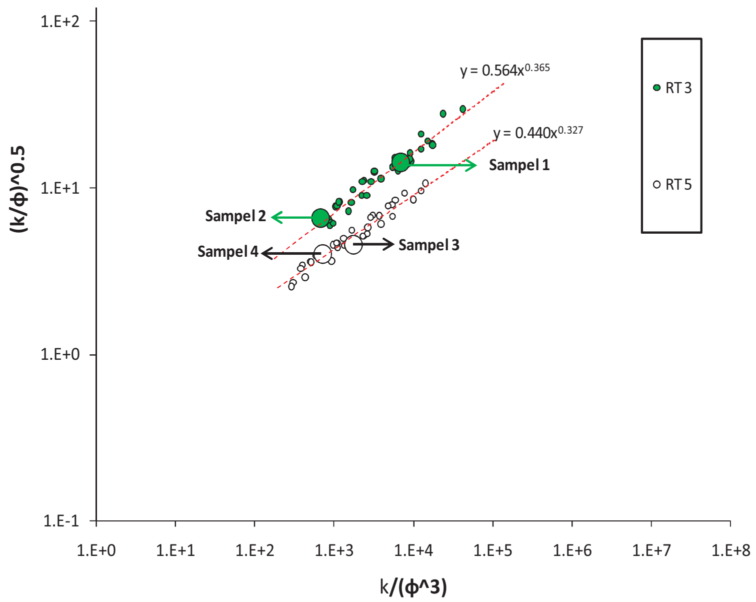
Carbonate rock typing should be based on the similarity of diagenetic. The final result diagenetic process determines physical characteristics of carbonate rocks and played a role in the forming of the pore architecture. Petrophysical properties of

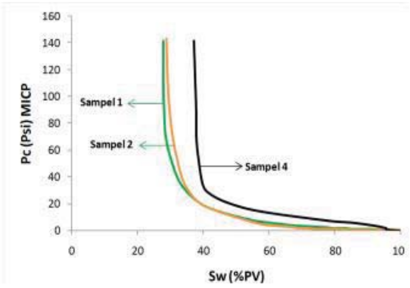
**Table 2**
**Rock Typing Reservoir A**

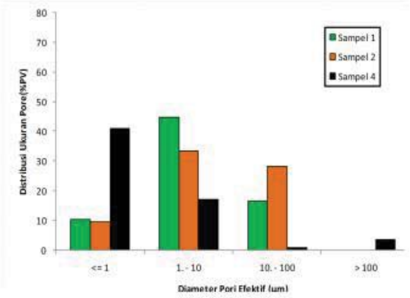
| Rock Type | Mikroskopik fitur geologi | Persamaan Rock Type | *k* (md) | ϕ (%) |
|---|---|---|---|---|
| 1 | LM ; Packstone-Grainstone, medium hard, coarse grain, well sorted, coral, sli.foram, sli.algae, sli.mollusks, quartz, mottled.vug, mould, intra particle, inter crystalline, pinpoint, slice cemented (equant, locally blocky), calcite sparite, slice micrite, slice siderit. | | 444 | 33 |
| 2 | LM ; Wackestone-Packstone, medium hard-hard, medium-coarse grain, medium-well sorted, coral, sli.foram, sli.algae, sli.mollusks, slice milloid, carbonate mud, slice detrital clay, quartz, mottled.vug, mould, intra particle, inter crystalline, pinpoint, slice cemented (equant, locally blocky), calcite sparite, slice micrite, slice siderit, slice pyrite. | (k/ϕ)^0,5= 0,403x(k/ϕ^3)0,441 | 28 -1800 | 19-27,5 |
| 3F | LM ; Wackestone-Packstone, medium hard-hard, fine-medium grain, poorly-mediumorted, coral, slice foram, slice algae, slice mollusks, slice milloid, carbonate mud, slice detrital clay, quartz, pinpoint-mottled.vug, mould, intra particle, inter crystalline, styllolites, slice cemented (equant, blocky), calcite sparite, slice micrite, slice pyrite, nattural fracture. | | 490-917 | 10-15 |
| 3 | LM ; Wackestone-Packstone, medium hard-hard, fine-medium grain, poorly-mediumorted, coral, slice foram, slice algae, slice mollusks, slice milloid, carbonate mud, slice detrital clay, quartz, pinpoint-mottled.vug, mould, intra particle, inter crystalline, styllolites, slice cemented (equant, blocky), calcite sparite, slice micrite, slice pyrite. | (k/ϕ)^0,5 = 0,568x(k/ϕ^3)0,365 | 7-137 | 13-25 |
| 4 | LM ; Wackestone-Packstone, hard, fine-medium grain, poorly-mediumorted, coral, foram, slice algae, carbonate mud, quartz, pinpoint-mottled.vug, slice mould, intra particle, slice inter crystalline, styllolites, slice-moderate cemented (equant, blocky), slice calcite sparite, micrite. | (k/ϕ)^0,5 = 0,467x(k/ϕ^3)0,353 | 3,5-21 | 10-22 |
| 5 | LM ; Wackestone-Packstone, hard-very hard, mud-medium grain, poorly sorted, coral, foram, slice algae, slice carbonate mud, quartz, pinpoint-mottled.vug, slice intra particle, Slice styllolites, slice-moderate cemented (equant, blocky), slice calcite sparite, micrite. | (k/ϕ)^0,5 = 0,430x(k/ϕ^3)0,331 | 1-10 | 8-17 |
| 6F | LM ; Wackestone-Packstone, hard-very hard, fine-medium grain, poorly-medium sorted, slice coral, foram, slice algae, carbonate mud, quartz, slice pinpoint-mottled.vug, styllolites, slice-moderate cemented (equant, blocky), slice calcite sparite, micrite, slice pyrite, nattural fracture. | | 6-18 | 3,7-4,4 |
| 6 | LM ; Wackestone-Packstone, hard-very hard, fine-medium grain, poorly-medium sorted, slice coral, foram, slice algae, carbonate mud, quartz, slice pinpoint-mottled.vug, styllolites, slice-moderate cemented (equant, blocky), slice calcite sparite, micrite, slice pyrite. | (k/ϕ)^0,5= 0,317x(k/ϕ^3)0,33 | 0,5-3 | 5,5-14 |
| 7F | LM ; Wackestone-Packstone, hard-very hard, mud-medium grain, poorly-medium sorted, slice coral, foram, slice algae, slice milloids, slice carbonate mud, quartz, slice pinpoint.vug, slice intra partcles, styllolite, slice-moderate cemented (equant, blocky), slice calcite sparite, micrite, slice pyrite, nattural fracture. | | 29 | 1,73 |
| 7 | LM ; Wackestone-Packstone, hard-very hard, mud-medium grain, poorly-medium sorted, slice coral, foram, slice algae, slice milloids, slice carbonate mud, quartz, slice pinpoint.vug, slice intra partcles, styllolite, slice-moderate cemented (equant, blocky), slice calcite sparite, micrite, slice pyrite. | (k/ϕ)^0,5 = 0,342x(k/ϕ^3)0,289 | 0,3-3,22 | 2,74-10,5 |
| 8 | LM ; Wackestone-Packstone, very hard, mud-medium grain, poorly-medium sorted, coral, slice foram, slice algae, slice mollusks, carbonate mud, micro cristalline, slice quartz, slice mould, styllolite, moderate cemented, slice calcite sparite, slice micrite, slice pyrite. | (k/ϕ)^0,5 = 0,277x(k/ϕ^3)0,279 | 0,1-0,7 | 2,3-8,3 |
| 9 | LM ; Wackestone-Packstone, very hard, mud-medium grain, poorly-medium sorted, slice coral, slice foram, slice algae, mollusks, carbonate mud, micro cristalline, slice quartz, mould, styllolite, moderate cemented, slice calcite sparite, slice micrite, slice pyrite. | (k/ϕ)^0,5 = 0,234x(k/ϕ^3)0,266 | 0,05-0,3 | 2,5-6,5 |
| 10 | LM ; Wackestone-Packstone, very hard, mud-medium grain, poorly-medium sorted, coral, slice foram, slice algae, mollusks, slice carbonate mud, micro cristalline, pin point vug, styllolite, moderate cemented, slice calcite sparite, slice pyrite. | (k/ϕ)^0,5 = 0,213x(k/ϕ^3)0,238 | 0,03-0,06 | 2,6-5,6 |
| 11 | LM ; Wackestone, very hard, mud, well sorted, slice coral, slice foram, slice algae, mollusks, slice carbonate mud, trace cristalline, moderate cemented, slice calcite sparite, slice micrite, slice pyrite. | (k/ϕ)^0,5 = 0,205x(k/ϕ^3)0,211 | 0,02 | 3,4-4,4 |
| 12 | LM ; Wackestone, very hard, mud, well sorted, slice crystalline, moderate cemented | | 0,006 | 4,3 |
| 13 | LM ; Wackestone, very hard, mud, well sorted, slice crystalline (fine-medium grain), moderate cemented | (k/ϕ)^0,5 = 0,1x(k/ϕ^3)0,166 | 0,001 | 1,3-4,7 |

carbonate rocks is strongly influenced by the shape, size and relationship pores (pore architecture). In other words, the petrophysical properties of rocks including carbonate rocks is strongly influenced by the physical character formed by geological events that occurred at the end of carbonate rocks. Thus, based on the similarity diagenetic rock typing and pore architecture parameters (geometry and pore structure) provides a consistent correlation antarsifat petrophysical carbonate rocks.

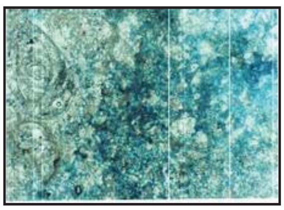
Dissolution of carbonate minerals by fresh water will form vuggy porosity through grains and matrix (non-fabric selective) and moldic porosity in organic shells (fabric selective). Framework carbonate rocks



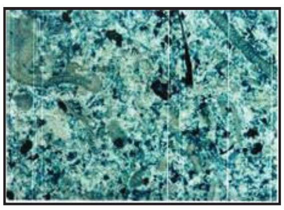




**Sampel 1**
k = 35 md ; ϕ = 17,11%
LM, **Pck-GrnStn**, ltbrn, hd, f-crs, coral, **foram**, **foss frag**, Loc. **succrosic**, **mot vugs**, **mold**, **intrapart**.



**Sampel 3**
k = 2,24 md ; ϕ = 11%
LM, Wck-PckStn, Crm, vhd, L-foram, Mollusks, pp vugy, mold, calc spar, micritic, sli.pyr

**Sampel 2**
k = 11 md ; ϕ = 25,33%
LM, **PckStn**, Lt.Gy-Lt.Brn, hd, vf-Mod.csl, **foram**, **sli. Foss frag**, **sucrrosic**, **mot vugs**, **mold**, **intrapart**, sli.Micro.X-Ln.



**Sampel 4**
k = 2,41 md ; ϕ = 15%
LM, WckStn, Lt.Brn, vhd, vf-Mod.csl, L.foram, Mollusks, sli.vugs, mold, calc spar, micrite, sli.pyr

No *thinsection*

**Figure 6**
**Microscopic geological features and petrophysical of core samples**

are often saturated with CaCO3 formed vuggy with diameters up to 10 mm. such conditions tend to form small tortuosity and specific surface area is small. Thus, fluid friction with the smaller rocks so that the smaller the capillary pressure and fluid flow more easily through the pores of the rock system. Therefore, vuggy limestone to form the geometry and structure of large pores. While moldic limestone especially moldic unrelated (separate moldic) tend to form large pore geometry with a small pore structure. However, it does not apply to framework with carbonate rocks is the main component of grain. Moldic limestone in carbonate rocks or bioclastic framework with the main components grain and touching (rudstone, grainstone) can be having similar petrophysics characteristic with vuggy limestone.

Figure 2 shows a group of rocks with similar characteristics in microscopic physical geology features form a single line with a certain slope trend line on the graph PGS. The slope of the trend line for each group of rock is influenced by the complexity of the relationship between the shape of the pore and pore. In other words, the value of the pore structure in the graph exponent PGS can describe the complexity of the forms of rock pores. Uniformity pore shapes in the rock type is indicated by the equal value of pore structure exponent. If the system has a perfectly round capillary structure exponent of 0.5, then the media will have a real porous structure exponent <0.5. Rock group with a high level of complexity will form a line with the smaller slope and at the bottom of the graph PGS.

Each group has a curved rock J(Sw) is unique (Figure 5), meaning that the similar physical characteristics of the rock produces similar pore architecture. Pore size distribution of the rock group tend to be similar, as shown by the similarity of the shape of the capillary pressure curve of water saturation of rock samples in a group of rock and different from other rock groups (Figure 6). We understood that the pore size distribution is one of the important parameters pores connectivity establishment (pore structure). In other words, rock type tends to have the same pore geometry and pore structure. It supports the concept of the J-function expressed by Leverret (1940), Brown (1951) and El-Khatib (1995). Thus, the rocks can be quantitatively characterized by porous architecture (pore geometry and pore structure).

## VII. CONCLUSION

The physical characteristics of carbonate rocks are determined by all geological events during the formation process in an environment of deposition and diagenetic. Pores architecture of rock (geometry and pore structure) is very closely linked to the physical character of the microscopic geological features. Products diagenetic (type pores, cementation, chalky, mineral content and composition impuritis (siderite, pyrite)) more affected the pore geometry and pore structure of carbonate rocks. Especially pore size and connectivity of vugs that really control the pore geometry and pore structure of carbonate rocks. It is mean that the presence or absence of vugs determine the distribution of the rock types. fossils (type, content, wholeness) and rock texture influences the geometry and pore structure of carbonate rocks. Especially carbonate rocks that are not experiencing diagenetic intense, physical characteristics of rock depositional process results determine the outcome of the rock typing. The similarity of the physical characteristics of carbonate rocks to form a link geometry and pore structure are influenced by the complexity of pore shape and the pores relationship. Pore geometry and pore structure can be quantified based on the equation of flow in porous media has been widely adopted in the petroleum engineering. Thus, the rock types can be quantitatively by the pore geometry and pore structure of the rock through petrophysical parameters are commonly used and without ignoring the geological aspects.

Carbonate rocks rock typing method based on the geometry and pore structure can bridge aspects of the geology and petroleum engineering in reservoir rocks characterize carbonate rock typing in accordance with the concept that has been expressed by Archie (1950).

## REFERENCES


1. **Al-Farisi, O., Elhami, M., Al-Felasi, A., Yammahi, F.,** and **Ghedan, S.** (2009): Revelation of carbonate Rock Typing-The Gap Resolved, *Paper SPE 125576 presented at the SPE/EAGE Reservoir Characterization and Simulation Conference held in Abu Dhabi, UAE,* October 19-21.
2. **Amaefule, J.O., Alunbay, M., Tiab, D., Kersey, DG,** and **Keelan, DK** (1993): Enhanced Reservoir Description: Using Core and Log Data to Identify Hydraulic (Flow) Units and Predict permeability in

Uncored Intervals / Wells, *Paper SPE 26436 presented at the 68 th 3. Annual Technical Conference and Exhibition of the SPE held in Houston, Texas*, October 3-6.

3. **Archie, G.E.** (1950): Introduction to Petrophysics of Reservoir Rocks, *Bulletin of the American Association of Petroleum Geologists,* v.. 34, no. 5, 943-961.
4. **Archie, G.E.** (1952): Classification of Carbonate Reservoir Rocks and Petrophysical Consideration, *Bulletin of the American Association of Petroleum Geologists*, v.. 36, no. 2, 278-298.
5. **Chilingarian, G.F., Mazzulo, SJ, Rieke, HH** (1992): Carbonate Reservoir Characterization: a geologic - Engineering Analysis, Part I, *Elsevier Science Publishing Company INC,* 59-102.
6. **Dunham, R.J.** (1962): Classification of Carbonate Rocks According to depositional Texture, *Memoir of the American Association of Petroleum Geologists,* no. 1, 108-121.
7. **El-Khatib, N.** (1995): Development of a Modified capillary Pressure J-Function, *Paper SPE 29890 presented at the SPE Middle East Oil Show held in Bahrain*, March 11-14.
8. **Folk, R.L.** (1962): Spectral Subdivision Types of Limestone, *Memoir of the American Association of Petroleum Geologists*, no. 1, 62-84.
9. **Gunter, G.W., Finneran, J.M., Hartman, D.J.,** and **Miller, J.D.** (1997): Early Determination of Reservoir Flow Units Using an Integrated Petrophysical Method, *Paper SPE 38679 presented at the SPE Annual Technical Conference and Exhibition held in San Antonio*, Texas, October 5-8.
10. **Ham, WE, Pray, L.C.** (1962): Modern Concept and Classifications of Carbonate Rocks, *Memoir of the American Association of Petroleum Geologists,* no. 1, 2-19.
11. **Leverett, M.C**. (1940): Behavior in Porous Solids capillary, *Petroleum Technology,* 1223, 152-169.
12. **Lucia, J.F.** (1999): Carbonate Reservoir Characterization An Integrated Approach 2nd Edition, *Springer-Verlag Berlin Heidelberg*, 29-65.
13. **Lucia, J.F., Jr. Jening.** (2003): Carbonate Reservoir Characterization, *Bureau of Economic Geology*.
14. **Permadi, P.** and **Susilo, A.** (2009): permeability Prediction and Characteristics of Pore structure and Geometry as Inferred From Core Data, *Paper SPE 125350 presented at the SPE / EAGE Reservoir Characterization and Simulation Conference held in Abu Dhabi, UAE,* October 19-21.
15. **Purcell, W.R.** (1949): capillary Pressure - Their Measurement Using Mercury and the Calculation of permeability therefrom, *Trans. AIME*.
16. **Rushing, J.A., Newsham, K.E.,** and **Blasingame, T.A.** (2008): Rock typing-Keys to Understanding Productivity in Tight Gas Sands, *Paper SPE 114164 presented at the SPE unconventional Reservoirs Conference held in Keystone, Colorado, USA,* February 10-12.
17. **Scheidegger, A.E.** (1960): The Physics of Flow Through Porous Media, *University of Toronto Press,* 1-155.
18. **Skalinski, M., Zeh, S.G., Moss, B**. (2005): Defining and Predicting Rock Types in carbonates - Preliminary Results from an Integrated Approach Using Core and Log Data in Tengiz Field, SPWLA 46th Annual Logging Symposium, June 26-29.
19. **Skalinski, M., Kenter, J., Jenkins, S.,** and **Tankersley, T.** (2010): Updated Rock Type Definition and Pore Type Classification of a Carbonate buildup, Tengiz Field, Republic of Kazakhstan, *Paper SPE 139986 presented at the SPE Caspian carbonates Technology Conference held in Atyrau, Kazakhstan*, November 8 to 10.