ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 8 , August 2021

Porosity Determination and Characteristics of Jeribe Formation, Bekher Mountain, Zakho, Kurdistan Region of Iraq

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ABSTRACT: This paper summarizes field observations and porosity calculation along the two traverses of the Bekher mountain range (Chiya), Betas Village, Zakho, Kurdistan Region, Iraq. Generally, Porosity is a measure of storage capacity of the rock, the aim of this work is to determine the porosity of a carbonate rock (Jeribe Limestone) using the liquid saturation method. To determine the porosity, it needs firstly, to find out the bulk volume and pore volume for each sample in order to know the suitability of the rock for considering it to be a reservoir rock.

The measurement of porosity is important to the petroleum engineer since the porosity determines the storage capacity of the reservoir for oil and gas. The rock property data are essential for reservoir engineering calculations as they directly affect both the quantity and the distribution of hydrocarbons and, when combined with fluid properties, control the flow of the existing phases (i.e., gas, oil, and water) within the reservoir. So,the understanding of petrophysical and multiphase flow properties is essential for the assessment and exploitation of hydrocarbon reserves; these properties in turn are dependent on the geometric and connectivity properties of the pore space.

KEYWORDS : Jeribe Formation, Carbonate, Lower-Middle Miocene, Porosity, Capacity and Reservoir

I. INTRODUCTION

This research studied the carbonate units (Jeribe Formation) at Betas Village, Bekher Mountain, Zakho, Kurdistan Region, Iraq (Fig 1). The Jeribe Formation was first described by Damesin (1936, In Bellen et al., 1959), but later was defined by Bellen (1957, in Bellen et al., 1959) from the type locality near Jaddala Village in Jebel Sinjar Anticline and assumed to be of Early Miocene age. Al-Kharsan (1970) studied Lower Oligocene and Lower Miocene stratigraphy of the eastern area of Khanaqin, Iraq. In Syria the formation, according to Ponikarov et al., (1967), occurs in the Jezira Basin; where the formation has transgressive character and is conglomeratic at its base. In Iraq, it could be broadly correlated with the Govanda Limestone but older than facies and paleogeographic position in Iran; equivalents of the formation are the Kalhur Limestones (Buday, 1980). The formation may be similar to the upper part of the Middle Asmari and the Upper Asmari of Iran, as defined by James and Wynd (1965). Mohammed (1983) studied biostratigraphy of Kirkuk Group formations in Kirkuk and Bai Hassan areas and described the lower boundary of Jeribe Formation as unconformable. Al-Hashimi and Amer (1985) studied the Tertiary microfacies of Iraq which included the Miocene microfacies too. The Jeribe Formation is an important reservoir in many of Iraq's important oil fields (Aqrawi et al., 2010) such as Kirkuk and Tawki oil fields (Ahmed, 2007; Abdula, 2010).

The Zagros Foreland Basin occupies much of northern Iraq along a NW-SE trend and extends into NE Syria and SW Iran. The basin includes the succession deposited during the Zagros collision (Upper Eocene to Holocene). The Early Miocene units in Iraq represent deep water facies of the Serikagni Formation (basinal) and shallow carbonate and evaporite facies of the Euphrates, Dhiban, and Jeribe

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Formations (Aqrawi et al. 2010). These facies are time-equivalent to the shallow water carbonate of the Asmari Formation in Iran of approximately Oligocene-Early Miocene age (James and Wynd 1965). The Asmari Formation was regionally developed across what is now the Zagros Mountain range and is the main hydrocarbon reservoir in Iran (Amirshahkarami et al., 2007; Amirshahkarami 2013). Regionally, the Early Miocene palaeofacies covered most of the northeastern margin of the Zagros Basin (Ziegler 2001). These Early Miocene facies are significant as a carbonate reservoir in the Zagros Foreland Basin (Beydoun et al., 1992), and they have recently been a main focus of study in the Kurdistan Region of Iraq.

The Jeribe Limestone in this study area characterizes a well bedded, well jointed, yellowish massive beds. The Jeribe Formation is composed of recrystallized and dolomitized carbonates that are interbedded with evaporite and dolomite.

Porosity is a measure of storage capacity of a reservoir. It is defined as the ratio of the pore volume to bulk volume. The porosity can be expressed either as a fraction or as a percentage in equation form:

$$\phi = \frac{Vb - Vg}{Vb} = \frac{Pore\ Volume}{Total\ Bulk\ Volume}$$

The determination of porosity is paramount because it determines the ultimate volume of a rock type that can contain hydrocarbons. The value and distribution of porosity, along with permeability and saturation, are the parameters that dictate reservoir development and production plans.

It should be noted that the porosity does not give any information concerning pore sizes, their distribution, and their degree of connectivity. Thus, rocks of the same porosity can have widely different physical properties. An example of this might be a carbonate rock and a sandstone. Each could have a porosity of 0.2, but carbonate pores are often very unconnected resulting in its permeability being much lower than that of the sandstone. Permeability and porosity of a rock are interrelated as higher porosity implies higher permeability (Sadeq QM, Wan Yusoff WIB (2015).

Fig. 1 Bekher Mountain, Betas Village (Study area).

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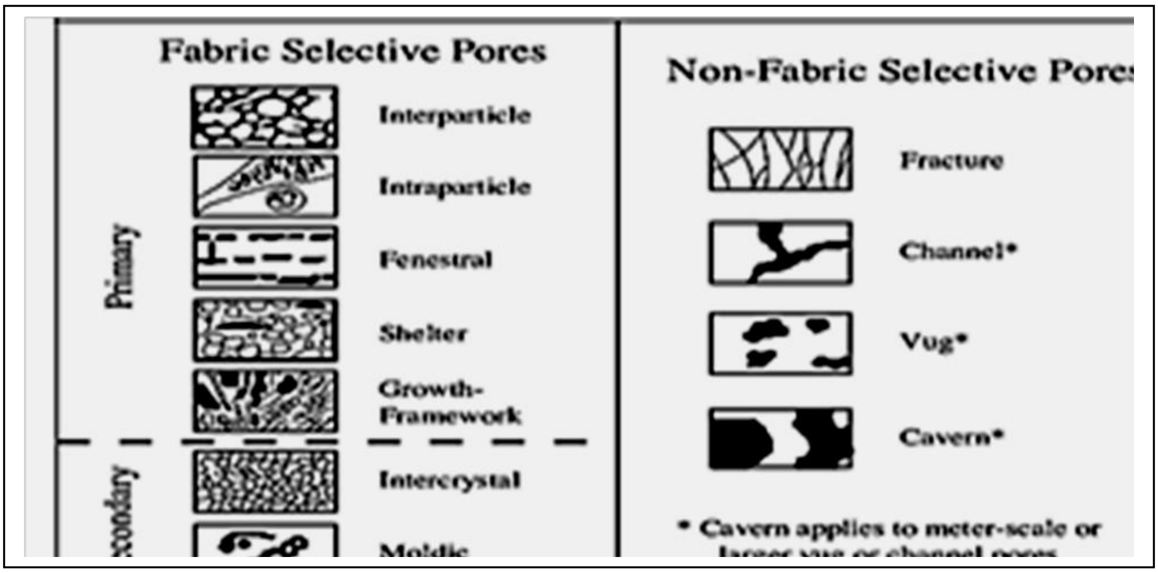
Vol. 8, Issue 8 , August 2021



II. METHODOLOGY

The material of which a petroleum reservoir rock may be composed can range from very loose and unconsolidated sand to a very hard and dense sandstone, limestone, or dolomite. The grains may be bonded together with a number of materials, the most common of which are silica, calcite, or clay. Knowledge of the physical properties of the rock and the existing interaction between the hydrocarbon system and the formation is essential in understanding and evaluating the performance of a given reservoir (Trek,2006). Porosity of a rock is the fraction of the volume of space between the solid particles of the rock to the total rock volume. The space includes all pores, cracks and vugs. The porosity is conventionally given the symbol (∅), and is expressed either as a fraction varying between 0 and 1, or a percentage varying between 0% and 100%.

PRIMARY AND SECONDARY POROSITY OF A ROCK

Porosity in rocks originates as primary porosity during sedimentation or organogenesis and as secondary porosity at later stages of the geological development. In sedimentary rocks, the porosity is further classified as intergranular porosity between grains, intragranular or intercrystallite porosity within grains, fracture porosity caused by mechanical or chemical processes, and cavernous porosity caused by organisms or chemical processes. Solid rock is often not so solid. Sandstone might have started out as a sand dune or a beach, which got buried and compressed. But spaces remain between the particles. These spaces, or pores, are where water, oil and gas may be found. If you look at a sponge, you can see many open spaces. Sandstone is like that, only the spaces are generally much smaller, so small that they cannot be seen without a microscope. Pores, can be classified as micro and macro. Pore diameters larger than 0.06 mm are called macropores and those less as micropores. Rock grains are of different sizes, shapes and mineralogical composition. They are bound into a more or less dense structure. Among these grains, we can always find voids, which indicates that some rocks can be justly considered a porous material. These voids are filled with gas, oil, or water.
Porosity varies from less than 10% to greater than 40% in sandstones and from 5% to 25% in limestones and dolomites. Porosity can be greater than 25% in some vuggy or moldic limestones or dolomites.

ABSOLUTE POROSITY AND EFFECTIVE POROSITY

Many geologists and petroleum engineers recognize two types of porosity: The total porosity, also referred to as physical or absolute porosity, equivalent to the ratio of all the pore spaces in a rock to the bulk volume of the rock, regardless of whether they are isolated or intercommunicative;

$$\varphi_{Total} = V_{Total}/Vb$$

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The absolute porosity is defined as the ratio of the total pore space in the rock to that of the bulk volume. A rock may have considerable absolute porosity and yet have no conductivity to fluid for lack of pore interconnection. The absolute porosity is generally expressed mathematic interconnection (Tarek, 2006). The effective porosity is the value that is used in all reservoir engineering calculations because it represents the interconnected pore space that contains the recoverable hydrocarbon fluids.

The effective (useful or dynamic) porosity, is the ratio of interconnected void spaces to the bulk volume. (i.e., immobile fluid retained by capillary forces in minute pores, crevices, and cracks).

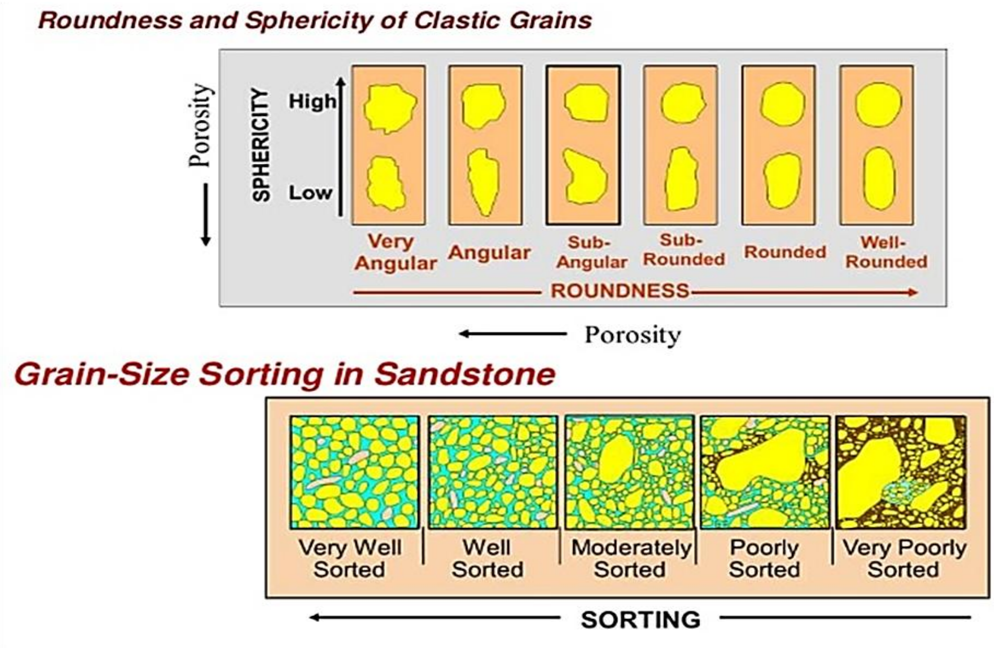
$$\varphi_{effective} = V_{interconnected}/Vb$$

The measurement of porosity is important to the petroleum engineer since the porosity determines the storage capacity of the reservoir for oil and gas. The understanding of petrophysical and multiphase flow properties is essential for the assessment and exploitation of hydrocarbon reserves; these properties in turn are dependent on the geometric and connectivity properties of the pore space. It is necessary to distinguish between the types of porosity (absolute, effective and isolated porosity) because in porous rocks there will always be a number of blind or unconnected pores (Sadeq QM, Wan Yusoff WIB (2015).

Factors affecting porosity

The initial (pre-diagenesis) porosity is affected by three major microstructural parameters. These are grain size, grain packing, particle shape, and the distribution of grain sizes. However, the initial porosity is rarely that found in real rocks, as these have subsequently been affected by secondary controls on porosity such as compaction and geochemical diagenetic processes.

1. Grain size distribution and sorting



(Fig. 2): Grain size roundness and grain sorting

2. Grain packing arrangements

From a random loose packing to a random close packing when compression is applied. The porosity of the pack during the rearrangement process decreases from 50% to about 35% (Luc Alberts & Gert Jan Weltje).

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International Journal of Advanced Research in Science, Engineering and Technology
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Packing	Maximum Porosity (fractional)
Random	≥0.399 (dependent on grain size)
Cubic	0.476
Orthorhombic	0.395
Rhombohedral	0.260
Tetragonal	0.302

Table 1: Maximum porosity for different packing arrangements

3. Grain shape

Grain Shape	Maximum Porosity (fractional)
Sphere	≥0.399 (dependent on grain size)
Cube	0.425
Cylinder	0.429
Disk	0.453

Table 2: The effect of grain shape on porosity

4. Cementation, Compaction and Vugs and Fractures

Cementing is the agent which has the greatest effect on the original porosity and which affects the size, shape and continuity of pore channels. Cementation reduces the porosity and permeability of a sand. In some cases, however, solution of cement or grains can reverse this trend. Compaction is a geological factor which reduces porosity due to overburden pressure of the overlying sediments. Vugs fractures formed by a planar break in the rock, porosity increase with increasing fracture.
(Bennett et al. 1989) suggested that the parameters are largely controlled by the microfabric and grain size distribution, the environmental processes, and specifically the consolidation history. At high overburden stress, compaction processes that drive out the interstitial water alter the particle arrangements (microfabric) and change the pore size distribution, thus changing the porosity and permeability.

III.DATA COLLECTION AND METHOD OF MEASUREMENTS

This study is achieved through field observation and laboratory work (porosity measures). Extensive field work was done in the Bekher Mountain (Betas Village), Zakho, Kurdistan Region, Iraq, in order to study general geology characteristics and choose the appropriate outcrops (traverses) of Jeribe Limestone for sampling and description, 22 fresh samples were carefully collected from the Area (traverses) of study.
There are at least 4 common methods of measuring the porosity (fluid saturation, helium porosimetry, buoyancy, and mercury porosimetry). In this study we use the saturation method. Since effective porosity is the porosity value of interest to the petroleum engineer, particular attention should be paid to the methods used to determine porosity. For example, if the porosity of a rock sample was

ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
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determined by saturating the rock sample 100% with a fluid of known density and then determining, by weighing, the increased weight due to the saturating fluid, this would yield an effective porosity measurement because the saturating fluid could enter only the interconnected pore spaces (Tarek,2006).

The saturation method is used to measure the porosity of the rock, firstly, by removing the weathered parts, cleaned and dried the rock, then weigh the rock in its dry state to give the dry weight, Wdry. Then fully saturate the rock in a wetting fluid and weighed the saturated sample after (removing any excess fluid from its surface to give its saturated weight, Wsat, and determine the bulk volume of the rock, Vbulk.

Fig. 3: The equipment used for porosity measurement (saturation method equipment

IV. CALCULATION AND DISCUSSION

It should be noted that if the bulk volume and dry weight, or the bulk volume, saturated weight and porosity of a rock sample is known, then the grain density can be calculated. This parameter is commonly calculated from the data to compare the results with the known grain densities of minerals as a QA check. For example, the density of quartz is 2.65 g/cm^3, and a clean sandstone should have a mean grain density close to this value. Because Porosity is the ratio of the pore volume to the bulk volume of the reservoir rock in percentage basis, so its formula for determination will be:

$$\text{Porosity} = \frac{pore\ volume}{bulk\ volume} * 100\%$$

$$\rho = \frac{mass}{volume}$$

$$\text{Porosity} = \frac{pore\ volume}{bulk\ volume} = \frac{Vbulk - Vmatrix}{Vbulk} = \frac{Vbulk - {}^{Wdry}/_{\rho matrix}}{Vbulk}$$

$$porosity = \frac{Vpore}{Vbulk} = \frac{Vbulk - Vmatrix}{Vbulk} = \frac{(Wsat - Wdry)/\rho f}{Vbulk}$$

Number of samples	Area (traverse)	porosity %
1	1	16.2
2	1	15.0
3	1	14.6
4	1	14.3
5	1	13.7
6	1	14.0
7	1	16.5
8	1	15.7
9	1	13.8
10	1	14.1
11	1	13.0
12	1	13.8
13	2	19.5
14	2	17.5
15	2	18.2
16	2	17.0
17	2	18.2
18	2	22.3
19	2	23.3
20	2	21.9
21	2	24.3
22	2	23.8
Total 22	Total 2	Total Average 17.3

Table 3: The calculated porosity

The porosity describing the following types: fracture, jointed, vuggy and interparticle carbonate rock giving a good storing capacity for holding hydrocarbon. According to the results of these analyses, the porosity of Jeribe formation changes from 13.0% and 24.3%, with an average rate of 17.3%. These results are showing as good porosity, and had been enhanced by some diagenetic processes, especially dolomitization and dissolution, and later followed by secondary effects from tectonics activities.

V. CONCLUSION

As it has been mentioned before determining reservoir properties accurately is important, and one of the most important one is porosity, which can be used to calculate the total hydrocarbon volume present in the reservoir. Hydrocarbon volume in the reservoir equals pore volume, and to determine porosity accurately we should have a good understanding of pore types due to engineering point view and geological point view. Nowadays porosity can be increased by enlarging the pores, using the chemicals and fracturing the rock in EOR (enhanced oil recovery) and when the pores are enlarged the permeability will increase too and it will affect the flow rate and production rate of each well in that reservoir.

ISSN: 2350-0328

International Journal of Advanced Research in Science, Engineering and Technology

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REFERENCES

- Abdula, R.A., 2010. Petroleum source rock analysis of the Jurassic Sargelu Formation, northern Iraq: Master's thesis (unpublished), Colorado School of Mines, Golden, Colorado, 106pp.
- Abdullah, H.G., Collier, R.E.L. & Mountney, N.P. The palaeoshoreline of Early Miocene formations (Euphrates and Jeribe) at the periphery of the Zagros Foreland Basin, Sulaimani Governorate, Kurdistan Region, NE Iraq. *Arab J Geosci* **12,** 574 (2019).
- Ahmed, S.M., 2007. Source rock evaluation of Naokelekan and Barsarin formations (Upper Jurassic) Kurdistan Region/ N Iraq: Master's thesis (unpublished), Science College, University of Sulaimani, Sulaimani, Iraq, 174pp.
- Al-Hashimi, H.A.J. and Amer, R.M., 1985. Tertiary microfacies of Iraq: Directorate General for Geological Survey and Mineral Investigation (GEOSURV), Baghdad, 159pp.
- Al-Kharsan, A.Z.H., 1970. Lower Oligocene and Lower Miocene stratigraphy of the eastern area of Khanaqin Qadha, Iraq: Journal of the Geological Society of Iraq, Vol.3, No.1, p. 97 − 98.
- Amirshahkarami M (2013) Microfacies correlation analysis of the Oligocene-Miocene Asmari Formation, in the central part of the Rag-e-Safid anticlinal oil field, Zagros Basin, south-west Iran. Turk J Earth Sci 22:204–219
- Amirshahkarami M, Vaziri-Moghaddam H, Taheri A (2007) Sedimentary facies and sequence stratigraphy of the Asmari Formation at Chaman-Bolbol, Zagros Basin, Iran. J Asian Earth Sci 29:947–959
- Aqrawi, A.A.M., Goff, J.C., Horbury, A.D. and Sadooni, F.N., 2010. The petroleum geology of Iraq: Scientific Press, 604pp.
- Bellen, R.C., Van Dunnington, H.V., Wetzel, R. and Morton, D., 1959. Lexique Stratigraphic International. Asie, Fasc. 10a, Iraq, Paris, 333pp.
- Bennett, R. H., K. M. Fischer, D. L. Lavoie, W. R. Bryant, and R. Rezak. 1989. Porometry and fabric of marine clay and carbonate sediments: Determinants of permeability. Marine Geology 89:127-152.
- Buday, T., 1980. The regional geology of Iraq, Vol.1, Stratigraphy and paleogeography: Dar Al-Kutub Publishing House, University of Mosul, Mosul, Iraq, 445pp.
- James, G.A. and Wynd, J.G., 1965. Stratigraphic nomenclature of Iranian oil consortium agreement area: AAPG Bulletin, Vol.49, No.12, p. 2182 – 2245.
- Luc Alberts & Gert Jan Weltje. Department of Applied Earth Sciences, Delft University of Technology. PO Box 5028, NL-2600 GA Delft, The Netherlands
- Mohammed, Q.A., 1983. Biostratigraphy of Kirkuk Group in Kirkuk and Bai Hassan areas (Unpublished) Master Thesis: College of Science, Baghdad University, 187pp.
- Ponikarov, V. P. and Kazmin, V. G.: Precambrian and Paleozoic deposits in northwestern Arabian Peninsula, Sovetskaya Geologiya, N3, 89–99 (in Russian), 1965.
- Sadeq QM, Wan Yusoff WIB (2015) Porosity and Permeability Analysis from Well Logs and Core in Fracture, Vugy and Intercrystalline Carbonate Reservoirs. J Aquac Res Development, Vol. 6, issue 10: 371.
- Tarek, A. 2006. Reservoir Engineering handbook, 3 Ed.
- Ziegler, M.A. (2001) Late Permian to Holocene Paleofacies Evolution of the Arabian Plate and Its Hydrocarbon Occurrences. Geo Arabia, 6, 445-504.