

## The Effect of Clay Fraction Quality and Quantity on Petro Physical Characteristics: Smulated Case Study Investigation

Nada Achi\*, Benzagouta Mohamed Said, Khodja Mohamed, Lateef Akendji

Department of Geology, University of OEB, Algeria

\***Corresponding author:** Nada Achi, Department of Geology, University of OEB, Algeria. Tel : +213770259557 ; Email: na-daachi@yahoo.fr; msbenzagouta@gmail.com

**Citation:** Achi N, Said BM, Mohamed K, Akendji L (2018) The Effect of Clay Fraction Quality and Quantity on Petro Physical Characteristics : Smulated Case Study Investigation. Arch Pet Environ Biotechnol : APEB-134. DOI : 10.29011/2574-7614. 100034

**Received Date :** 17 April, 2018 ; **Accepted Date :** 19 June, 2018 ; **Publisher Date :** 25 June, 2018

### Summary

Reservoirs rocks can be of high economical interest. The porous mediums are allocated to fluid storage and circulation. They can be under the control of diverse parameters when they are found at reservoir conditions. Involvement of clay fraction and type, filling pores, is of high contribution towards the reduction of pore volumes. Similar situation is responsible for the creation of micro barriers, bridges and occlusion. In the case study, investigation based on laboratory experiments has revealed, that, reservoir is mainly controlled by compaction in addition to the type and fraction of simulated cement. It has been found that impact on petro physical characteristics was down to the type of clay, beyond burial pressure, grain-to-grain degree of contact related to grain textural type. The overall results reveal that sandstone with illite clay fraction is better concerned with permeability and porosity development and preservation. Thus, similar statement leads to efficient fluid circulation and better recovery.

**Keywords:** Artificial Cores; Permeability; Porosity; Reservoir

### Introduction

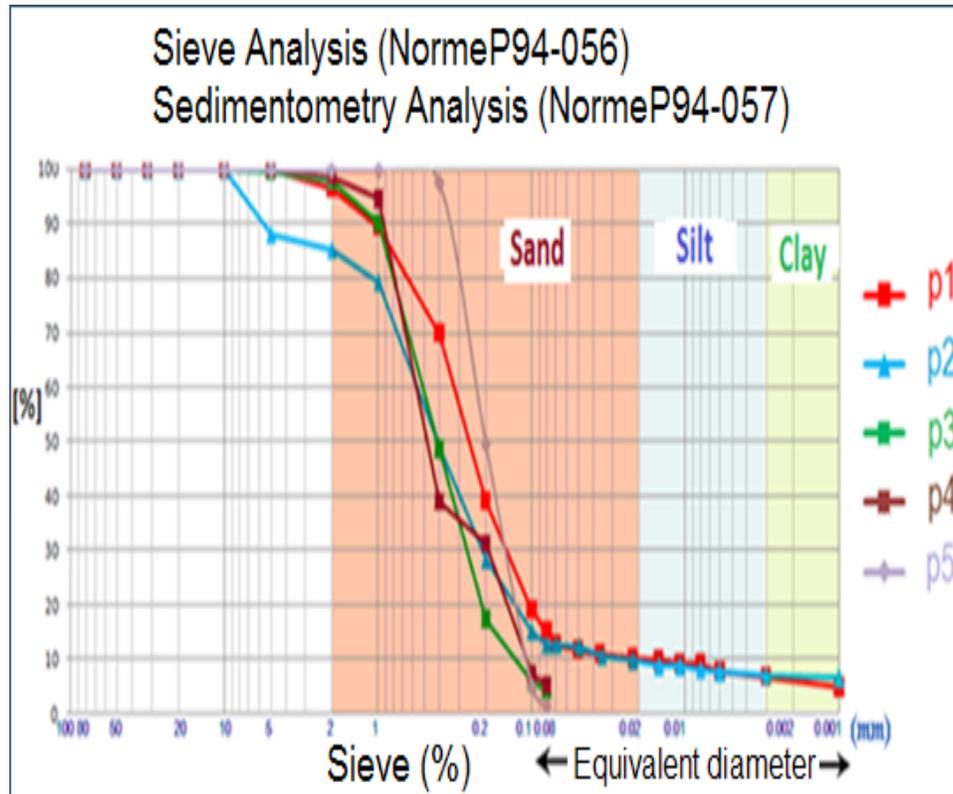
It is known that reservoir systems can be made of different types of essentially sedimentary lithology, composed of types of mineralogy, grain sizes, pores, pore throats and their geometry. Investigation in that purpose has been led by different researches [1-2]. Control on detailed reservoir characterization and, for better understanding, can be approached through its physical properties: formation testing, and laboratory analysis services [3-5]. Introduction and investigation on artificial reservoir rock behavior and fluid circulation can be an issue for the optimization of the reservoir lifetime performance prior to a real and natural reservoir [6]. Previous investigations have focused on the combined effects of fluid saturation, potentials and Petrophysical characteristics required in achieving the desired reservoir quality [7]. However, the inter-relationship between the complex reservoir rock morphology and fluid circulation potential, in relation to variation of textural and physical properties, is yet to be entirely understood.

Thus, the purpose of this research is to establish the degree to which the permeability of synthetically generated sandstone samples varies based on clay cement injection. The selected sandstone was of a mixture of different textural and physical properties. Complex geological internal arrangement with grain size distribution, composition, morphoscopy, injected clay mineral types and fraction, compaction and pressure and the degrees of heterogeneity of material, are the most considered parameters in this investigation. Focus on other in situ parameters controlling fluid circulation such as, the shape factor, tortuosity coefficient and pore radius and pore shape geometry are equally involved in the change of fluid circulation potential.

In this case study, locally selected quartz dominant sand quarries were obtained on the basis of textural and physical properties. The configuration and physical properties of the artificial model are similar to Berea Sandstone, Dundee Samples, Split Rock - Liver Rocks or Ohio Sandstone Samples (USA). Beyond the obtained results, the adopted procedure can be faster and less expensive prior to natural reservoir cores analysis use.

## Equipment and Methods

Materials were identified on the basis of textural particle size analysis by sieving fraction distribution and sedimentometric analysis for dispersed sediments: detrital sediments with quartz dominant minerals (Figure 1).



**Figure 1:** Indicating the sampling versus Particle Size Distribution (PSD) at different located areas.

Collection of sands from different Algerian sites (Table 1) in addition to well-known clay minerals (bentonite, kaolinite and illite)

Sampling	Situation	Lambert coordinats		
		Y	X	Z(m)
P1	Sand quarry Hamma Bouziane - Constantine, Algeria	6°33'44.70"E	36°25'40.72"N	387
P2	PK224 Zighoud Youcef - Constantine, Algeria	6°43'16.34"E	36°31'13.77"N	606
P3	Sand quarry Elma Labiod - Tebessa, Algeria	8°05'50.21"E	36°25'40.72"N	1089
P4	Sand quarry Cheria - Tebessa, Algeria	7°58'10.31"E	35°14'40.27"N	1191
P5	Sand quarry Boussaâda - M'sila, Algeria	4°07'01.16"E	35°15'04.86"N	671

**Table 1:** Localization of collected samples.

Chemical analysis and cleaning was also achieved in the laboratory for the purpose of expelling undesired compounds prior to the mixture step. This cleaning process is targeting material less than 2 $\mu$ m using sedimentometric sieving [8].

### Morphoscopic Grain Analysis was also Made

#### Cores preparation

Sand mixed with each type and amount of clay was prepared. The overall is pressurized progressively up to normal reservoir conditions pressure around 8000ft, thus, artificial compaction corresponding to natural reservoir burial was generated. Cores are obtained according to the cylindrical odometer core holder (Figure 2)



**Figure 2:** Indicating the sand - samples preparation and mixture with clay injection type.

### Experimental Procedure

Grain Size Analysis and Grain Size Distribution (GSA and GSD) and sedimentometric process worked out from collected material were restrained to some parameters calculation e.g. uniformity coefficient (CU),  $\Phi_d$  (grain diameter) and fine grains fraction. This procedure was aimed to better characterization of the material. Analysis was made using French norms (NF P94-056). Results are illustrated through a semi logarithmic graph, designed to screening the dispersion spreading grain size intervals versus cumulative weight percent. Oute comes were illustrated graphically as shown in Figure 1. Sedimentometric analysis was also brought out. Its application was conducted to fine grains less than 80 $\mu$ m analysis according to the French norms (NF P94-057). This method is mainly based on Navier-Stockes equation where fine material movement and settlement is related to particle density, particle diameter, fluid viscosity, gravity and velocity. However, the overall of this process was to assess the Particle Size Distribution (PSD) which can greatly affect the efficiency of fluid circulation prior to any clay injection. This extra amount of clay might introduce an additional out of control obstacle, when it consists on the filterability of the liquid versus the mentioned particle size present. Tools used for that purpose are mainly at sedimentometric scale measurement set in the Geotechnical Laboratory (Figure 3) (Table 2)

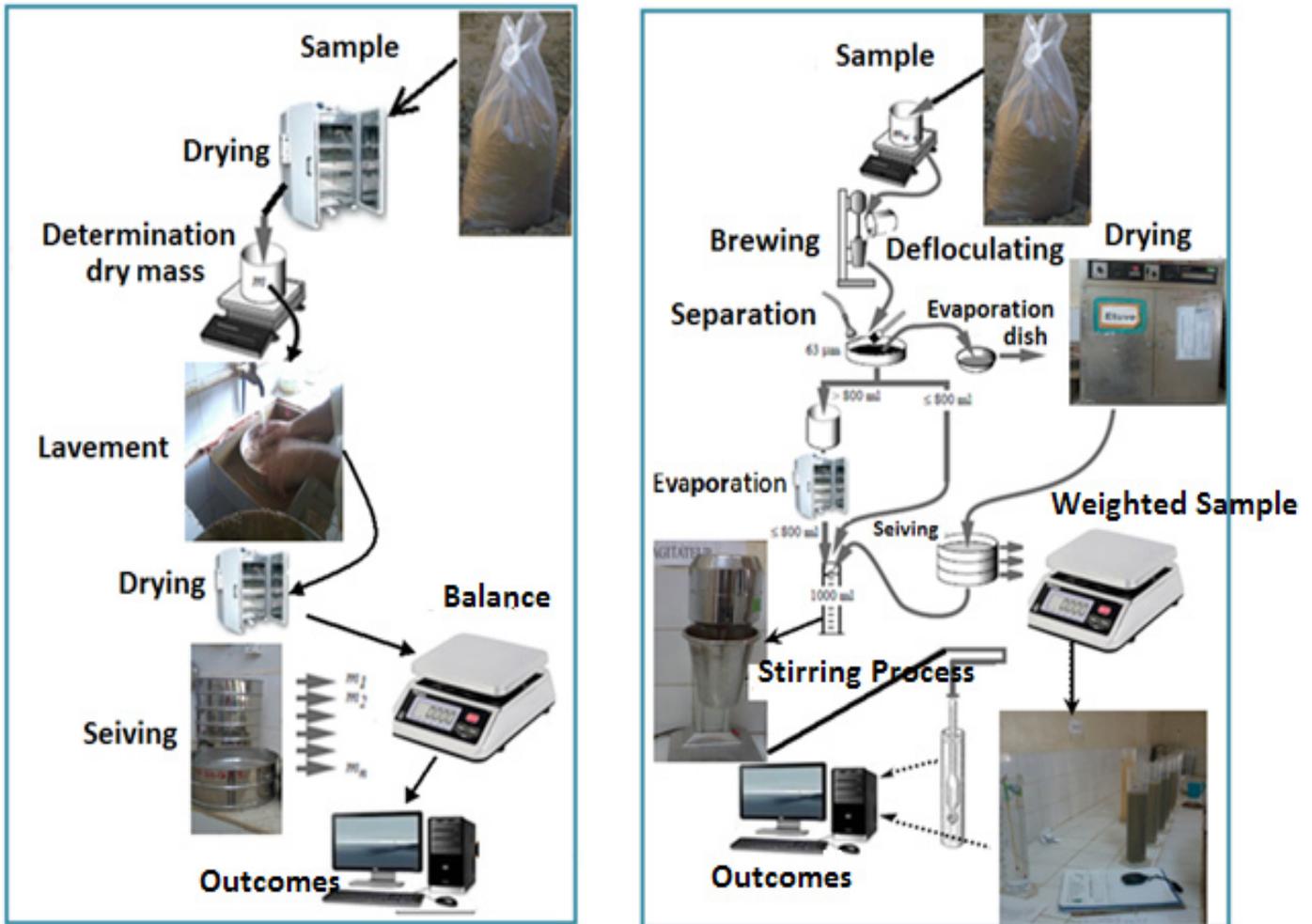


Figure 3: Showing the used material in the laboratory for the purpose of measuring the less than 2µm fraction contained in the selected samples.

Size	P1	P2	P3	P4	P5
D max (mm)	5	5	2	1	0.4
2mm	96%	85%	98%	99%	100%
80µm	15%	13%	4%	5%	2%
60µm	13%	13%	/	/	/
2µm	6%	7%	/	/	/
Cu	6.66	15.71	3.33	4.58	1.83
Cc	19.26	2.29	1.04	0.60	0.96
Curve Classification	Expanded and continuous	Expanded and discontinuous	Tight curve	Tight curve	Tight curve

Table 2: Results of Pore Size Distribution (PSD) analysis supporting the outcomes of Figure 2 with Cu coefficient of conformity and Cc curvature coefficient.

Data analysis in that use has revealed the expanded curves outcomes where material is fluctuating from sand dominant amount to silt fraction with a lesser amount of clay portion (Figure 2). Based on the obtained graph, it is known that, once mixed, similar material will result on any required heterogeneity statement. Subsequently, similar material with related extending intervals will affect petro physical characteristics in dissimilar ways. Obtained results (Figure 2) allow, as mentioned previously, the calculation of parameters such as coefficient of uniformity based on  $d_{60}$  and  $d_{10}$  (in mm) and Curvature factor according to the formula

$$C_u = \frac{d_{60} \text{ (mm)}}{d_{10} \text{ (mm)}}$$

$$C_c = (d_{30})^2 / (d_{10} \cdot d_{60})$$

$C_u$ : The Hazen Coefficient of Uniformity

$C_c$ : The coefficient of curvature

$d_i$ : diameter corresponding to  $i\%$  of percentage of cumulated sieve

These material parameters calculation are carried out to view the gradation impact versus permeability ( $K$ ) and porosity determination beside heterogeneities effect. These factors express also the particles size distribution, which has a direct impact on the considered material physical properties.

## Permeability Measurement

Regardless both petro physical characteristics which were targeted in this investigation, our action in this research is focusing mainly on the permeability or the hydraulic conductivity changes based on the process of consolidation (load or discharges). We have to stress that cores preparation was made by system of consolidation: air expulsion in a vacuum prior to water saturation. Thus, behavior of rocks on subsurface can be similar to the soil but under certain pressure and temperature conditions [9].

In the case study, permeability was measured at ambient temperature (20°C). The permeability measurement was made according to the following operating mode and under the experimental norms XP CEN ISO/TS 17892-11. The modal type is an oedometer consisting of:

- Oedometer host Graduated Piezo metric tube, Water disposal feeding with 3 spot water,
- Oedometric cell for drainage (flow rate)
- Oedometric ring and chronometer

Related principle is allowing the variation in porous medium and expulsion of certain fluid. The flow rate change can be noticed through the variation of water column head feeding. Ability and variation in sample hydraulic conductivity performance is up

to the sample physical and petro physical attributes under the set conditions of pressure, clay type and fraction. Thus, results under these conditions reveal the reservoir behavior: reservoir characterization and changes.

## Results

### Permeability Results

#### Review on permeability measurement

More details in that purpose can be from the use of hydraulic conductivity where calculation of  $K$  using statistical parameters determination can be stated on the basis of Graphic Geometric Mean ( $G_m$ ), effective grain size ( $C$ ) [10] Permeability calculation or hydraulic conductivity can be deduced from:

$$K = 760(G_m)_d^2 e^{-(1.31\sigma)} \text{ (mm}^2\text{)}$$

$K$ : intrinsic permeability (Darcies)

$G_m_d$ : geometric mean grain diameter

$\sigma$ : standard deviation

Thus, most poorly, moderate or well-sorted particle size distribution with a lesser or greatest size distribution classes is directly affecting the petro physical properties. It will reveal the mixture distribution and then the heterogeneity system. Similarly, the porosity can be calculated from statistical grain size distribution method thus [11]

$$\sigma = -\log_2 d = -\left[\frac{\log_{10} d}{\log_{10} 2}\right] = -\log_2 d = -\left[\frac{\log_{10} d}{\log_{10} 2}\right]$$

For permeability calculation, diverse equations can be used essentially for soil drainage, engineering properties seepages [12-14]. Several empirical equations have also been proposed for the evaluation of the coefficient of permeability. One of the earliest method is that proposed by [15]. He developed the well-known empirical equation:

$$K = C(d_{10})^2$$

$K$ : coefficient of permeability “conductivity” (Cm/s)

$d_{10}$ : effective size (mm)

$C$ : constant, varying from 1.0 to 1.5

Support for the evaluation of permeability measurement and evolution can be from the determination of porosity with the involvement of grain size distribution, mean, and median [16-18]. In related approach, the Kozeny and Carmen equation, (1939) where permeability determination, in a single phase, cannot be established without grains properties such as: Grains Volume (gv), Specific Surface Area (SSA) and porosity determination. The equation can be set as:

$$k = \alpha \left(\frac{\Omega}{S}\right)^2 \frac{\phi^3}{(1 - \phi^2)}$$

In the case study, the experimental investigation and k determination were defined according to the method XP CEN ISO/ TS 17892-11 and Hazen (1937):

$$k = 2.3 \frac{A}{S} \cdot \frac{H}{(t_1 - t_0)} - \log \left(\frac{h_0}{h_1}\right)$$

A: piezometric tube section (Cm<sup>2</sup>)

S: pipe section (Cm<sup>2</sup>)

H: pipe thickness (Cm)

h: reading of peizometric tube level changes “differential head of water changes” (Cm)

t: time changes in readings (s)

Under different types of clay injection and their rate, the permeability measurements results were (Table 3). The obtained results were depending on each statement we scheduled: clay injection type and rate, pressure effect and grain characteristics.

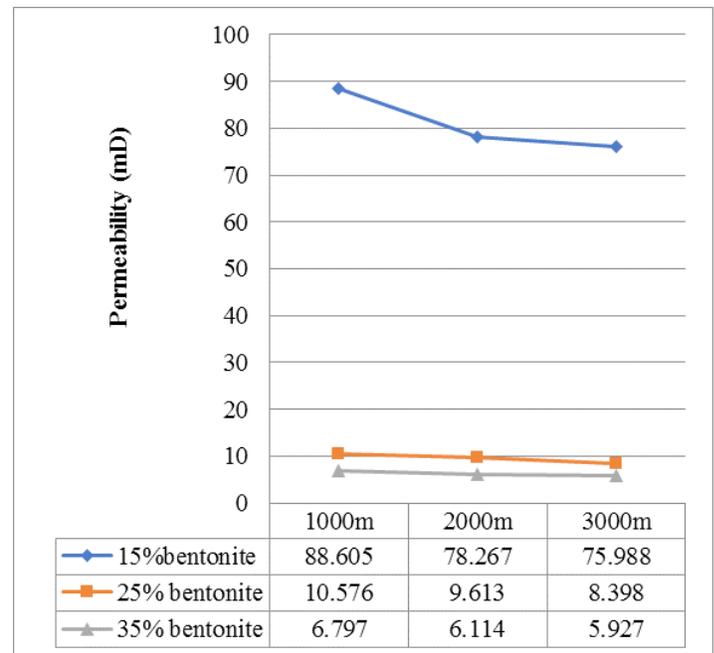
Sample designation	Permeability (mD)	Classification (K)	Clay type and rate injection
1-1	6.5	Low	35% bentonite
1-2	6.1	Low	
1-3	6	Low	
2-1	10.5	Very low	25% bentonite
2-2	9.5	Low	
2-3	8.2	Low	
3-1	88.6	Moderate	15% bentonite
3-2	78.3	Moderate	
3-3	76	Moderate	
4-1	91	Moderate	35% kaolinite
4-2	82.5	Moderate	
4-3	76.5	Moderate	
5-1	160.5	Moderate	25% kaolinite
5-2	104	Moderate	
5-3	90	Moderate	
6-1	272	Well	15% kaolinite
6-2	247.8	Well	
6-3	219.3	Well	
7-1	79.6	Moderate	35% illite
7-2	76	Moderate	
7-3	73.6	Moderate	
8-1	157.5	Moderate	25% illite
8-2	90.2	Moderate	
8-3	83.2	Moderate	
9-1	213.7	Well	15% illite
9-2	207.8	Well	
9-3	180.5	Moderate	

**Table 3:** Permeability Results with K classification and clay type in addition to clay type and rate.

However, these Permeability laboratory results according to pressure effect have indicated diverse gradient decreasing changes. These petro physical transformations are ascribed to the level of burial. Pressure gradient was a principal factor in that purpose [19]. Another significant in that cause is from the type and fraction of clay injection.

## Discussion

Variation of permeability versus clay types and fraction is not similar according to the variation in depth. According to the following obtained model: clay fraction, type and depth versus petro physical parameters, (mainly permeability), we set up that, permeability change is relatively erratic versus each involved parameter (Figure 4,5 and 6). However, the general tendency is towards the decline of the permeability (k) but, respectively to each type, amount of clay and considered depth. This decrease is in harmony with the increase of each depth and clay fraction. The most harmful clay type is bentonite, with a lesser extent to illite with regard to kaolinite effect.



**Figure 4:** Indicating the effect of clay type and fraction versus depth on permeability decline (case of bentonite).

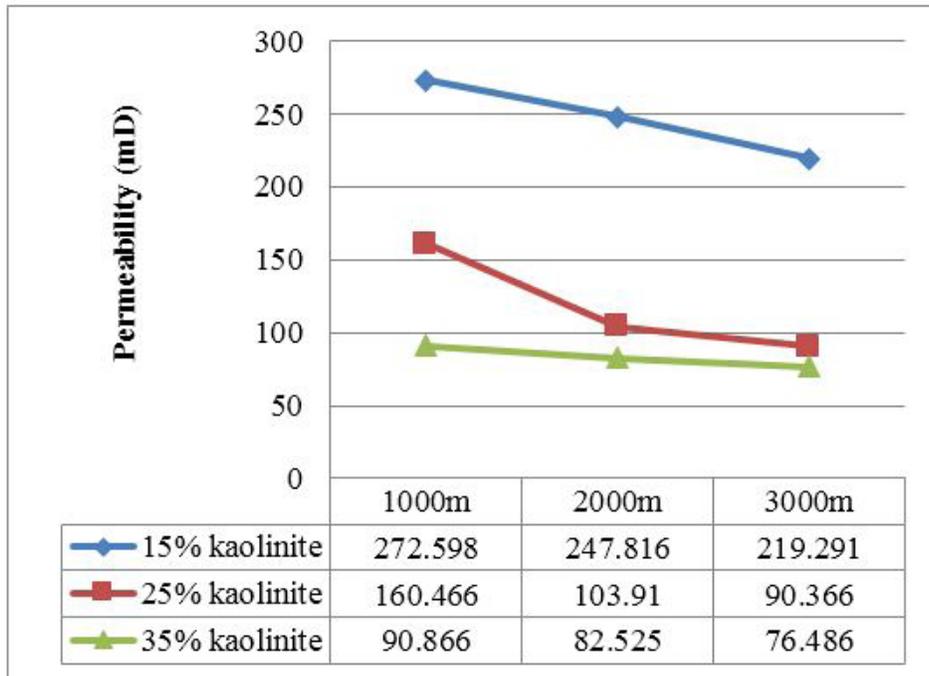


Figure 5: Indicating the effect of clay type and fraction versus depth on permeability decline (case of kaolinite).

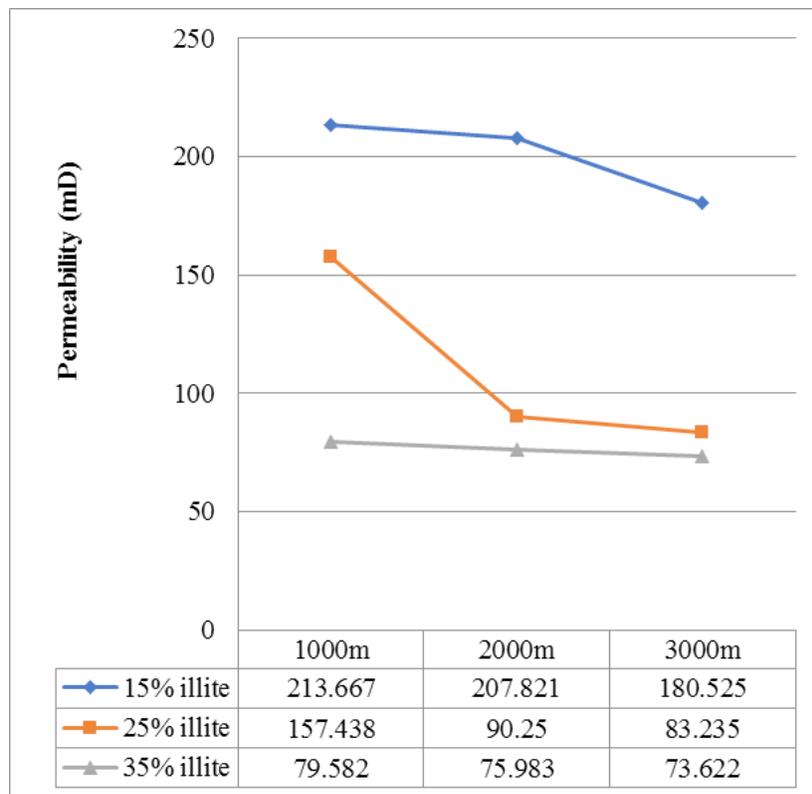


Figure 6: The effect of clay type and fraction versus depth on permeability reduction (Case of illite).

Using similar records and with reference to Boursier graphic adapted to the case study results. (Figure 7).

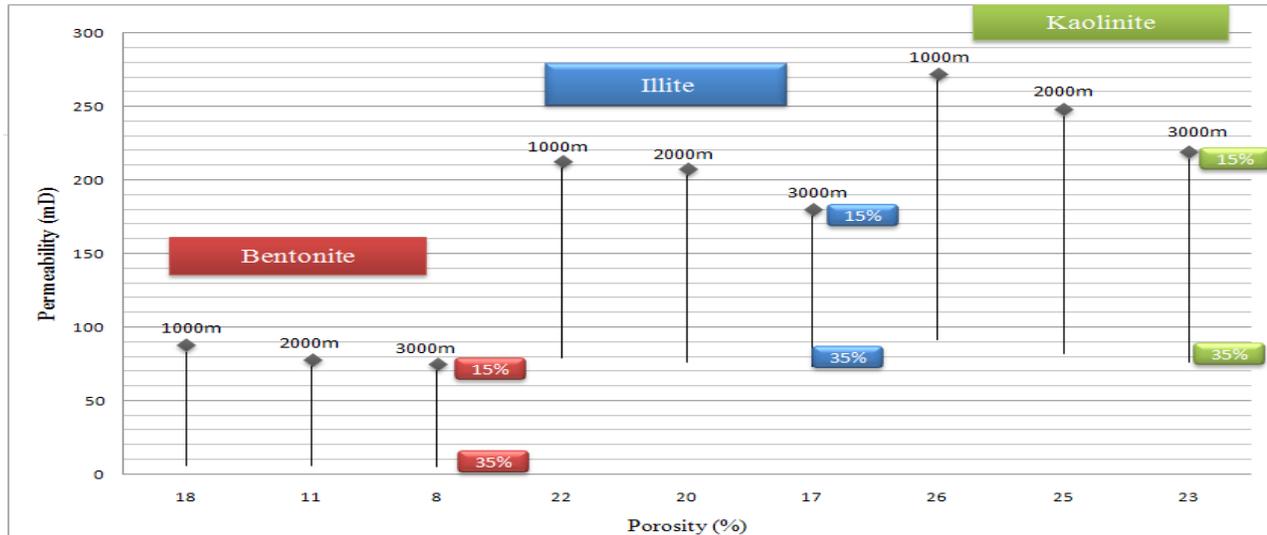


Figure 7: Illustrating results on the decline of petro physical characteristics based on overload pressure and clay type -injected fraction.

However, the focus on the permeability changes can be related to clay properties where their hydrophilic and hydrophobic properties play an essential role in that principle. It is known that clay minerals are composed structurally by aluminosilicate hydrates, which are associated with some cations (Ca, Na, Mg, K and Fe) on the surface. The presence of similar ions can be responsible for the properties changes of the minerals. In the presence of water, similar ions will be hydrated leading to a considerable increase of their diameter. This increase is up to the cations concentration and also to the specific Surface Area of the Grain (SSA) [20]. The change occurring is associated to the Cations Exchange Concentration (C.E.C). Similar occurrence conducts to the adsorption phase. Occurrence is more important with bentonite Clay (SSA 800m<sup>2</sup>/g) rather than illite (SSA 100m<sup>2</sup>/g) or kaolinite with (10 to 20 m<sup>2</sup>/g). For sands sample specific area, we know that it cannot exceed 5m<sup>2</sup>/g. Similar process is encouraged by the typical structure of clay as phyllosilicates or interlayers arrangement leading to differential swelling process. Thus, this swelling becomes responsible for the reduction of pore spaces and impeding fluid circulation. The clay growth plays an important role in creating bridges and occlusion resulting on the inhibition of fluid circulation [3,6]. In addition to this, simulated cores with material physical properties, starting from particle size distribution (PSD) up to the pore size distribution. These parameters are also involved in the permeability control regarding the different rock measurable and determined properties: shape factor, tortuosity coefficient, pore radius, and textural grain parameters including consolidated grains degree. The overall is issued mainly from the compaction factor, which is the main source in that regard. All

these parameters are implicated in the effect of the flow pattern and fluid circulation within the porous medium [21-26].

In our case study, the artificial material arrangement with the synthetic cement filling pores cannot certainly reveal the real reservoir. They can be representing the host of H-C reservoirs storage and circulation, under some reserves. We approached this simulation without including the diagenetic effect responsible for occlusion and secondary pores generation. Similar processes are able, and up to a certain degree, to change the reservoir porous medium characteristics. The simulation is intended to investigate in the field and to build up any reservoirs with some essential records, allowing better understanding, and saving massive real material prior to consuming authentic reservoir cores. However, and in the case study, advantage in hydraulic conductivity simulated discrepancy can be receptive since detailed changes in the artificial model, we build up, can be under control. But, we can be convicted that, the led investigation is not reflecting a real reservoir since; we are not able to control the real in-situ parameters behavior.

## Conclusion

Reservoirs rocks and porous medium can be of high economical interest. The porous mediums are allocated to fluid storage and circulation. They can be under the control of diverse parameters when they are found at reservoir conditions. Involvement of clay fraction and type, filling pores, is of high contribution towards the reduction of pore volumes. It is responsible for the creation of micro barriers and occlusion for fluid accumulation and mobility. In the case study, investigation

based on laboratory experiments has revealed, in that regards, that reservoir is mainly controlled by compaction in addition to the type and fraction of simulated cement. It has been found that impact on petro physical characteristics was down to the type of clay, beyond pressure and grain texture type. Kaolinite clay mineral type was the less harmful with regard to the permeability and porosity in comparison to illite and mainly bentonite. However, in the presence of aqueous solution, swelling intensity was higher with bentonite mineral in comparison to kaolinite and illite. During drainage and essentially the imbibition, impact from the wettability (soaking and suction) system was defined. Results were in harmony with the imbibition rather than drainage at atmospheric conditions. Within the diphasiques phases, imbibition supports the hydrophilic character of the bentonite illite clay minerals, whereas the kaolinite was as hydrophobic. Thus, and regarding the reservoir, sandstone reservoirs with the presence of kaolinite are better reservoir characteristics but hydrphobe. Reservoirs with bentonite clay fraction are less petro physical characteristics development; even so, it is important to mention that bentonite is hydrophilic type. The overall results reveal that sandstone with illite clay fraction is the better concerned with permeability and porosity development or preservation leading to efficient fluid circulation and recovery.

## References

1. Asquith G, Gibson C (1982) Basic Well Log Analysis. AAPG published by American Association of Petroleum Geologists, Copyright 215.
2. Selley R (1998) Elements of Petroleum Geology. In : 2<sup>nd</sup> Edition, Academic Press Limited, London NW1 7DX, UK.
3. Benzagouta MS (1991) Petrophysical Characteristics Control on the Buchan Oilfield (North Sea). unpublished thesis of PhD, 330, University of Newcastle upon Tyne, UK.
4. Benzagouta MS (2001) Reservoir heterogeneities, in fracturing Fluvial reservoirs of the Buchan Oilfield (Northern North Sea). Oil and Gas Science and Technology-Rev, IFP (French Institute for Petroleum) (ISI) 56 : 327-338.
5. Benzagouta MS (2013) Investigation on the Impact of Rock Physical Properties on Permeability Variation: Case Study for the Reservoir Heterogeneity Development. Nafta. Regards Technical editor B 64: 130-134.
6. Achi N, Benzagouta MS (2015) Caractérisation d'un réservoir gréseux par simulation de crottes artificielles. Thèse de magister. Université de Constantine 1, Algérie.
7. Katza J, Thompson AH (1985) Fractal sandstone pores : implications for conductivity and pore formation. 54: 1325.
8. Atterberg AM (1905) La classification national des sables et graviers. Chemiker Zeitung 29.
9. Whitlow R (2000) Basic soil mechanics. Edition Harlow: Prentice Hall oil & Gas Science and Technology 45 : 685-701.
10. Pfannkuch HO, Paulson R (2013) Grain Size Distribution and Hydraulic Properties.
11. McManus J (1988) Grainsize determination and interpretation. In Techniques in Sedimentology, Tucker M (ed). Blackwell : Oxford 63-85.
12. Bowels JE (1970) Engineering Properties of Soils and Their Measurement. McGraw HillBook Co New York
13. Darcy H (1856) Les fontaines publiques de la ville de Dijon-Exposition et application des principes à suivre et des formules à employer dans les questions de distribution d'eau. Victor Dalmont éditeur.
14. Lambe TW, Whitman RV (1979) Soil Mechanics SI Version. John Wiley and Sons, New York, 553.
15. Hazen A (1930) Flood flows : A study of frequencies and magnitudes. Editeur: J Wiley & Sons New York 199.
16. Fair GM, Hatch LP (1933) Fundamental factors governing the streamline flow of water through sand. J American Water Works Ass 25 : 1551-1565.
17. Krumbein WC, Monk GD (1942) Permeability as a function of the size parameters of unconsolidated sand. Transactions of the American Institute of Mining and Metallurgical Engineers 151: 153-163.
18. Harleman DRF, Melhorn PF, Rumer RR (1963) Dispersion-permeability correlation media. Am Soc Civ (NY) 2: 67-85.
19. Benzagouta MS (2012) Reservoir heterogeneities determination by the use mercury injection capillary pressure (M.I.C.P) method tight case.
20. Philipponnat G, Hubert B (2003) Fondations et ouvrages en terre. Edition EYROLLES 576.
21. Carman PC (1956) Flow of Gases Through Porous Media. New York City: Academic Press Inc.
22. Amyx JW, Bass DM, Whiting RL (1960) Petroleum Reservoir Engineering. New York City McGraw-Hill Book Co.
23. Hears TJR, Nelson PH, Paillet FL (1985) Well Logging for Physical Properties. New York City: John Wiley & Sons 18: 576.
24. Timur A (1968) An Investigation of Permeability, Porosity & Residual Water Saturation Relationships for Sandstone Reservoirs 9 : 10.
25. SPWLA-1968 Society of Petro physicists and Well Log Analysts (SPWLA), Houston 9th Annual Logging Symposium, 23-26 June, New Orleans, Louisiana
26. Walsh JB, Brace WF (1984) The effect of pressure on porosity and the transport properties of rock. Journal of Geophysical Research: Solid Earth 89 (B11): 9425-9431.