MICROSCOPIC EFFECTS AND POROUS MEDIUM

Reçu le 04/12/2004 – Accepté le 26/06/2007

Résumé

L'objectif de cet article est de montrer un travail expérimental permettant d'éclaircir l'effet des tailles d'échantillons de roches sur la porosité. Autrement dit, ce test révèle deux domaines :
- Les effets microscopiques où de grandes variations de porosité devraient être observées.
- Le milieu poreux homogène où l'effet d'ajouter ou de soustraire un ou plusieurs pores, n'a pas d'influence significative sur la porosité

Mots clés: *Effets microscopiques, milieu poreux, tailles des échantillons de roches, porosité ouverte (porosité efficace), saturation en eau, technique du vide, grès, coupes, homogène, hétérogène, pore unique.*

S. GHEBOULI
Département Science de la Terre
Faculté des sciences de la Terre,
De la Géographie, et de
l'Aménagement du territoire.
Université Mentouri Constantine
Algérie

Abstract

The objective of this paper is to show an experimental work elucidating the effect of rock sample sizes on porosity. Otherwise, this testing reveals two domains :
- The microscopic effects where a great variations in porosity should be observed.
- The homogeneous porous medium where the effect of adding or subtracting one or several pores, has no significant influence on the porosity.

Keywords: *Microscopic effects, porous medium, rock sample sizes, effective porosity, water saturation, vacuum technique, sandstone, cuts, homogeneous, heterogeneous, single pore*

ملخص

الهدف من هذا المقال هو إظهار عمل تجريبي يسمح بتوضيح تأثير الحجم لعينات من الصخور على المسامية. وبطريقة أخرى, التجربة تبين مجالين :
- التأثيراتالمجهرية أين يجب أن تظهر اكبر التغيرات المسامية.
- الوسط المسامي المتجانس أين تأثير زيادة أونقصان واحد أوعدد كبير من المسام، ليس له فاعلية معتبرة على المسامية.

الكلمات المفتاحية *: التأثيرات المجهرية، الوسط المسامي، الأحجام لعينات من الصخور، المسامية الفعالة، التشبع بالماء، تقنية التفريغ, الحجر الرملي, القطع, متجانس، غير متجانس، السم الأحادي*

Groundwater is one of the most important resources on earth. It exists almost everywhere although not always in recoverable quantities and in many areas, it is more valuable than surface water because of its lack of pollution. Most of it is stored in and transmitted through porous media which are characterized by one of the aquifer properties known as porosity.

Porosity is a property of great importance in the estimation of the economic value of porous medium, as it indicates the total water content of aquifers and petroleum reservoirs.

This paper deals with an experimental work elucidating the effect of rock sample sizes on porosity.

It briefly describes an effective porosity determination by water saturation using vacuum technique. It, also, explains particularly a low variation in effective porosity within a small size or a small volume of a rock samples.

Taking into consideration that, an effective porosity determination was done on a different block sizes of a fine grained sandstone.

1. EXPERIMENTAL WORK

The method used for the laboratory testing of effective porosity was a direct method of water saturation using vacuum technique [2].

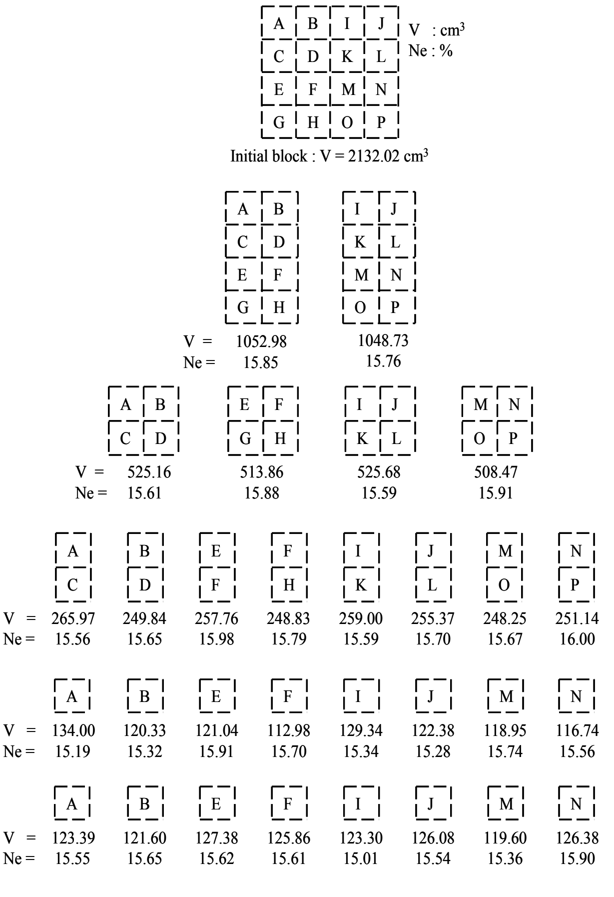

Figure 1 : Diagrammatic representation of the cutting procedure of the large sandstone block and effective porosity determinations. (In Ghebouli, 1988. p. 58).

This saturation technique is not similar than that of the one used in direct contact within atmospheric air during for example a study of the behavior of an immersed core sample in a distilled water solution [3].

The experimental process consists of determining the porosity values of a large sandstone block and that of the blocks obtained after repeated subdivisions of the latter.

The large block obtained, measuring 25.046 x 15.840 x 5.374 cm^3, was labeled as shown in the diagrammatic representation (figure 1).

The initial whole block was not tested because it could not be placed in the desiccator for vacuum saturation.

Two tests were simultaneously carried out and the testing conditions (vacuum, temperature of distilled water and degree of saturation) were kept similar.

The fist test was run from the half-block: A, B, C, D, E, F, G and H to the single resulting blocks: A, B, C, D, E, F, G and H.

The second test was run with the other half-block: I, J, K, L, M, N, O and P to the single resulting blocks: I, J, K, L, M, N, O and P.

The technique of effective porosity determination was a direct method of testing. Each rock sample was labeled. It was rinsed in tap water and left overnight in a 1% solution of sodium hypochlorite (NaOCl) in order to remove fines which were produced during the cutting and to eliminate the growth of micro-organisms such as algae.

The rock sample was then dried in an oven at 105 degree C for a minimum period of 24 hours. The dry rock sample was first weighed. It was then saturated in a vacuum desiccator containing distilled water for a minimum period of 24 hours. It was carefully wiped and then weighed.

It was again dried and weighed in order to see if any particles were lost during the handling and the preparation process.

The volume of the rock sample was measured by taking caliper readings of the different dimensions.

Effective porosity is defined as follows [4]:

$$Ne = [V_v / V_t] \times 100\ \%.$$

where V_v and V_t denote respectively the gravity water and the total volumes of the rock sample.

In this case, it is meant by "V_v" the volume of the interconnected void spaces.

It should be noted that the void volume concerns only the interconnected pores.

Finally, effective porosity N_e(%) was determined by using the following formula :

$$N_e = [(M_s - M_d) / (V_t \cdot D_w)] \times 100\ \%.$$

where :

M_s and M_d denote respectively the saturated and dry weights of the half-block or the resulting block, expressed in g ;

V_t the volume of the half-block or the resulting block, expressed in cm^3; and

D_w denotes the specific gravity of water which was taken equal to 1 g/cm^3.

2. RESULTS AND DISCUSSION

The effective porosity values are mentioned in figure 1 and are in good agreement with the predictions, in the range of typical material [5].

From thirty determinations, the average effective porosity value was 15.63 %.

In order to show the effective porosity variations, four plots were done (figures 2, 3, 4 and 5).

The arrows indicate the direction of the cuts from a large to a small rock sample volumes.

Once all the volume (v) and effective porosity (N_e) values were obtained and plotted, the resulting curves $N_e(v)$ could be analyzed as follows.

Two domains might be mainly distinguished. They are defined as :

- First, the domain of microscopic effects and
- Second, the domain of porous medium.

Bear (1975) [6] mentioned that porosity will show variations if the sandstone is heterogeneous. He showed again that below a certain sample volume, large fluctuations in porosity will also be observed when the sample volume approaches that of a single pore and this is known as a domain of microscopic effects (figure 6).

This is not the case here. These plots (effective porosity against rock sample volume) do not show a consistent variation within a volume changes. The difference is less than 1 % for both tests, precisely 0.99 %.

This leads, therefore, to classify this fine grained sandstone tested in the domain of porous and homogeneous medium.

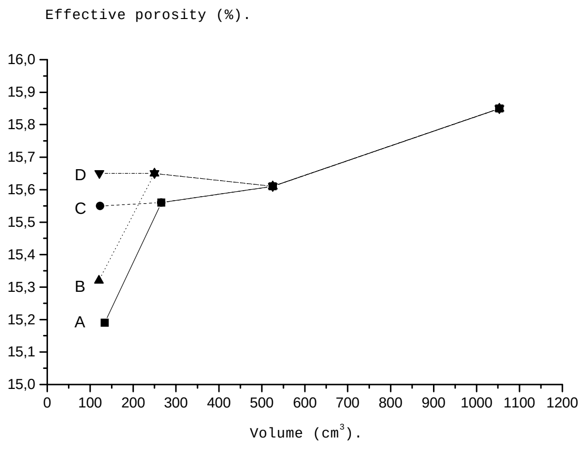

Figure 2 : Schematic curves relating effective porosity N_e to rock sample volume v (First test, samples: A, B, C and D).

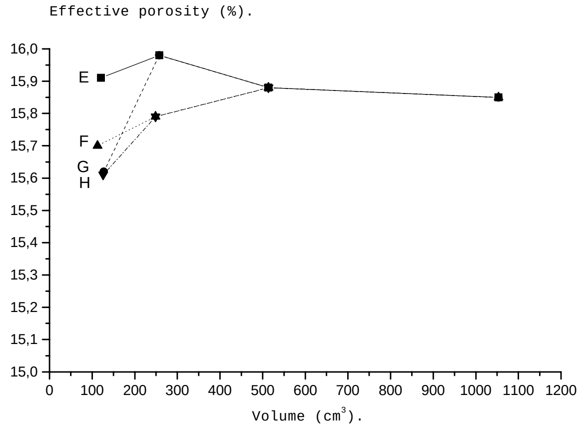

Figure 3 : Schematic curves relating effective porosity N_e to rock sample volume v (First test, samples: E, F, G and H).

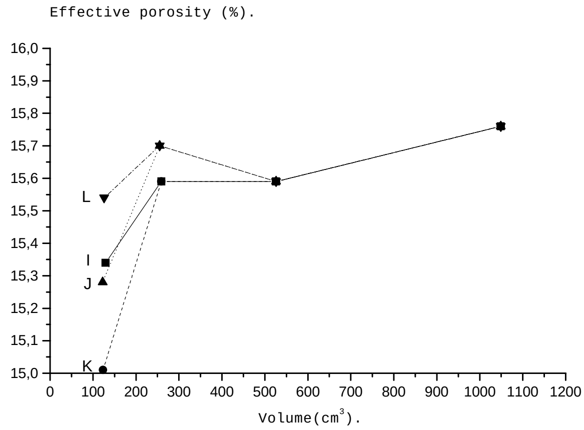

Figure 4 : Schematic curves relating effective porosity N_e to rock sample volume v (second test, samples: I, J, K and L).

Finally, it is suggested that if any small effective porosity fluctuations were obtained, this could be due to the effect of weights or that of rock sample volumes if some particles were lost during the testing process.

Consequently, this concept of 'microscopic effects and porous medium domains' leads to take into consideration:

First, for data to be representative [7], the measurement density should be such enough until approaching a sample that would be a representative elementary volume (R.E.V.);

Second, the application of the homogeneity concept to 'earth' medium which shows that it is closely related to the scale of the considered least elementary volume [8].

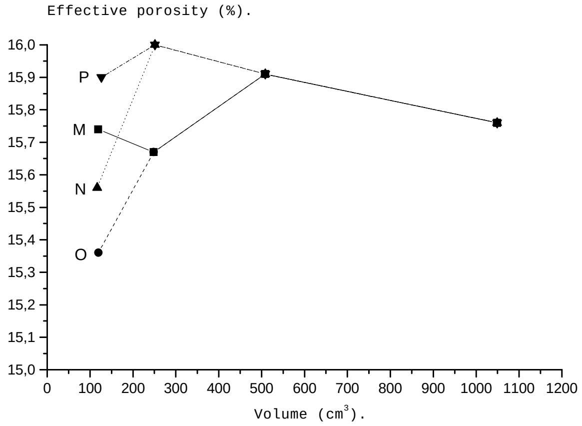

Figure 5 : Schematic curves relating effective porosity N_e to rock sample volume v (second test, samples: M, N, O and P).

The volume of the R.E.V. should be selected such that the volumetric averages can be considered as satisfactory estimates of all the relevant statistical parameters of the void space configuration [9].

Illustration to the determination of the R.E.V. size for a given porous medium domain has been shown by Bear and Verruijt (1987) [10].

Once the range of the R.E.V. is defined, the ratio V_v / V_t represents the medium porosity.

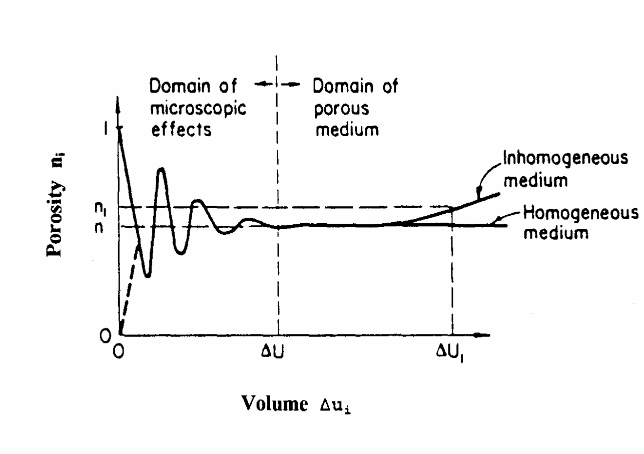

Figure 3 : Definition of porosity and representative elementary volume. (In Bear, 1975. p. 20). (modified).

CONCLUSION

With particular reference to water saturation using vacuum technique, the test process conducted does not consistently reveal the microscopic effects and porous medium domains. However, it shows a porous and homogeneous medium.

A further experimental work might be carried out, in order that emphasizes should be focused at the definition or the accurate boundaries of a representative elementary volume.

To clearly explain this porosity variations and taking into account an homogeneous sandstone, a further experimental work should be carried out on a very small sizes of rock samples. That is to say that the latter approaches the volume of a single pore.

REFERENCES

[1]- Unesco, “International Glossary of Hydrogeology”, First preliminary edition, Technical documents in hydrology, U.N.S.C.O., SC-77/WS/71, Paris, (1978), pp. 33 and 43.

[2]- Ghebouli S., “The aquifer and geophysical properties of some Devonian, Carboniferous and Permian sandstones”, M. Phil. thesis, University of Newcastle upon Tyne, (1988), pp. 42-58.

[3]- Ghebouli S., “Behavior of an immersed core sample in a fluid container during a saturation technique”, Sciences et Technologie, N°17, Revue semestrielle de l’Université Mentouri, Constantine, Algérie, (2002), pp. 119-121. **[4]**- Castany G., “Principes et méthodes de l’hydrogéologie”, Dunod Université, Paris, (1982), p. 87.

[5]- Todd D.K. “Ground water hydrology”, John Wiley and Sons Inc., U.S.A., (1959), p. 16.

[6]- Bear J., “Dynamics of fluids in porous media”, American Elsevier Publishing Compagny, Inc., New York,(1975), pp. 19-151.

[7]- Lepiller M., “Influence de la densité des observations sur la résolution des cartes piézométriques et la représentation conceptuelle des aquifères carbonatés : l’exemple de l’aquifère karstique de la craie du Gâtinais (Loiret et Yonne)”, Géologues, revue officielle de l’union française des géologues, N° 129, I.M.B., Paris, 2001, pp. 15 – 21.

[8]- Metreveli V., “Hydrogéologie et phénomène de transport”, O.P.U., Alger, (1990), p. 6.

[9]- Bachmat Y. and Bear J., “Macroscopic modelling of transport phenomena in porous media, 1: The continuum approach”, Transport in Porous Media 1, 1986, pp. 213-240.

[10]- Bear J. and Verruijt A., “Modeling groundwater flow and pollution”, D. Reidel Publishing Company, Dordrecht, Holland, (1987), pp. 17-21.