

A SIMPLE METHOD FOR MEASURING POROSITY IN ROCKS

BY S. BALAKRISHNA AND G. SHANKAR NARAYANA

(*Geology Department, Osmania University, Hyderabad-7*)

Received March 24, 1960

(Communicated by Dr. S. Bhagavantam, F.A.Sc.)

1. INTRODUCTION

THE measurement of porosity of a rock involves the evaluation of its pore volume and bulk volume. Any method that will enable the reliable determination of these quantities may be employed. The bulk volume can be determined either by direct measurement of its geometric form or by displacement of an equivalent volume of suitable liquid by immersing the coated specimen. The measurement of pore volume is an important and difficult feature of this experiment and several methods have been employed for this purpose. Tickell and others (1933) devised a porosimeter employing the phenomenon of change of length of mercury column with volume change in a manometer. Fancher (1950) employed the familiar Russel volumeter to measure the porosity of consolidated samples by saturating the sample with a suitable fluid and then observing the displacement or loss of weight resulting from immersion. Hughes and Cooke (1953) measured the porosity of rocks by using a modified Boyles Law apparatus which involves the evacuation of air contained in a rock by a pump. Davis (1954) suggested an empirical formula for estimating the porosity of sedimentary rocks from the bulk density. He had also shown that such estimated values closely agree with (3% discrepancy) the experimental results. The authors in the present investigation have employed Tickell's porosimeter with certain important modifications which make the method simpler and the results repeatable. The ease and accuracy with which the pore volume could be determined for a given rock and thereby the porosity calculated from its bulk volume is the essential feature of this method.

2. EXPERIMENTAL TECHNIQUE

Figure 1 shows the modified form of Tickell's porosimeter. The chief modifications introduced are:

(1) The height of the specimen chamber is increased to handle bigger samples.

(2) The constancy of the mercury level at the bottom is maintained by keeping a small dish in another bigger dish and thereby allowing for an overflow, instead of a shallow dish employed by Tickell, where the level of mercury is not likely to be constant.

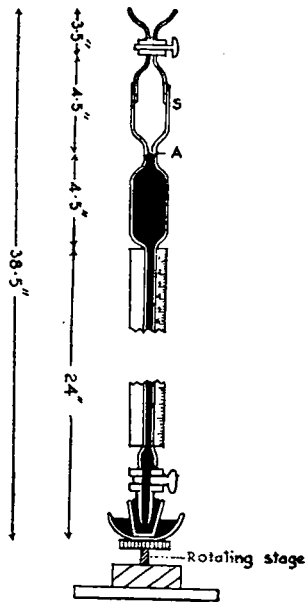


FIG. 1. Porosimeter.

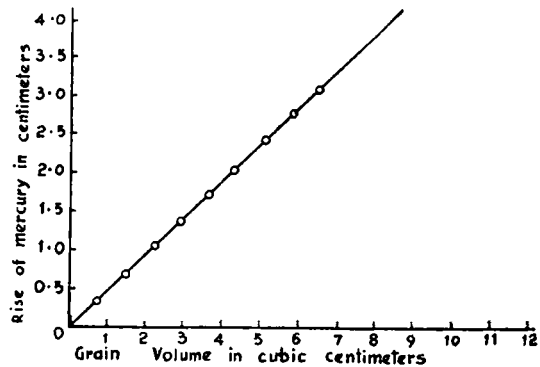


FIG. 2. Calibration Graph.

The bulk volume of the specimen is determined by measuring its geometric dimensions. Closing the lower stop-cock, mercury is poured in the vertical tube to the mark (A). By closing the upper stop-cock and releasing the lower stop-cock, mercury is allowed to fall into the dish and attain a steady state which is taken as initial reading (I_1). Again mercury is refilled to the mark (A) and in fact this operation is to be done whenever a fresh reading is to be taken. The dry specimen whose bulk volume is already determined is introduced in the specimen chamber (S). By releasing lower stop-cock, mercury is now allowed to come to rest at a higher position (I_2), since there is a reduction of air in (S) due to the grain volume of the sample. The difference between I_2 and I_1 will be the length of mercury column corresponding to the grain volume itself. Care has been taken to see that joints are airtight and the instrument is free from air-bubbles. From a knowledge of $I_2 - I_1$, the grain volume is then read off from an already prepared calibration graph (Fig. 2). From the knowledge of the bulk volume and grain volume, the pore volume is calculated from which the effective porosity ($P\%$) is computed.

The instrument is calibrated by taking a number of uniform ball-bearing shots (0.723 c.c.). As these B.B. shots are assumed to be practically non-porous, the rise in mercury column is due to the displacement of equivalent volume of air as a result of insertion of specimens in the chamber (S). Figure 2 shows the graph connecting the volume of ball-bearing shots with the corresponding rise in mercury level ($I_2 - I_1$) for the apparatus we have constructed. It can be seen from the graph that every 1 c.c. increase of volume will result in rise of mercury column to 0.5 cm. approximately. Further, the variation is found to be strictly linear as should be expected.

The rock specimens chosen here are of definite geometric shape usually of rectangular parallelepipeds. Such specimens will enable us to determine the bulk volume easily without taking recourse to wax coating and subsequent measurement by displacing a suitable liquid equivalent to its volume as done by other workers. The present method enables us to repeat our experiments and get the mean values while in other methods this becomes an impossibility. Another significant feature is that the specimen does not come into contact with the liquid. Air, because of its nearly perfect expansibility and low viscosity, penetrates the small and poorly connected pore spaces and gives a more accurate measurement of the effective porosity. This method is not affected by the variation of atmospheric pressure as we are taking I_1 and I_2 , at the same time and temperature correction is made whenever required.

3. RESULTS AND DISCUSSION

Employing the porosimeter described above and taking all possible precautions, measurements have been made in some limestones and sandstones. Results are given in Table I. Here density (ρ) is in grams/c.c., surface area (S.A.) is in square cm., Bulk Volume (B) is in cubic cm., difference in mercury level $I_2 - I_1$ is in cm., grain volume (G) is in cubic cm. as read off from the calibration graph. Porosity ($P\%$) is given as a percentage.

I_1 is 21.2 at room temperature 27° C. and atmospheric pressure 760 mm.

The values (Table I) are mean values of readings obtained a number of times. The values are repeatable and the accuracy is found to be fairly high.

The empirical formula suggested by Davis and referred to earlier for estimating the porosity (ϕ) in sedimentary rocks from Bulk density (ρ_b) in C.G.S. Units is

$$\phi = \left[\frac{2.654 - \rho_b}{1.654} \right] \times 100.$$

TABLE I
Porosity values

Specimen	ρ	S.A. sq.cm.	B c.c.	I_1-I_2 cm.	G c.c.	P%
Limestone—						
1	.. 2.7	8.98	1.818	0.8	1.7	6.49
2	.. 2.7	13.144	3.027	1.4	2.95	5.15
3	.. 2.7	35.897	10.85	5.1	10.65	1.84
4	.. 2.7	38.918	11.48	5.4	11.3	1.57
Sandstone—						
1	.. 2.47	24.138	5.615	2.1	4.3	23.44
2	.. 2.47	30.09	7.413	2.8	5.8	22.4
3	.. 2.47	34.687	9.05	3.4	7.1	21.55
4	.. 2.47	45.425	12.72	4.9	10.25	19.42

The expected or mean error in ϕ was shown by him to be small and equal to about 3%. The authors have calculated the porosity employing this formula and the results (a) are tabulated in Table II along with the porosity values measured by the conventional method (b). Mean values obtained in the present investigation (c) are given for comparison.

TABLE II
Comparison of porosity values

Specimen	<i>a</i>	<i>b</i>	<i>c</i>
Limestone	.. 2.05	1.96	1.84
Sandstone	.. 20.19	19.20	19.42

The results in Table II are in good agreement with each other.

In order to study the effect of size and surface area, number of parallelepipeds of limestones and sandstones have been prepared (perfect rectangular shape) and the results obtained are given in Table I.

Figure 3 shows the change in porosity value with surface area of the specimen. The graph shows that the porosity approaches constancy with increase in surface area in relation to bulk volume. Thus it can be seen that best results can be obtained by taking a number of small samples to

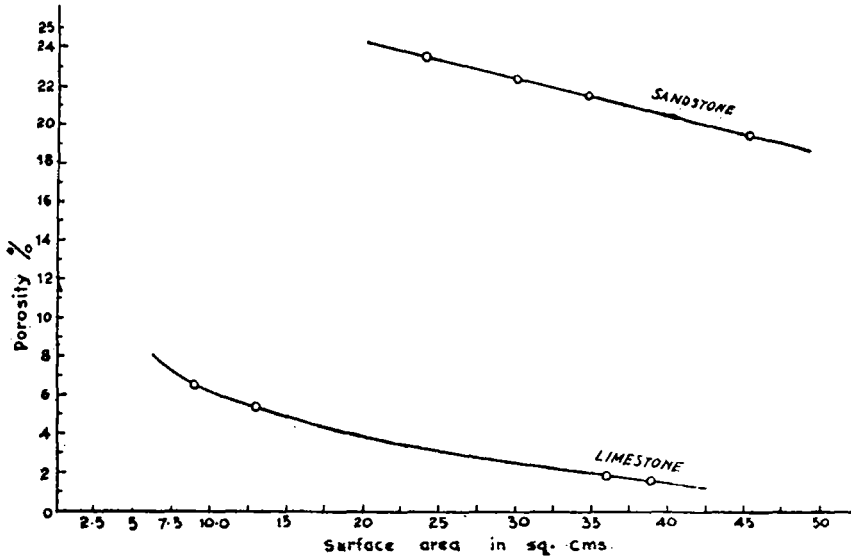


FIG. 3. Variation of Porosity with Surface Area.

fill up the chamber rather than by taking one big sample. This is what one should expect. Care should be taken to see that the sample surfaces are plane parallel in order to get good results.

4. CONCLUSION

A simple porosimeter has been designed with a view to handle large volumes of samples and determine the grain volume with the help of a calibration graph. Bulk volume is determined directly from the geometric shape of the samples. The results obtained are repeatable and are found to be in good agreement with those obtained by other methods.

REFERENCES

- Davis, D. H. .. *Jour. of Geo.*, 1954, 62, 1.
- Fancher, G. H. .. *Texas Res. Comm.*, 1950, Bulletin No. 4.
- Hughes, D. S. and Cooke, C. E. *Geophysics*, 1953, 18, 2.
- Tickell, F. G. .. *The Examination of Fragmental Rocks*.
- Mechem, O. E. and McCurdy, R. C. *Trans. Amer. Inst. Min. Met. Eng.*, 1933, 103, 256.