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Comparison of porosity in carbonate petroleum reservoir rocks of Bombay offshore

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Abstract

In carbonate rocks porosity is of varied origin, subsequently modified, destructively or constructively by several stages of diagenesis. The ultimate porosity of a carbonate reservoir rock is an algebraic sum of all these processes. As a result, porosity in carbonate rocks varies over very short distances both horizontally and vertically. A partial solution to this problem of evaluating porosity variations may be had by generating and comparing frequency distributions of porosity over neighbouring wells. The method is illustrated by comparing porosities of two wells from Bombay offshore area by the simple non-parametric Kolmogrov-Smirnov distance or 'D' statistic. By this method it is shown that Bassein 3 and South Bassein well No. 1 are significantly different; further, it is shown that South Bassein well No. 1 has a better porosity development than Bassein well No. 3. Kolmogrov-Smirnov 'D' statistic is an universal one and must find favour among Petroleum Engineers and Reservoir Geologists.

Introduction

Porosity is one of the fundamental properties of petroleum reservoir rocks. It is that which determines the storage capacity of a pay thickness of reservoir rocks. Porosity studies in carbonate rocks offer some special problems. Pore spaces in carbonate rocks are of different modes of origin (Fabric selective, non-fabric selective) subsequently or simultaneously increased or decreased by several sequences of diagenetic changes. Ultimate porosity of carbonate reservoir rocks may be an algebraic sum of all these processes. Therefore, it is not surprising that carbonate porosity varies in a reservoir facies sometimes foot to foot both horizontally and vertically. This variation is quite an elusive prospect to the petroleum engineer and the geologist. Methods must be available to compare porosity of carbonate pay thickness from well to well over a pay thickness or between pay thicknesses. A partial solution to the problem may be found by generating porosity frequency distributions and comparing them by simple statistical means. This paper attempts a comparsion of two porosity frequency distributions of two Bombay offshore wells as a test project by the simple non-parametric Kolmogrov-Smirnov distance 'D' statistic and presents the results of the study.

Kolmogrov-Smirnov distance 'D' statistics

Kolmogrov-Smirnov distance 'D' statistic compares two relative cumulative sample frequency distributions collected on the same interval scale and computes class by class difference between the two sample relative frequency distributions. The maximum difference is regarded as the distance 'D'. The significance of this is tested against the null hypothesis (Ho) that there is no real difference between the two sample frequency distributions, the observed differences are due to chance causes alone. The significance test takes on two forms. In one where the sample size associated with each frequency distribution is small, that is, sample size (n_1) associated with the first frequency distribution (F_1) and the sample size (n_2) associated with the second frequency distribution (F_2) where either $n_1 = n_2$ or $n_1 \neq n_2$ and $n_1 + n_2$ is always less than forty. The other one is where n_1 may or may not be equal to n_2 and the sum $n_1 + n_2$ is more than forty. This is the large sample test. The small sample ($n_1 + n_2 < 40$) test is performed by using five per cent critical value relative cumulative histograms published by Seigel (1956) for one and two tail tests. The more general form is large sample ($n_1 + n_2 > 40$) test of the form, for one tail test

$$X^2 = 4\,D^2 \frac{n_1 n_2}{n_1 + n_2} \qquad \text{........ (1)}$$

for 2 degrees of freedom and two tail test

$$D > 1.36 \frac{(n_1 + n_2)^{1/2}}{(n_1 n_2)} \qquad \text{........ (2)}$$

where n_1 and n_2 are the respective sample sizes of the compared relative cumulative frequency distributions.

The single tail test provides the answer that F_1 is significantly different than F_2 and the two tail test simply says that the two frequency distributions are significantly different more than due to chance causes alone.

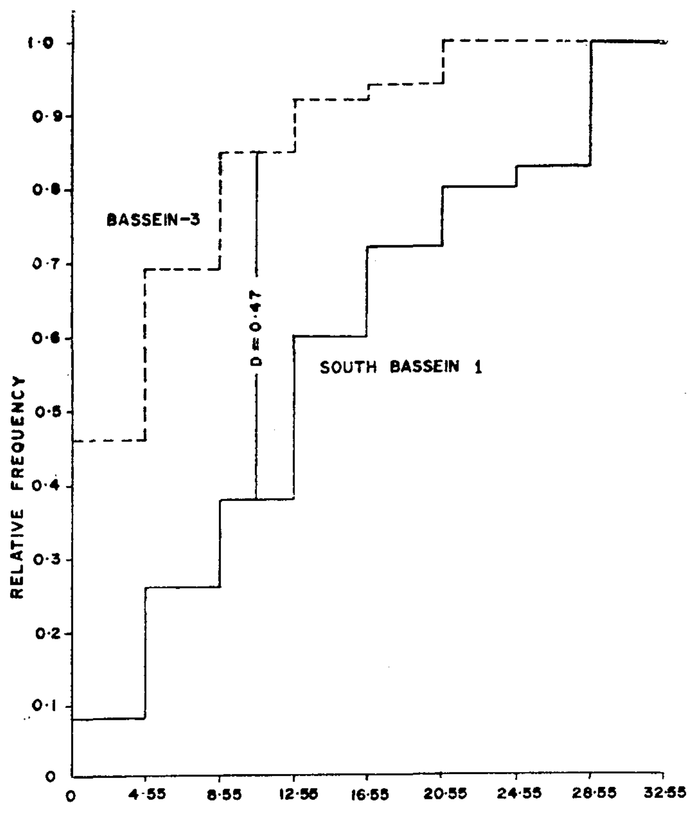

Figure 1. Sample relative cumulative frequency distribution of Bassein South 1 and Bassein 3, Bombay Offshore with 'D' value shown in.

Application

Two wells Bassein 3 and South Bassein 1 were chosen for purposes of comparison. Both the wells are located in identical reservoir facies. Aggregate porosity for each well over the pay thickness was computed by point count methods (Bassein 3, $n_1 = 56$ and South Bassein 1, $n_2 = 96$) and the relative cumulative histograms for the two porosity frequency distributions are shown in text figure 1. In the present example the large sample test is the logical one to follow as both n_1 and n_2 are greater than forty. The computed Chi square for the single tail test (formula 1) is 31.25 which for two degrees of freedom is more than the critical value tabulated for five per cent alpha error. Therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted that the porosity in Bassein 3 (F_1) is significantly different from the porosity in South Bassein 1 (F_2) more than due to chance causes alone. The two tail test gives the value (formula 2) of 0.02272 which is less than D = 0.47 thus again leading to the rejection of (Ho) and accepting the alternative hypothesis (Ha) that the two wells differ significantly in porosity more than due to chance causes alone. Examination of text fig. 1 shows that South Bassein 1 has a higher density of porosity than Bassein 3 as in Kolmogrov-Smirnov test better frequency distribution is always placed to the right of the poorer one.

Conclusion

Porosity distribution in carbonate reservoir rocks is of complex nature. Fabric selective and non-fabric selective porosities may be further modified constructively or distructively by diagenesis. Kolmogrov-Smirnov 'D' statistic offers a quick non-parametric method of comparing porosities between two neighbouring wells in the same pay thickness or wells of identical reservoir facies but in two different pay thicknesses. South Bassein 1 definitely has better porosity and distinctly differs in porosity from Bassein 3. Kolmogrov-Smirnov 'D' statistic is simple and finds an universal application and must find more favour among petroleum engineers and reservoir geologists.

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