Fractal dimension and induced polarization?

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Fractal theory is applied to describe the structure of geometric objects. The fractal dimension D of a straight line is equal one, but for a tortuous line it becomes larger than one. In a similar way, the fractal dimension of a smooth surface is equal two. A rough surface is described by a fractal dimension $D > 2$. A uniform pore size distribution corresponds to a fractal dimension of three, but a variation in the pore size distribution results in a fractal dimension $D < 3$.

The geometry of pore structure of reservoir rocks is described by the shape, size, distribution and connection of pores and pore throats. Pore space properties are important for the description and characterization of fluid storage and transport in reservoir rocks. We used the fractal concept to describe the geometrical structure of the pores of 25 samples from a Tertiary sandstone formation in China. The fractal dimensions of the sandstone samples were determined from capillary pressure (CP) curves and transverse relaxation time distributions of nuclear magnetic resonance (NMR).

An additional study should show whether complex conductivity spectra can be used to determine the fractal dimension of the pore space. We transformed the relaxation time distribution of complex conductivity spectra determined by Debye decomposition (DD) into a curve showing the cumulative intensity as a function of increasing relaxation time τ. The total chargeability is attributed to the total pore volume. A reliable relation between relaxation time and pore radius r is needed to transform the relaxation time distribution into a distribution of pore radii. The theory suggests a power-law relation $\tau \sim r^b$ with an exponent $b = 2$. Figure 1 displays the comparison between mean relaxation time τ_{mean} resulting from DD and an effective pore radius r_{eff}, which has been determined from permeability and formation factor. The slope of the fitting line indicates a considerably lower exponent ($b = 0.35$). Studies of other authors identified lower exponents, too. Therefore, we decided to assume for a first test a linear relation with an exponent $b = 1$. In this case, the volume fraction $S_v = V(<r)/V$ corresponds to the ratio of cumulative intensity to total intensity.

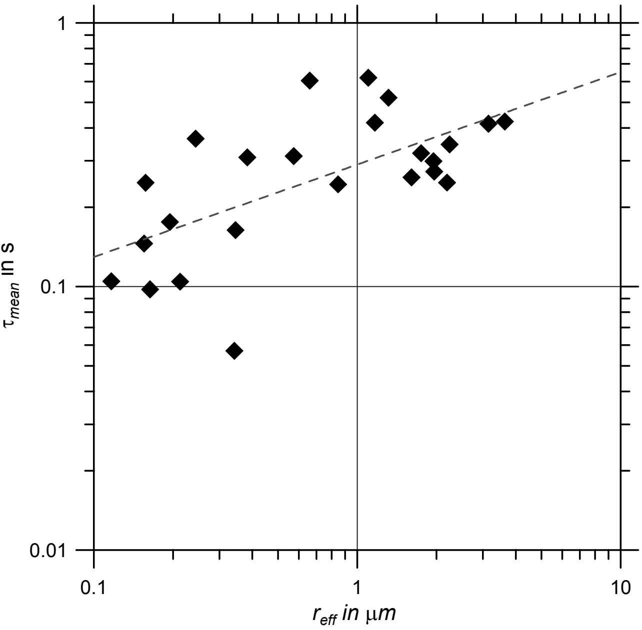

Fig. 1: Relation between mean relaxation time and effective pore radius for 25 sandstone samples. The dashed line indicates the power-law fit with a slope of 0.35.

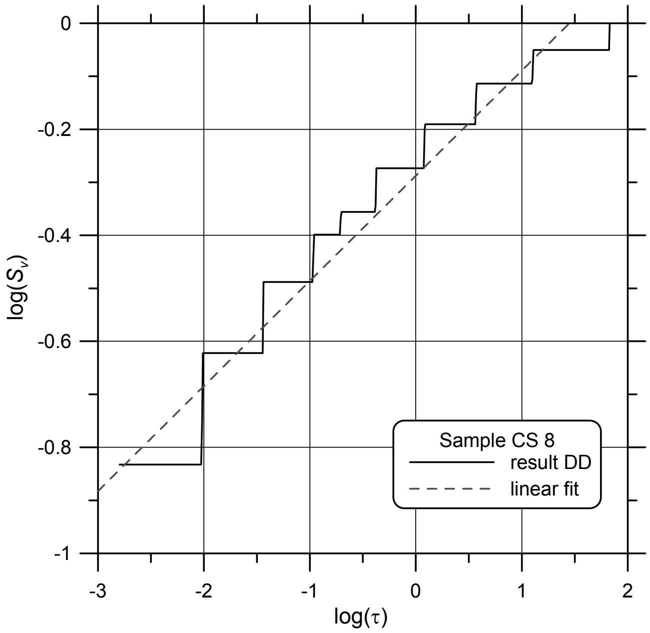

Fig. 2: The fractal dimension D_{IP} of sample CS 8 is determined from the slope of the linear fitting equation $\log(S_v) = 0.198 \log(\tau) - 0.288$ *($R^2 = 0.958$) with $D_{IP} = 3 - 0.198 = 2.802$.*

The cumulative curve is presented in a double logarithmic plot showing the relation log (S_v) versus log (τ). Figure 2 displays this curve for sample CS 8. In the case of fractal behaviour of the pore volume distribution, the slope s of the fitting line is used to get the fractal dimension $D_{IP} = 3 - s$. The resulting fractal dimension varies for the investigated samples in a range between 2.75 to 2.88. The values of D_{IP} are comparable to the 'volume dimension' determined by CP curves and higher transverse relaxation times of NMR.

Figure 3 displays the fractal dimension D_{IP} as a function of the specific internal surface S_{por}. A similar increase of fractal dimension with increasing specific internal surface S_{por} has also been observed for the fractal dimensions derived from NMR data.

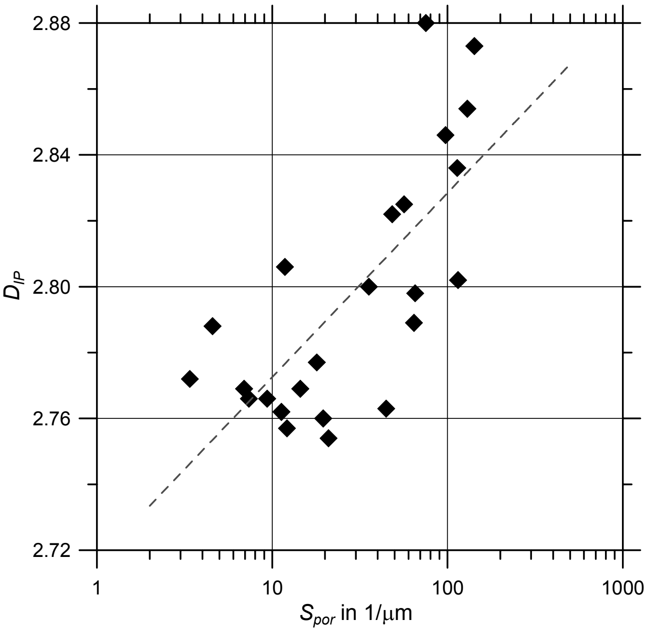

Fig. 3: The relation between the fractal dimension and specific internal surface. The dashed line indicates the fitting equation $D_{IP} = 0.0559 \log(S_{por}) + 2.685$ *($R^2 = 0.528$).*

The study has shown that a fractal dimension can be determined on the basis of an IP relaxation time distribution. Further investigations will compare the fractal dimension D_{IP} with the fractal dimension derived from other methods. Additionally, it will be investigated how this fractal dimension can be integrated in models of permeability prediction.