ROCK PERMEABILITY ESTIMATES BASED ON MERCURY POROSIMETRY

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RESUMO: Mercury porosimetry technique was developed for allowing petrophysical measurements in small and irregular pieces of rock (e.g. cuttings), not possible in standard gas porosimeters which require samples in a regular cylindrical shape. Besides the basic parameters also measured with gas, such as matrix and bulk volume, matrix and bulk density and effective porosity, it further delivers drainage and imbibition capillary pressure (P_C) curves all in a single and fast analysis. Mercury porosimetry is also called mercury injection capillary pressure (MICP) technique from which pore size distributions are obtained and absolute permeability can be estimated. Mercury is injected gradually into the pore network filling in step-like increments the pores connected by the larger apertures and then the pores connected by the smaller apertures. Considering pore-throats (that connect pore bodies) as cylindrical capillary tubes, P_C is inversely proportional to the pore-throat radius such that $R = -2\sigma \mathrm{COS}(\theta)/P_C$, where σ and θ are the air-mercury interfacial tension and the surface contact angle, respectively. There are many models that use MICP data to estimate permeability, however this work shows that, based on the fundamental Kozeny-Carman theory, a simple permeability estimator can be derived from two measured parameters: the effective porosity, e.g. ϕ_{Hg}, and an average of the distribution of pore throat radius, R_{avg}. Such estimator can be written as $K_{avg} = a\phi_{Hg}^{b}\left(R_{avg}\right)^{c}$, or in a linearized form as $\log\left(K_{avg}\right) = \log(a) + blog\left(\phi_{Hg}\right) + clog\left(R_{avg}\right)$, where a, b and c are fitting coefficients. The coefficients were adjusted using a multiple linear regression and were full cross-validated. For the first time, we evaluate different types of average for permeability estimation, such as the median $R_{med} \rightarrow K_{med}$, and the Pythagorean means: harmonic $R_{har} \rightarrow K_{har}$, geometric $R_{geo} \rightarrow K_{geo}$ and the arithmetic $R_{ari} \rightarrow K_{ari}$. The performance of all the estimators is compared using a rock data catalogue that includes different oil and gas reservoirs around the globe, nineteen are sandstones and six are carbonate reservoir. The data base comprises rocks of different geological ages, lithology, diagenesis and mineralogy. Based on the r-squared and standard error, our results show that all the four types of permeability estimators K_{avg} have better performance compared to the standard permeability-porosity cross plot (c-coefficinet equal to zero). The increase in performance is notable (up to 8 times bigger) mainly when permeability poorly correlates with porosity. Other relevant observations is that the harmonic mean is the the average that less contributes to performance increase and that coefficients are dependent on rock type and c-coefficient fluctuates around 1.4. This work shows that mercury porosimetry is a powerful technique and that permeability can be estimated straightforwardly using pore-throat averages.

KEY WORDS: Petrophysics, permeability, porosity.