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Fracture analysis in the Amellago outcrop and permeability predictions

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Fractures influence the hydraulic and transport properties of natural geological formations. The purpose of the present work is to predict the properties of a real field comprising fractured carbonates, in particular, its percolation status and its permeability.
Field observations from four vertical outcrops and one pavement in the Eastern High Atlas Mountain, near Amellago (Morocco) and the corresponding trace maps are analyzed.
The analysis of the available data yields a unique description of the fracture orientation distribution. This distribution can be modeled by two and four Fisher families with a good agreement with the real 3D data. However, the distribution with four families yields the best approximation of the 3D observations.
The fractures are assumed to be rectangles with a constant aspect ratio f. f, the probability distribution of the length of the rectangles, the volumetric area of fracture surfaces, the fracture mean size, and the fracture density are derived for each observation window.
The permeability of the fracture networks can be calculated in different ways. First, the Snow approximation is used. Basically, this approximation which assumes that the fractures are infinite, is valid for high fracture density. Its application necessitates the knowledge of the volumetric area of fracture surfaces and of the orientations. Three calculations were made with the real orientations and the approximations by two and four Fisher distributions. The differences between the resulting permeability tensors are very small.
Second, full numerical calculations were performed for two particular outcrops. Fracture networks with spatially periodic boundary conditions along the three directions of space were generated and meshed. Then, the Darcy equation was discretized by the finite volume method and the resulting set of linear equations for pressure is solved by a conjugate gradient technique. Three calculations were made when the networks are generated with the real orientations and the approximations by two and four Fisher distributions. As previously, the results obtained with these various fracture orientations only differ by a few percents. Then, comparison of the results with the Snow equation is made for two vertical outcrops. Except for the vertical component, the permeability tensors are in remarkable agreement. To be more specific, the two components along the horizontal axes do not differ by more than 5%; the vertical component provided by the Snow approximation is about twice larger than the one obtained by the full calculations.