Fractal-geometry-based quantification of rock fabrics

Jörn H. Kruhl

Tectonics and Material Fabrics Section, Technische Universität München

Fabric anisotropy and inhomogeneity are fundamental properties of most natural and artificial crystalline materials and fabric (or pattern) quantification is a necessary pre-requisite for studying material properties. It is most easily and precisely performed by fractal geometry methods (Mandelbrot, 1982; Kaye, 1989; Turcotte, 1989). Even if the combination of geometrical and non-geometrical characteristics of a fabric appears promising with respect to the amount and quality of information, a purely geometrical fabric analysis, i.e. pattern analysis, is still the first and most effective step in fabric investigation – the more so as the limits of pattern analysis are not touched by far and a large variety of methods are still waiting for being explored. However, common fractal geometry methods are not able to investigate such fabric properties and have to be modified. First promising steps show that modified Cantor-dust, perimeter and box-counting methods are useful in quantifying anisotropies as well as inhomogeneities.

(1) A modified Cantor-dust method leads to a direction-related fractal dimension and, consequently, quantifies the intensity of pattern anisotropy (Velde et al., 1990; Volland & Kruhl, 2004). This allows the characterization of anisotropy-forming processes and may support the comparison of natural with technical or experimental processes.

(2) A modification of the perimeter method allows determining the fractal dimension of complex curves in relation to their average orientations (Kruhl et al., 2004). The application on e.g. grain boundary curves may provide information about the interaction between the development of crystallographic preferred orientations and the migration of grain boundaries.

(3) The application of the box-counting method, combined with kriging, results in an contour map of the fractal box-counting dimension, which reveals the local inhomogenieties of a pattern ('map-counting method': Peternell et al., 2003; Kruhl et al., 2004). This is a very general method, easily automated and therefore very fast and uncomplicated. It already proved useful in studying crystal distribution patterns in magmatic rocks but may be also applied to any type of material fabrics on any scale.

Three directions appear promising in relation to further investigation of rock fabrics: (1) the combination of fractal and non-fractal properties of fabrics, e.g., the combination of fractal dimension contours, based on the map-counting method, with chemical and/or mineralogical data (grain types, shapes, sizes; rock chemistry); (2) the investigation of distribution patterns of fractal dimension that are potentially fractal and could be studied with fractal geometry methods; (3) the analysis of fractal dimension data sets such as the arrangement of data points in a log-log-diagram that may contain information about the analyzed pattern, which is not provided by the fractal dimension value (Suteanu & Kruhl, 2002).

In general, all presented methods can be automated, even if not always easily, and, therefore, can be provided as useful tools for broader application. The information about pattern-forming processes will be more detailed and more profound with increased precision and completeness of pattern analysis. Since fractal rock fabrics are the result of non-linear geological processes the fabrics are our basic source of information on these processes and, therefore, worth to be studied.

Kaye BH, 1989. A random walk through fractal dimensions. VCH, Weinhein, pp. 421, 1989.

Kruhl JH, Nega M, 1996. The fractal shape of sutured quartz grain boundaries: application as a geothermometer. Geologische Rundschau 85, 38-43.

Kruhl JH, Andries F, Peternell M, Volland S, 2004. Fractal geometry analyses of rock fabric anisotropies and inhomogeneities. In: Kolymbas D (ed.), Fractals in Geotechnical Engineering. Advances in Geotechnical Engineering and Tunnelling 9. Logos, Berlin, 115-135.

Mandelbrot BB, 1982. The Fractal Geometry of Nature. Freeman, San Francisco, 486pp.

Peternell M, Andries F, Kruhl JH, 2003. Magmatic flow-pattern anisotropies – analyzed on the basis of a new ‘map-counting’ fractal geometry method. DRT Tectonics conference, St. Malo, Book of Abstracts.

Suteanu C, Kruhl JH, 2002. Investigation of heterogeneous scaling intervals exemplified by sutured quartz grain boundaries. Fractals 10, 435-449.

Turcotte DL, 1989. Fractals in Geology and Geophysics. PAGEOPH 131, 171-196.

Velde B, Dubois J, Touchard G, Badri A, 1990. Fractal analysis of fractures in rocks: the Cantor’s Dust method. Tectonophysics 179, 345-352.

Volland S, Kruhl JH, 2004. Anisotropy quantification: the application of fractal geometry methods on tectonic fracture patterns of a Hercynian fault zone in NW-Sardinia. Journal of Structural Geology, 26, 1499-1510.