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APPLICATION OF THE FRACTAL ANALYSIS IN THE REGIONAL MORPHOSTRUCTURAL STUDIES

Abstract: The landforms are a product of complete interaction between endogenous and exogenous geodynamic processes. In this aspect main indicators for surface expression of endogenous processes are the morphostructures. In the light of the Plate tectonics concept during the last decades in the exploration of the regional relief made it possible to introduce new scientific principles and methods. Such modern methodical approach is the fractal analysis. Its implementation in morphostructural studies gives the opportunity to explore the level of Earth's crust fragmentation in local level and allows for various comparative studies.

Keywords: fractal analysis, morphostructures, Plate tectonics, fragmentation.

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Introduction

In the field of geomorphology one of the main methods for the study of the Earth's topography appears the morphostructural analysis. This creative method has not only scientific knowledge, but also a certain practical value. That is right because the condition of the Earth's relief is one of the possibilities to get informed about the nature of the effects of endogenous processes on the lithosphere. Natural continuously "release" of the asthenospheric energy by volcanoes and earthquakes necessarily passes through the Earth's surface and affects Earth's topography. It is therefore obvious is the need to make the most detailed study. And this is the enduring relevance of morphostructural analysis – one of the important ways to explore the geodynamics of the Earth's surface (Tzankov, 2013).

Over the last decades by investigation of the level of Earth's crust fragmentation in the field of Earth Sciences as the main methodical instrument has entered the fractal analysis. On the one hand, its application to regional morphostructural studies provides a statistical-mathematical tool for tracking and evaluation of the processes of self-organization in the development of Earth's relief. On the other hand, the fractal analysis can serve as the basis for various morphostructural comparative studies. This defines the main goal of this article, namely the possibilities of applying fractal analysis in regional morphostructural studies.

Fractal definition

In the field of Geosciences is accepted that definition of the different "fractals" as „real physical objects is most often connected to fragmentation" (Korvin, 1992). This reveals that each measurable object has a length, surface or volume, which depends on the measuring unit and the object's form irregularity. The smaller the measuring unit is, the bigger is the total value for the linear (surface, volume) dimension of the object and vice versa. The same is valid for 2D and 3D objects (Ranguelov, 2010). Fractal objects are generally characterized by the following basic properties (Liebovitch, 1998):

1) Self-similarity- the little pieces are smaller copies of the larger pieces.
2) Scaling- the values measured depend on the resolution used to make the measurement.
3) Statistics- the “average” size depends on the resolution used to make the measurement.

The classical example of a fractal object first is defined by French mathematician Benoit Mandelbrot in his book "*Fractal geometry of Nature*” (1982). The term "fractal" (introduced for the first time by Mandelbrot in 1975) derives from the Latin „*fractus*”, which means "a fracture". If the length of an object P is related to the measuring unit length *l* by the formula:

$$P \sim l^{1-D} \qquad (1)$$

then P is a fractal and D is a parameter defined as the fractal dimension. This definition was given by B. Mandelbrot in the early 60-s of the 20-th century. His ideas support the view that many objects in nature can not be described by simple geometric forms, and linear dimensions, but they have different levels of geometric fragmentation. It is expressed into the irregularities of the different scales (sizes) – from very small to quite big ones. This makes the measuring unit extremely important parameter, because measuring of the length, the surface or the volume of irregular geometric bodies could be obtained that the measured size could vary hundred to thousand orders (Ranguelov, 2010).

Another definition of a fractal dimension is related to the serial number of measurement to each of the measuring units used and the object dimensions. If the number of the concrete measurement with a selected linear unit is bigger than r, then it might be presented by (Turcotte, 1997):

$$N \sim r^{-D} \qquad (2)$$

and the fractal is completely determined by D as its characteristic fractal dimension.

Applying this definition for the elements of faulting and faults fragmentation, some authors use this idea to depict formal models of the Earth’s crust fragmentation, which indicates the level of fracturing of the upper Earth’s layers (Ranguelov, Dimitrova, 2002; Ranguelov, Ivanov, 2017). In this respect, only morphostructural analysis results allow exploration of the Earth’s crust fragmentation on a regional or local scale.

Fractals in regional morphostructural investigations

Fractals are a descriptive aspect of geomorphology (landforms, drainage networks, etc.). Two important types of fractal statistics exist, the first is self-similar fractals and the second is self-affine fractals (Turcotte, 2007). Many times series have been shown to be self-affine fractals. Examples include 1/f noise and Brownian walks. Self-similar and self-affine fractals are applicable to landforms. First, consider self-similar fractals. Several definitions exist, but the simple number-length scaling *(2D* objects) can form the basis for almost all natural applications, such as the length of the coastlines, the degree of similarity of the drainage network, the cracks in the rocks, the extent of the relief, slopes inclination, etc. (Burrough, 1981; Hastings et al., 1993; Hirata et al., 1987; Mandelbrot, 1967; Paredes, 1995; Turcotte, 1997, 2007; Velde et. al., 1990; etc.). The three-dimensional structure of landforms (surface fractals) is generally well represented as a self-affine fractal (Turcotte, 2007).

As the main working tool of geomorphology, the morphostructural analysis aims at the study, analysis and synthesis of the different types of data on origin, structural features and morphogenic development of the relief in different parts of the Earth's crust (Tzankov, 2013). In this connection, the fractal analysis is an indispensable tool for analyzing the degree of fragmentation of the regional or local relief. Such a study should be based on the dominant morphostructural type (generation), i.e. which determines the basic morphostructural appearance of the terrain, which does not always coincide with the prevailing type of relief. According to the adopted methodology for surface fractals, the number and area of the individual morphostructural generations in the studied area is taken as the basis. The methodology based on the correlation *number-area* is following the algorithm presented and effectively applied in a number of publications (Meyback, 1995; Ranguelov, 2010; Ranguelov et al., 2003, 2004):

- presentation of the data for each selected element (total number, investigated parameter, dimensions – (only linear (1D) and surface sizes (2D) are considered)

- calculation of the number for the graphics (selection of the calculation step for X and Y axes, scale on X and Y axes, values for each selected parameter).

- presentation of the results on the graphics – on the X axis the semi-logarithmic scale is most convenient, on the Y axis, z denotes in linear scale the numbers calculated for each element.

The measurement of areas of the individual morphostructures is carried out through the well known *box-counting* method. The investigated area is covered by boxes of varying size, and the number of boxes required to cover the pattern is counted for each box size (Hirata, 1989). For box counting, N represents the number of occupied boxes, and r is the length of the box sides. Another modern interactive tool for area calculations are various free GIS products. They enable fast, high-precision calculations.

The calculated areas are visualized on semi-logarithmic graphics and the fractal dimension (D) is calculated too (Fig.1). A fractal dimension is an index for characterizing fractal patterns or sets by quantifying their complexity as a ratio of the change in detail to the change in scale (Mandelbrot, 1982) The fractal dimension can be calculated through appropriate software or manually using the following formula (*Aki*, 1981):

$$D = \log N / \log A \quad (3),$$

Where N is the total number and A is the average area (in square kilometers) of the studied morphostructures. The resulting number is an important diagnostic mark that can be used to clarify the degree of fragmentation of the local relief. On this basis, various comparative analyzes can be carried out both on morphostructural zones and areas (at a higher taxonomically level) and in morphostructural regions (at a lower taxonomically level).

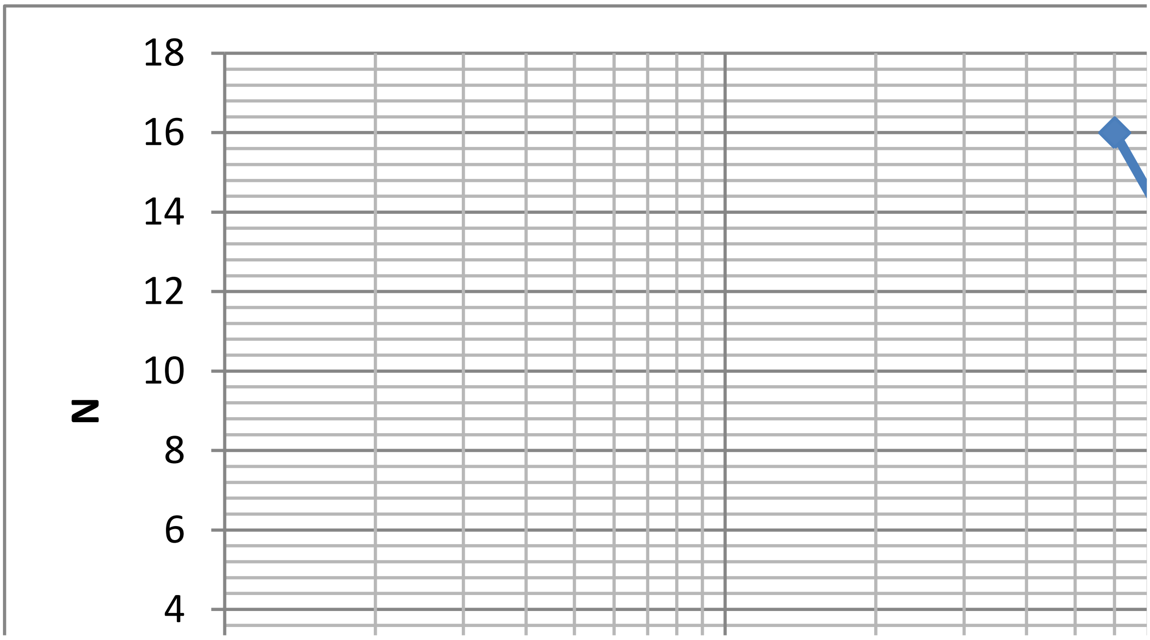

Fig.1 An example for fractal analysis of the dominant morphostructural type (generation). At the top, the calculated fractal dimension (D) is plotted.

Conclusion

The fractal analysis is a very important methodology tool in the modern morphostructural investigations. It is given the really scientific grounded possibilities for the complexes interpretations of the seismic data with the more or less intensive block– mosaic pattern of the Earth’s relief. The specific peculiarities of the mentioned analysis is, that it allows the real interpretation of the concrete regional or local geodynamic processes in different parts of the Earth’s crust. This right approach considerably increase the interpretation punctuality of spatial position and character of the local topography. The full possibilities and role of the fractal analysis for the morphostructural and morphotectonic investigation will be explained in a future.

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