Application of Fault Statistics and Fractal Geometry in Geology

Thesis of a PhD study

by

ZOLTÁN UNGER

Theme leader: Dr. Antal FÜST

SZEGED UNIVERSITY
Faculty of Science

2007, Szeged

1. Premises

Fractal geometry used to be considered a neglected branch of science, nevertheless nowadays it has gained in prestige, its tools and discoveries have become widely used in different fields.
When I encountered the limits of fault statistics, I became aware about the need to look for other means to trace faulted blocks.

The approach via fractal geometry helped to bridge this problem. Fault-statistics alone seemed to be insufficient to determine the position and size of the faulted rocks. Fractal geometry proved to offer a solution, which I consider key issue for this problem.

Some theories start from the drill cores, while others from the tectonic maps (i.e. based on seismic interpretation) and try to predict the faults and the fracture network. They have two main deficiencies:

- the fractures identified from **drill cores** are considered as local data and this kind of information cannot be extrapolated on wide area (i.e. reservoir-wide);
- the resolution of the tectonic maps (i.e. derived from **seismic interpretation**) is lower the size of the fractures, therefore any predictions concerning fractured blocks bears a certain risk.

2. Aims

The deficiencies mentioned above and the connection between the macro-scale of the cores and giga-scale of the tectonic maps, I consider, have to be spanned. This is the main aim of the thesis.

Through eight case studies I proceeded by trial-and-error for faulted/fractured block investigations on different fields of geology using fault statistics and elements of fractal geometry. The two kinds of approach were highlighted for a hydrocarbon reservoir in case study no.8.

Finally I searched the ways of connection between the fault statistics and the fractal geometrical approach.

3. The applied methods

I assumed the work would proceed in two separate fields: in the field of fault-statistics and fractal geometry.

I commenced my work with fault statistical analysis. Previous studies encouraged me to check whether these fault-statistical methods are also applicable with further geological exploration as they had been successfully used in ore- and coal mining. With these-fault statistical methods, I analysed the distribution of fault-length. On this ground I was able to perform a fault-number prediction.

I used an iteration method in order to determine the most appropriate function to fit the empirical fault length frequency.

I realised immediately that this was not sufficient to characterize acreage since the positions of the faulted blocks remained unknown.

A step further was viewing the problem by the angle of fractal geometry.

I determined the fractal dimensions for the enumerated case studies by box-counting method.

I searched and found a mathematical relationship between the fault statistics and fractal geometry approach.

4. Thesis

Results of the fault statistic analysis

1. In the publication referred to for the analysed fault length the mentioned power law distribution was exclusively found in ore- and coal mining. The present thesis manages for the first time to apply fault statistic procedures to further fields of geology starting from the river network evolution to hydrocarbon reservoir modelling (UNGER Z. 2004a).

2. Based on the calculated power functions, I was able to determine the rate of fracturing and to predict the number of the missing or unidentified faults (e.g. under the seismic resolution) (UNGER Z. 2004a).

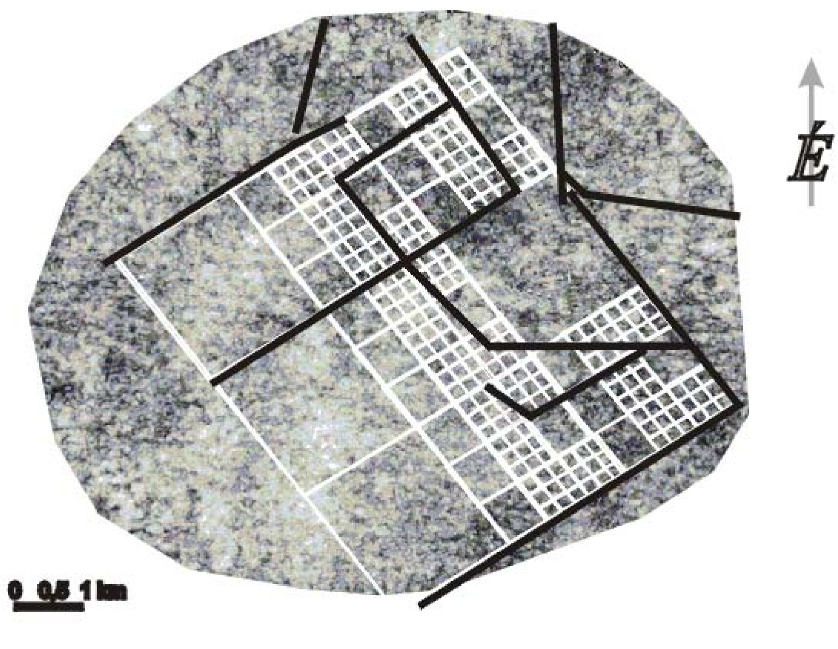
3. For finding the proper function for the empirical fault length frequency, I used iteration until the function has become predictable and stable. I consider the exponent of the function as an index for tectonics.

Results in fractal geometry

4. For each case study I calculated the fractal dimension using box-counting method, which is considered as a novelty in the respective areas. Thus I introduced an other index for the tectonics.

5. If a structure can be characterised by two fractal dimensions, this means that two phases of tectonics were identified. Considering these, we can state that the method is more sensitive than the calculation by fault statistics.

6. Using example 8. as an illustration, the fractured blocks determined by the fractal gasket and the fractured blocks in the average seismic coherence map present good coincidence. This is also an argument to support that the fractal pattern recognition is correct (UNGER Z. 2004b).



The three-generation modified Sierpinsky-gasket laid over the average seismic coherence map

Result on matching the fault statistics and fractal geometry

7. Based on the fault statistics, the frequency of the fault lengths were characterised by exponent $\boldsymbol{b}$ of the fitting power law function, which is equal with the fractal dimensions $\boldsymbol{D}$ in absolute value. This is not a random coincidence, but it was mathematically proven that this is a general law (UNGER Z. 2007).

REFERENCES:

UNGER Z. 2007: Vetőstatisztika és a fraktál geometria kapcsolata, Magyar Állami Földtani Intézet Évi Jelentése 2005-ről, pp. 185-191.

UNGER Z. 2004: Töredezett kőzettömbök nyomozása fraktálgeometriai elemekkel egy szénhidrogén rezervoár esettanulmánya, Földtani Közlöny, 134/2. pp. 281-289

UNGER Z. 2004: Statisztikai vetőnyomozás egy szénhidrogén kutatási területen, Földtani Közlöny, 134/3, pp. 423-441

UNGER Z. 2002: Fracture network investigation with elements of fractal geometry, IAMG Conference Proceedings, Berlin

UNGER Z. 1998: Statisztikai vetőnyomozás egy ordoviciumi tároló tető térképe alapján, MOL Rt. KKTÜ. Belső tanulmány – *bizalmas*. Budapest

UNGER Z. 1998: Mag és lyukgeofizikai paramétere matematikai és geostatisztikai vizsgálata, MOL Rt. KKTÜ. Belső tanulmány – *bizalmas*. Budapest

UNGER Z. 1996: Mathematical- and Geostatistical Analysis for Main Hydrocarbon Resource Parameters, MOL Rt. KKTÜ. Belső tanulmány – *bizalmas*. Budapest

UNGER Z. 1992: Egy szénhidrogén mező mélyfúrási-, telepadatainak geostatisztikai feldolgozása és földtani kockázatra vonatkozó elemzése, Magyar Geofizika,33, 127-142.