Preface

1. Introduction

The role of fractals in understanding the complex system in earth science has opened a new branch of science applied in geophysics, geology, geomorphology, environment, seismology, etc. (Mandelbrot 1982; Feder 1988; Barton and La Pointe 1995; Turcotte 1997; Dimri 2000, 2005a, b; Dimri et al. 2012). Time series generated by earth sciences observation are in general having long-term persistence with certain degree of correlation. Such correlation can be mapped in terms of fractal dimension for homogeneous models as the mono-fractals. For heterogeneous functions, mono-fractals are not applicable and multi-fractals have been proposed. A typical geological structure such as fault shows a relation with fractal in terms of fault length and displacement of fault zone thickness and throw. Methods such as Detrended Fluctuation Analysis (DFA) and Multi-fractal Detrended Fluctuation Analysis (MDFA) are central to many chapters applied to geophysical well-log data, seismological data and fire time series.

In Chapter "Scaling Laws in Geophysics: Application to Potential Fields of Methods Based on the Laws of Self-Similarity and Homeogeneity", Prof. Fedi systematically described the interpretation of potential field data in a frequency domain. Initially, a relation between random sources (density/susceptibility) and their fields was established which led a spectral analysis method. This method was extensively used by geophysicists for the estimation of depth or thickness of sedimentary basin from gravity and magnetic data. Later, it was found that the source is not a random; rather it is a fractal distribution, and hence, a new method called scaling spectral analysis method was proposed. This method finds its application in interpreting gravity and magnetic data, e.g. Chapter "Scaling Laws in Geophysics: Application to Potential Fields of Methods Based on the Laws of Self-Similarity and Homeogeneity" of this book. On the other hand, the author has elegantly described the homogeneous source distributions called "one point" distributions. Dr. Fedi has proposed, as a multi-homogeneous model, having a variable homogeneity degree versus the position. He concluded that while mono-fractals or homogeneous functions are scaling functions, multi-fractal and multi-homogeneous models are necessarily described within a multi-scale data set and recommended that specific techniques are needed to manage the information contained on the whole multi-scale data set.

In another Chapter "Curie Depth Estimation from Aeromagnetic for Fractal Distribution of Sources", Dr. Bansal et al. described scaling spectral method for estimation of Curie depth. The earth's magnetic field is used to find depth of anomalous sources as shallow as few metres to tens of km. The deepest depths found from magnetic field sometimes correspond to Curie depth a depth in crust where magnetic minerals lose their magnetic field due to increase in temperature. Estimation of depth from magnetic/aeromagnetic data generally assumes random and uncorrelated distribution of magnetic sources equivalent to white noise distribution. The white noise distribution is assumed because of mathematical simplicity and non-availability of information about source distribution, whereas from many borehole studies around the world, it is found that magnetic sources and also other physical properties such as density, conductivity, etc. follow fractal distribution. The fractal distribution of sources found many applications in depth estimation from magnetic/aeromagnetic data. In this chapter, Curie depth estimation from aeromagnetic data for fractal distribution of sources has been presented.

In Chapter "Fractal Faults: Implications in Seismic Interpretation and Geomodeling", Dr. Ravi Prakash Srivastava has combined the concept arrived from two different words, one called "Fractals" that follows scaling law seen in many natural phenomenon and the other called "Faults" encountered in geological studies. Author presented most updated use of fractal concept in geological understanding of faults and their significance in geological modelling of hydrocarbon reservoirs. It is reported in many studies that the faults show fractal/scaling behavior in terms of fault length and displacement fault zone thickness versus fault throw. However, large faults are identified and integrated in seismic data, but same is not true when they are small and hence below the resolution limit of seismic data. Thus, author is able to map smaller faults with geological knowledge of the faults in the reservoir model studies using a concept of fractals.

In Chapter "Detrended Fluctuation Analysis of Geophysical Well-Log Data", Subhakar and Chandrasekhar used geophysical well-log data as it provides a unique description of the subsurface lithology as well as they represent the depositional history of the subsurface formations, vis-à-vis the variation of their physical properties as a function of depth. For this, DFA technique has been described and applied to gamma-ray log, sonic log and neutron porosity log of three different wells from west coast of India. The whole chapter is organized in seven sections dealing with geology of the area, data used in the present study, basic theory of DFA, methodology used, discussion and interpretation of results derived and finally the conclusion of the studies.

Drs. Banerjee and Nimisha Vedanti in Chapter "Fractal Characters of Porous Media and Flow Analysis" proposed a fractal model of continuum percolation which quantitatively reproduces the flow path geometry. Porosity is an important property of geological formation and a complex function of many variables which control fluid flow. The variables include essentially the characteristics of pore structures such as type, size, shape and arrangement of pores; pore space connections; area of pores open for flow; and tortuosity of the flow paths and composition of pore. There is no general framework which explains the fluid flow through the fractured and complex subsurface geometry. In fact, a direct measurement of flow through complex permeable media is time taking; hence, an analytical model has been recommended. Therefore, the aim of this chapter is to develop a simple analytical model based on the medium structural characteristics to explain the flow in natural fractures. The authors showed that the pattern of fracture heterogeneity in reservoir scale of natural geological formations looks as the distributed self-similar tree structures.

In Chapter "Estimation and Application of Fractal Differential Adjacency Segregation (F-DAS) Scores in Analysis of Scanning Electron Micro Graph (SEM) Imageries Towards Understanding the Adsorption unto Porous Solids", Prof. Das et al. presented Fractal Differential Adjacency Segregation (F-DAS) which is different from the conventional approach for estimation of fractal dimension (FD) using box counting method. The box counting method is one of first methods to estimate fractal dimension and is also simple to use. However, for heterogeneous system, mono-fractal seems to be inappropriate. In this chapter, the limitation of use of mono-FD is explained and thus extended the concept of Fractal dimensioning into lower scale segregation levels and evaluating their differential scores. In this approach, F-DAS scores are estimated for each of the image pixels of scanning electron microscopy (SEM) imageries using the arithmetic means of the grey levels of the adjacency pixels enclosed by the box used for counting in the conventional methods. The authors claimed that the present analysis provides better understanding of variability of the system (in this case, adsorbents), unexplored by qualitative analysis of SEM imageries, as well as the functional groups using Fourier transform infrared spectroscopy.

Dr. Padhy in Chapter "The Multi-fractal Scaling Behavior of Seismograms Based on the Detrended Fluctuation Analysis" has explained the use of the multi-fractal scaling properties of seismograms in order to quantify the complexity associated with high-frequency seismic signals and hence to characterize medium heterogeneities at different scales. He recommended the MDFA method is capable of characterizing the multi-fractality of earthquake records associated with frequency- and scale-dependent correlations of small and large fluctuations within seismogram. The multi-fractal nature of earthquake records has been explained by computing the generalized Hurst and mass exponent and multi-fractal singularity spectrum. One of the findings is that the degree of multi-fractality decreases with increasing frequency, and is generally more for the time period windowing dominant seismic phases in the seismogram.

Finally in Chapter "Fractal Methods in the Investigation of the Time Dynamics of Fires: An Overview", Prof. Telesca reviewed the fractal methods applied to fire point processes and satellite time-continuous signals that are sensitive to fire occurrences. Fires represent one of the most critical issues in the context of natural hazards. Most of these fires could be natural as well as anthropic. Sometimes, summer drought can influence the ignition and spread of devastating fire.

The author gave very good description of methods to find the temporal distribution of sequence of fire. These methods include coefficient of variation (CV), Detrended Fluctuation Analysis (DFA) and Multi-fractal Detrended Fluctuation Analysis (MDFA). Other techniques such as Fano Factor (FF), Allan Factor(AL) and Count-based Periodogram (PG) for fire sequence as the count process has also been described through fire satellite time series. Author also applied these methods to know the information about the "health" of vegetation which is very important and can be used to find the status of vegetation after the big forest fire.

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