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RESEARCH NOTE

AN APPLICATION OF FRACTAL DIMENSION IN INFERRING THE VARIATION IN THE TECTONIC DISTURBANCE IN THE LESSER HIMALAYAN BELT

Abstract: Fractal analysis of the spatial disposition (pattern) of lineaments reflects the variation in the degree of tectonic disturbance. In the Lesser Himalayan zone, higher 'D' values obtained over allochthonous blocks (Krol and Garhwal) indicate higher degree of tectonic disturbance compared to the less deformed autochthonous block (Simla) of lower 'D' value.

Keywords: Fractal analysis, Tectonics, Lesser Himalayas, Uttar Pradesh

Introduction: Mandelbrot's concept on 'Fractals' (Mandelbrot, 1983) have made a great impact on scientific research. Wide range of applications of fractals, from generation of synthetic landscapes in motion picture industry (e.g. some scenes in Star Treck II and Return of the Jedi; Unwin, 1989) and video games to scientific analysis of patterns, forms and structures, are the outcomes of this impact. The term 'Fractal' derived from Latin verb "Frangere" means 'to break' i.e. if a part of a fractal image is broken and enlarged, it very much looks like the whole without any loss of details. This concept in fractal geometry is called "Self-Similarity".

In Euclidean geometry, the dimension of a curve is defined as 1, a plane as 2 and a cube as 3. This dimension is called topological dimension (D_T) and it is characterised by an integer value. In fractal geometry, the dimension of a curve or a plane may have dimension between 1 and 2, and between 2 and 3, respectively. This fractional dimension is called Hausdorff-Besicovitch dimension. Mandelbrot (1983) called this as Fractal dimension and defined fractals as "a set for which the Hausdorff-Besicovitch dimension strictly exceeds the topological dimension ($D>D_T$)". An essential feature of fractal forms is the persistence of complexity as observations progress to smaller scales. A coast line, an example of fractal curve, has `D' value 1 when it is smooth and it becomes 1.5 when coastline is rough or extremely jagged. Likewise, fault traces and fractures also display fractal behaviour (Scholz and Aviles, 1987). The study of fractal geometry and its applications in geology is in its infancy stage. Merely finding fractal dimension for a fracture/fault pattern may not be of much importance but variation in the `D' value can throw some light on the degree of tectonic disturbance.

In this study, spatial disposition of lineaments from satellite data has been subjected to fractal analysis to observe the changes/variation in the fractal dimension, 'D', in different tectonic blocks of Lesser Himalayan zone. Lineaments on satellite picture are surface manifestation of sub-surface as well as surface fractures, faults and other weak planar discontinuities. Aim of this study is to know whether the changing complexity of lineament pattern gets reflected through fractal dimension 'D' value.

Study Area: The study area lies around Satpuli (29°55'10"N - 78°42'45"E) and falls in Lesser Himalayan zone of Garhwal Himalayas in Pauri district, Uttar Pradesh. Geologically,

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the area has 3 distinct tectonic blocks - Simla autochthonous block, Krol allochthonous block and Garhwal allochthonous block. The three blocks are separated by major thrusts- Garhwal thrust and Krol thrust (Fig.1).

Methodology: A lineament map of the area has been prepared using IRS LISS-II data on 1:50,000 scale. Fractal dimension 'D' has been calculated for 3 different tectonic blocks using Box method. In box method, a box is divided into a grid with 2^n boxes, with 'n' varying from 1 to 5. In this study a box of 13 cm by 5 cm has been used. The orientation of the boxes is kept NW-SE because the boundaries of different tectonic blocks (Krol thrust and Garhwal thrust) are striking NW-SE. The grid is overlain over lineament map in NW-SE orientation and then number of boxes entered by lineaments is counted, starting with coarse grid of two boxes on one side and then with 4, 8, 16 and 32 boxes. This exercise of counting boxes is done over three tectonic blocks with the same box size. The box with varying grid size is shown in Fig.2. The logarithm of the number of boxes entered by lineaments is then plotted against

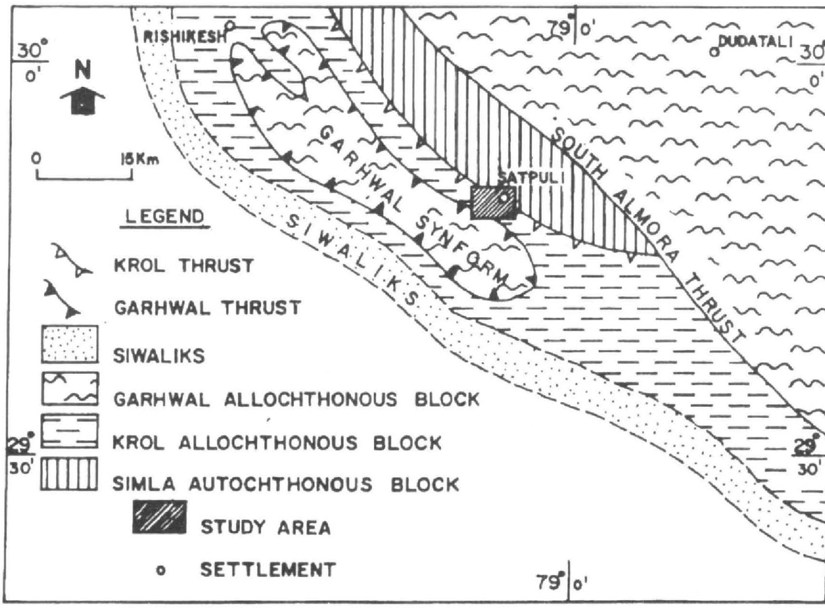


Fig.1. Regional Geological map of the area (After Gairola, and Saxena, 1979).

logarithm of the number of boxes on one side of the grid. The slope of the best fit line gives the fractal dimension 'D' (Fig.3). The results of the fractal analysis and the variation in the value of 'D' over three tectonic blocks are shown in Table I. Simla block, being an autochthonous block, has undergone the least tectonic disturbance which has also been reflected by the lowest value of D (1.38). Lower value of D reflects development of comparatively less complex pattern of lineaments which inturn is an evidence of less tectonic disturbance. The highest value of D (1.52) shown by Krol block can be attributed to intensive tectonic disturbance it has undergone while thrusting over the Simla block. Krol block is bounded by thrusts on both the sides; hence, tectonic disturbance in this block is likely to be more which is manifested on satellite data in the form of complex pattern of lineaments.

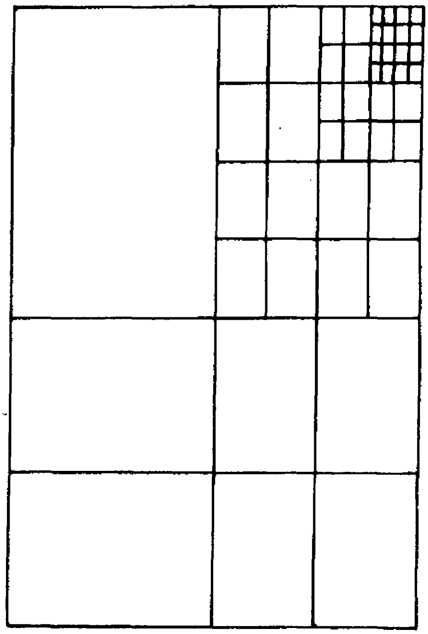
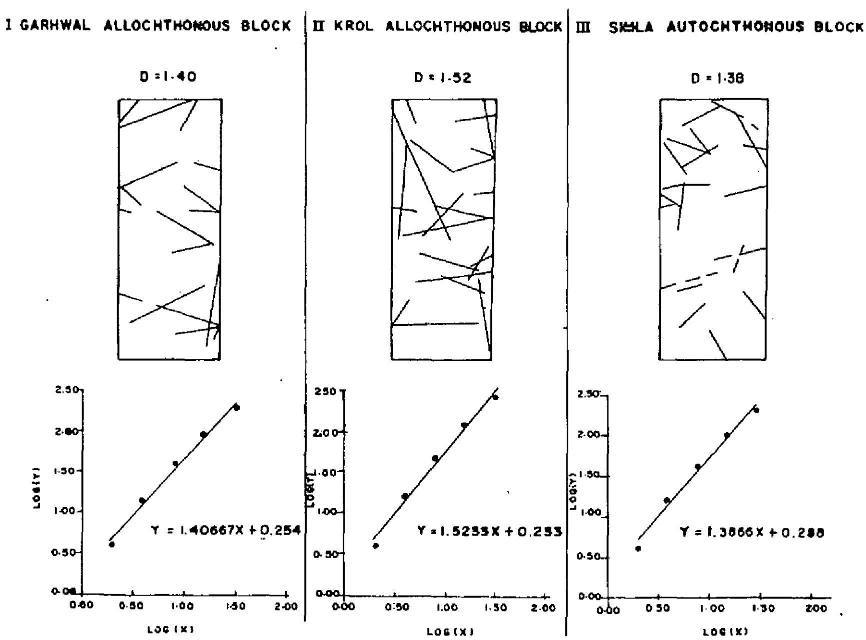


Fig.2. Type of Grid used for the fractal analysis. Grid size is progressively reduced, starting with a coarse grid of two large boxes on one side, then 2^n boxes with 'n' varying from 1 to 5. For clarity, the finer divisions are illustrated only in one corner of the figure.



X = No. of Boxes on one side of grid   Y= No. of Boxes entered by lineaments.

Fig.3. Lineament disposition in three tectonic blocks and the logarithmic plots, slope of which gives the 'D' value.

Table I.

No. of boxes on one side of the grid (x)	Log(x)	Garhwal Tectonic Block-I: No. of boxes entered by lineaments (y)	Log(y)	Krol Tectonic Block-II: No. of boxes entered by lineaments (y)	Log(y)	Simla Tectonic Block-III: No. of boxes entered by lineaments (y)	Log(y)
2	0.30	4	0.60	4	0.60	4	0.60
4	0.60	14	1.14	16	1.20	16	1.20
8	0.90	40	1.60	50	1.69	42	1.62
16	1.20	92	1.96	124	2.09	93	1.96
32	1.50	202	2.30	281	2.44	202	2.30
'D' value		1.40		1.52		1.38	

Garhwal block, being an allochthonous block, shows D value of 1.40 which is higher than that of Simla autochthonous block.

Conclusions: Satellite data are like frozen information of the dynamics of the earth and fractal analysis gives a key to understand it in numeric form. The intenisty of tectonic disturbance can be sensed by the D value between 1 and 2. D value close to 1 reflects less tectonic disturbance and it increases with the increase in the degree of deformation.

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References

GAIROLA, V.K. and SAXENA, R.K. (1979). Structural analysis of the area around Satpuli, Pauri Garhwal, U.P., Himalayan Geology, v.10, pp.156-177.

MANDELBROT, B.B. (1983). The Fractal Geometry of Nature, W.H. Freeman and Co., New York, pp.1-33.

SCHOLZ, C.H. and AVILES, C.A. (1987). Fractal Analysis applied to characteristic segments of the San Andreas Fault, Journal of Geophysical Research, v.92, No.B1, pp.331-344.

UNWIN, D. (1989). Fractals and the Geosciences: Introduction, Computers and Geosciences, v.15, No.2, pp.163-165.