Fractals' USE in physical geography and geology

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SUMMARY

Fractals can be defined as irregular contin ous curves without derirratives.The fractal or Housdorff dimension is not a necessary integer parameter and characterizes the form of a curve.

Fractal curves are located in many geographic objects such as coastlines,Karst regions,drainage basins and so on.

The distribution of the areas of sixteen Greek islands,the areas of Greek lakes and Greek plains display a Pareto distribution and a fractio nal behaviour as well.Fractional dimensi on measurments,for the recent faulted zones of Sifnos and Andros are D=1,10 and D= 1,02 respectively.

Lengths of rivers such as selinous river my have values close to D=1,10

Generally fractal dimensions may have low values when the faults measured are recent.

The values of D depend on the geomorphologic stage of a region.

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Low values are observed in the period of the original uplift and th panplain.On the other hand,the relief indicates elevate values in the intermediate stages.

The value of fractional dimension of the Landscapes is proportional to Entropy,which means that maximum Entropy reflects maximum disorder or randomness in nature and consequently Gaussian distribution of different variables.So we expect normal distribution for landscape variables on high D values

ΠΕΡΙΛΗΨΗ

Σαν Fractals ορίζονται συνεχείς μη "ομαλές" καμπύλες, μη παραγωγήσιμες. Η fractal dimension (F.D) είναι μία παράμετρος που μπορεί να λάβει και μη ακέραιες τιμές και χαρακτηρίζει την μορφή μιας καμπύλης.
Πολλές γεωμορφές όπως ακταγραμμές, Καρστ, υδρογραφικές λεκάνες κλπ, μπορούν να χαρακτηρισθούν σαν fractal μορφές. Η κατανομή του εμβαδού των 16 Ελληνικών νησιών των Ελληνικών λιμνών και πεδιάδων είναι μία Pareto κατανομή και επομένως "συμπεριφέρονται" σαν Fractals.
Μετρήσεις της F.D. για τις ρηγματωμένες πρόσφατα ακτές της Σίφνου και Άνδρου, έδωσαν τιμές D = 1,10 and 1,02 αντίστοιχα.
Τα μήκη ποταμών όπως ο Σελινούς έχουν D = 1,10 περίπου. Γενικά αναμένουμε χαμηλές τιμές της F.D. όταν τα υπο μελέτη ρήγματα είναι πρόσφατα.

Οι τιμές της F.D. εξαρτώνται απο το στάδιο εξέλιξης μιας περιοχής. Ετσι στο στάδιο ανύψωσης της περιοχής και στο στάδιο του πανεπιπέδου οι τιμές της F.D. θα είναι μικρές, αντίθεται στα ενδιάμεσα στάδια υψηλότερες.

Η τιμή της F.D. του αναγλύφου είναι ανάλογη της Εντροπίας, μεγάλη εντροπία σημαίνει μεγάλη "αταξία" ή "τυχαιότητα" στη φύση και κατά συνέπεια οι μεταβλητές του αναγλύφου θα σκολουθούν κατανομή κατά Gauss. Ετσι για υψηλές τιμές της F.D. αναμένουμε κανονική κατανομή των μεταβλητών των γεωμορφών.

INTRODUCTION

In 1967 Mandelbrot introduced "fractal" geometry,a new kind of geometry which is entirely different from the broadly accepted Enclidean geometry. The fractal curves can be defined as irregular continnous curves without derivatives.

Most nutural objects contain this kind of irregularity and this fact becomes clearer when we move our observa tion to different scales for example from small hills to great mountains.

This is the main characteristic of the fractal concept and it is called self-similarity.

A very well know geometrical example of self-similari- ty is the "Koch" curve (Figure 1).

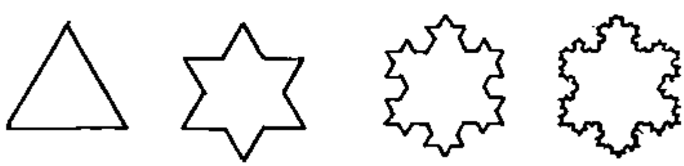

Figure 1:The "Koch" curve.

This curve called "Koch" island" was first studied by the mathematician Helge von Koch in 1904.It is constru cted by adding in the middle of each of the three sides of the triangle,another smaller triangle whose side length is equal to one third side length of the initial triangle.

The second important point in fractal theory is the fractal dimension, which is a number declaring the degree of curve irregularity and it is possible to take non-integer value as well. The formula to obtain the value of F.D. is D =-LOGN/LOGr (N) where N is the number of decomposed parts of a figure and r (N) is the similarity ratio, in the case of the figure 1 we have

The shape of fractal curves as it happens in "Koch" curves seems too geometrical to share characteristics in common with natural features, so that the concept of randomness must be necessarily introduced to provide more realistic curves. This is the model called fractional Brownian motion (Mandelbrot 1982) and the resulting fractal curves display statistically self-similarity.

Observing natural objects we easily realise that many of them represent fractional curves and so it is useful to study them with this new geometry.

Fractal's use in physical geography and geology

Coastlines can be regarded as the most typical fractal curves. Richardson (1961) stated an empirical law saying that the length of a coastline depends on the various yardsricklengths.

The value of D for a coastline can be calculated by means of a log-log graph plot, the number of segments of length and versus various sampling intervals. This slope of the line represents the value of D.

It is clear that the value of D reflectes the shape of a coastline and for D=1 a straight line arises.If D is increased,the shape of a coast becomes more irregular (Figure 2)

Figure 2:coastlines with D= 1,16

Observing the coast of Aegean islands the fractal dimension varies.For this reason Faulted coasts like the Northeastern Zonė of Sifnos and the Southwestern part of Andros have D=1,10 and D =1,02 (Figure 2A)

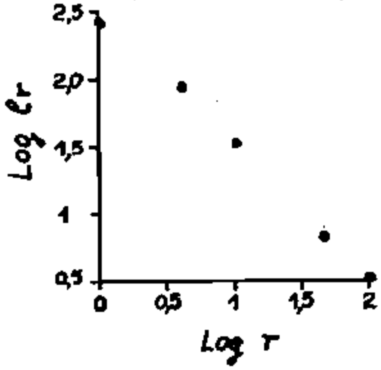

Figure 2A:Fractal dimension of the Northeastern part of Sifnos.D=1,105

but the same islands have coast with much more irregularity and the value of their D is 1,99 and 1,122 respectively.

It is worth noting that fractal shape "islands" (Figure 3) can be produced from Mandelbrot's simple formula

$$X_{n+1}=F(X_n)= X_n^2+ c$$

for $C=-0,12375+0,56508\ i$

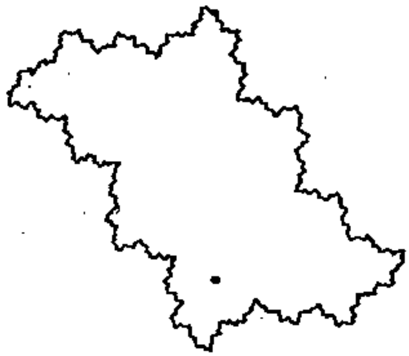

Figure 3:

Fractal shape "islands"

In a broad sense many natural features such as areas of lakes, islands and stretches of rivers display an hyperbolic size distribution (Korcak Law). This kind of distribution is the typical consequence of fractal landscapes .

The distribution of the areas of Greek islands, the areas of Greek plains and the lengths of rivers can be studied (Figures 4,5,6)

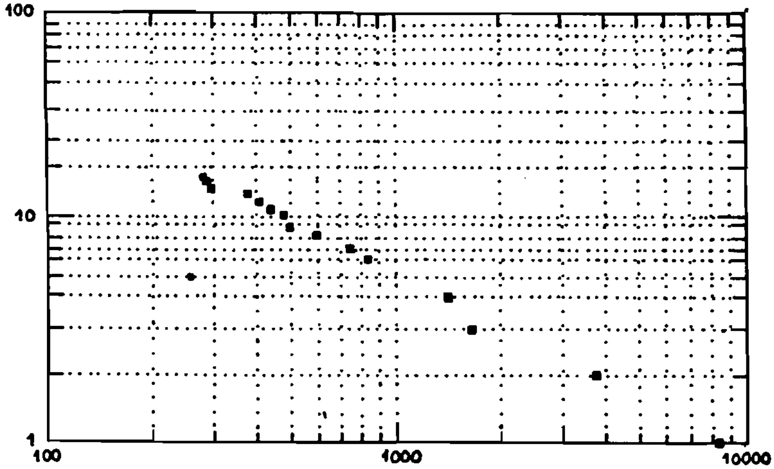

Figure 4:A plot between log(rank) and log(area) of 16 Greek islands.

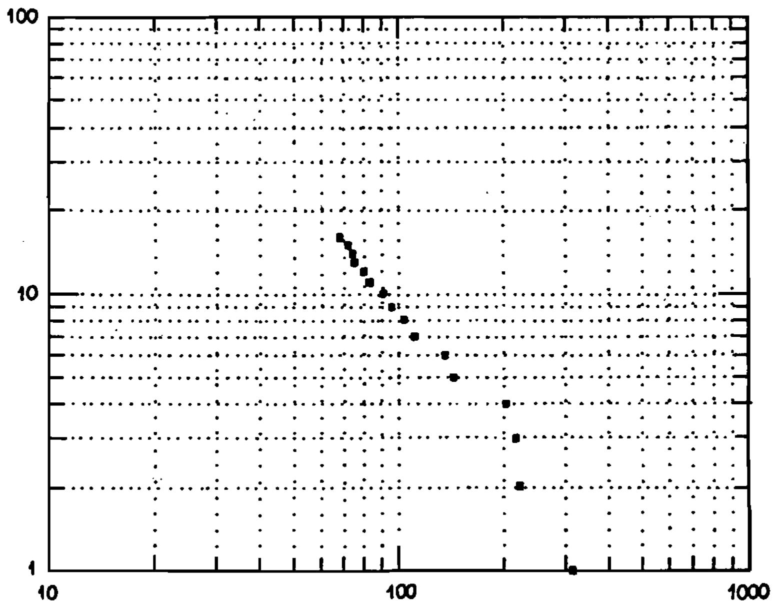

Figure 5:A plot between log(rank) and log (length) of the 17 Greek rivers

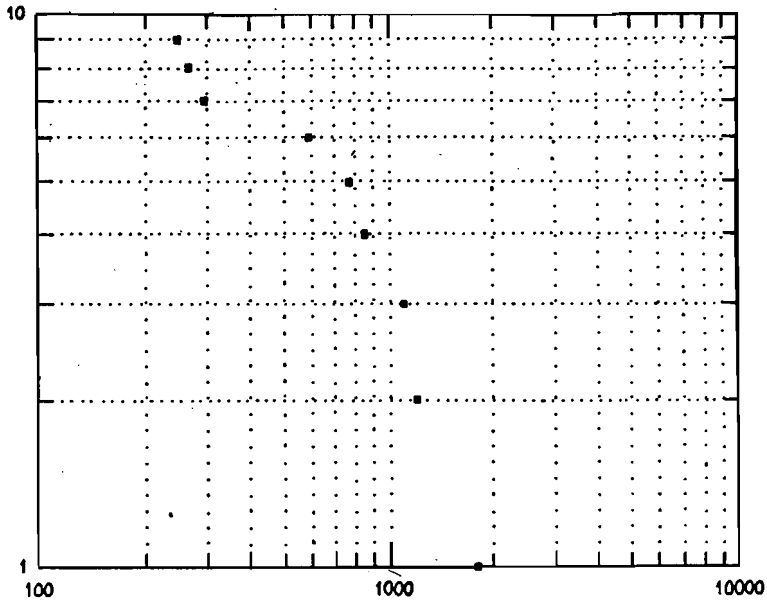

Fig.6:A plot between log(rank) and log (Area) of 9 Greek Plains

Observing the figures 4,5 and 6 we confirm the fractal nature of the above georgraphic objects.

Fractal "fragmentation" also shows the length of caves with D = 1,4 approximately (curl 1986,Lawrty 1987).Drainage system elements indicate a fractional behaviour such as the areas of drainage basins and stretches of streams.An instance of this is the fractal dimension of the length of Selinous drainage basin which has been calculated and gives value D

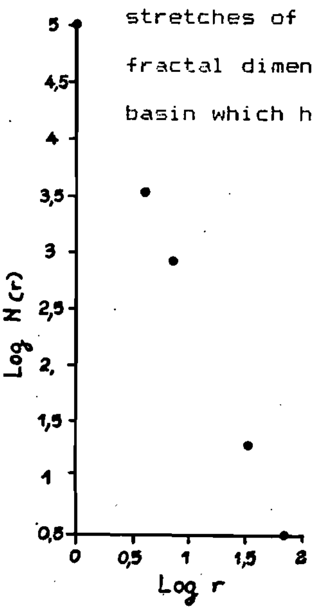

Figure 7:Fractal dimension of selinous river D =2,33

Self similar characteristics indicate also different tectonic elements such as fractures (chiles 1988), faults related to earthquakes, folds or world-wide crust deformation.

The study of fractures on the island of Mykonos shows a fractal dimension D = 2,23 (Figure 8)

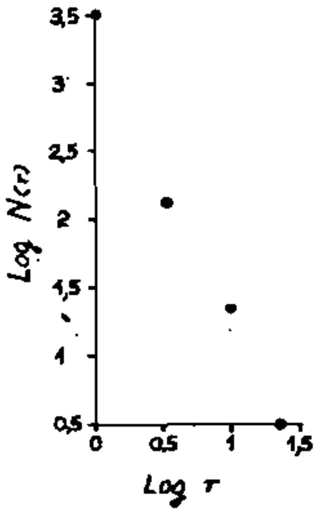

Figure 8: Fractal dimension of the fractures of Mykonos D = 2,23

The fractal dimension of a fault indicates its age and new faults have values close to one. Finally the soil covered topography displays a fractal geometry. The fractional dimension of this surface in temperate regions varies between 2.0 and 2.3 (Culling and Datko 1987) It is obvious that the values of D vary because of the stage of development of a region in the Davisian cycle.Thus during the first uplift and in the stage of panplain the fractal surface will have values close to 2,while in the intermediate stage the value D will be greater.

CONCLUSIONS

The existence of fractal behaviour has been proved for several geographic features in Greece, such as for areas of islands, plains and lakes and for the lengths of rivers.

The fractal dimension is "a handy tool" -to obtain greater knowledge of the form of a curve.
Low fractal dimension has been calculated for the faulted zone of Sifnos and Andros and the values of D have been calculated as 1,10 and 1,02 respectively. On the other hand non-recent faulted Zones present higher D values.
Finally, the fractal dimensions of traces of fractures of Mykonos and the drainage basins of selinous river have been measured to be D=2,23 and D=2,33

It becomes clear that the landscape -value of D is proportional to entropy and as the erosion proceeds the D diminishes

On the other hand maximum entropy results in maximum disoder which means randomness in nature and Gaussion distribution of different landscape variables.

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