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Session: Theoretical Geomorphology

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SUMMARY OF THE PAPERS SUBMITTED

Twelve papers were submitted at the Session of Theoretical Geomorphologv. The topics covered by such contributions range from the investigation of stream network by exploiting the fractal theory, to the production of word-wide geomorphological mapping.

These articles can be classified according to the topic investigated, the conceptual or operational tools used to approach the respective issues, and to the extent to which these works appertain to the realm of theoretical geomorphology.

Theoretical fluvial geomorphology, in general, and stream network analysis, in particular, are discussed in three papers.

In the first two works *Fractal properties and measure of drainage network* and *Self-similarity of fluvial topography: nature, origin and scaling implications*, by E. Tokunaga, and D. Veneziano, J.D. Niemann, G. Tucker and RL. Bras, respectively, the issues of the fractal dimension and properties of drainage networks are approached from a theoretical point of view.

In the first article, Tokunaga mainly summarises its previous work on the fractal characteristics of drainage networks. The author recalls that the fractal dimension (Dn) of the whole stream network coincides with that of the drainage basin (Db) for any value of the fractal dimension (Ds) of an individual stream. He points out the concept that the stream networks need not to fill up their respective basins to be two-dimensional. A drainage basin is filled up with subbasins of the lowest order and interbasin areas. Self-similarity is sustained until these subbasin and interbasin areas become infinitesimallv small together with stream links in the world of fractal geometry. The author argues that the so-called Tokunaga's tree is not merely a geometric structure but also reflects physical settings which help understanding actual stream networks. The Hack's law holds perfectly for drainage basins, which are constituted by infinitesimally small subbasins and interbasin areas. Hence such a law is not simply empirically based but constitutes a model that satisfies completely the condition of fractality. The fractal properties cannot be clarified by using the Horton's equation for the law of stream numbers.

In the second article, Veneziano and his co-workers attempt to review the fundamental fractal properties of natural stream networks discussing the concept of self-similarity, its origin and universal character, and its scale implications. The authors argue that in river basin topography self-similarity leads to scaling relations such as the Hack's law, the Tokunaga's cyclicity for streams, the slope-area law in stream channels and the power form of the distribution of the contributing area. Under the hypothesis of simple geological conditions, such as a drainage basin area carved into flat lying, homogeneous rock layers, the evolution of basin topography can be predicted by simple parameters (i.e. contributing area, slope, etc.). In addition, the authors argue that in most natural drainage networks the exponents (α and γ) of the Hack's law assume values equal or grater than 0.5 for α and $1 - \alpha$ for γ, respectively. As a result, they state that Tokunaga concepts should be revised and suggest the need to avoid Strahler ordering because in contrast with fractal topography.

In the third contribution *Fractal characterisation of drainage network geometry*, M. del Monte, P. Fredi, E. Lupia Palmieri & F. Salvini discuss the results of a longterm investigation on stream network geometry and characteristics from Italian drainage basins, which are characterised by contrasting geological, structural and climatic conditions. The authors point out the differences observed between a synthetically generated drainage network, which should have an ideal bifurcatio ratio (Rb) and a mean length ratio (R1) both equal to 2, and natural networks.

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Real networks expressed by «index values» exhibit geometric properties that are highly dependent on external factors such as tectonics and rock composition of the drainage basin area. Such a relationship can be clearly demonstrated by plotting the logs of stream length vs. number of channels or for networks formed in different environmental settings.

Owing to the diffusion of digital terrain models (DTM or DEM), in the recent years several investigators attempted to study river geomorphology by exploiting both DEM data and algorithms for automated derivation of drainage networks. D. Nalkayama and M. Nogami, in the paper *The effects of valley intensity parameter as thresholds of stream heads definition for Dem-based stream network properties* attempt to identify the most reliable criteria for defining the stream heads of a drainage network automatically extracted from a DEM. For the study area a 50x50 grid based DTM was available along with an algorithm enabling different drainage networks to be generated. To produce such networks, different criteria were used as threshold of steam head definition, among which: a) stream order, b) valley intensity, c) stream number. By comparing these networks with the stream lines manually obtained by using blue lines and contour craulation, it was demonstrated that bifurcation ratio and stream length ratio are both highly dependent on the criteria used to define stream head thresholds. In addition, they differ from the values obtained for the manually produced network. As a result, further work is needed along this line of research.

In the last paper, *Using fractal dimensions to quantify changes in the morphology of fluial suspended sediment particles during baseflow conditions* by D.H. De Boer, the variations in morphology of suspended sediment particles during baseflow conditions are investigated for a sample stream of the Canadian prairies. To accomplish this task, a transmitted light microscope, a Ccd camera and an image analysis system are used. Through such tools, it was readily possible to measure four fractal dimensions of the particles, namely: area-perimeter ratio (D), area-rank relationship (Dk), length-area relationship (D1) and length-perimeter relationship (D2). Of these particle dimensional parameters three (D, Dk and D2) proved to be able to reflect the variations of particle geometry that take place during summer low flow. Lastly, the authors argues that changes in particle morphology coincide with an increase in primary production in the form of algae.

A second group of rather heterogeneous paper incorporates very general geomorphological problems, such as the relevance of geomorphological maps at continental scale, the role of relief as factor for classifying landscape, and the identification of criteria for a rational taxonomy of geomorphological objects, are approached in three papers.

Following a consolidated tradition of Russian geographers and geomorphologists, in the article *Problems of megaregional and global geomorphological mapping*, N.I. Orlova & M.V. Piotrovsky stress the fundamental importance of producing basic geomorphological maps at global scale. Maps indeed displaying (through some means, i.e. contour lines, shaded-relied, etc.) relief and major structures at a continental or world scale may well help investigators to understand the main problems of geomorphotectonics and the general evolution of the earth surface.

V.V. Stetsyuk, in the paper *Relief as ecological-geomorphological factor: questions of hierarchy*, puts forth a rather complex classification of relief categories based on different relief-forming processes. The main categories of such classification are: a) elementary surfaces; b) morpholitogenetical systems; c) complex genetics systems; d) morphoclimatic zones. Among the processing of relief development, the author (not surprisingly) highlights the importance of those related to the arctic environment (nivation, cryogenetic, etc). Lastly, the author argues that the concept of morpho-climatic zones characterised by unique reactions of adaptation in the period of intensification of human impact on the environment, will promote the investigations in the field of ecological geomorphology.

M.A. Lazarenko, V.P. Palienko & R.A. Spitsa, in the article *Image recognition in geomorphology*, stress the complexity of any attempt aiming at creating a rational, consistent classification of geomorphological objects. Furthermore, the authors point out that an ideal geomorphological classification should meet the requirement that, for different scales, objects can be regarded as aggregates of elementary volumes, which are characterised by specific attributes. The authors using image recognition techniques attempt such a major issue. Through the use of cluster analysis, similarity criteria are defined for the set of geomorphological objects, which are used as training set. Subsequently, the analysis is extended to the entire data available (target set). Using 33 parameters of a set of morphological features, the technique was tested in two sample areas of the Transcarpathian and Eastern Carpathian regions.

Two papers deal with soil erosion using very different theoretical and operational approaches. In the first (*Theoretical and experimental approach to analysis of soil erosion process*), the estimate of soil erosion by water flow is examined by M.S. Kuznetsov, V.M. Gendugov and M.S. Khalilov who also reports experimental data. Following a mathematically-oriented approach, the authors revise the theoretical analysis of soil erosion by water flow according to the equation that links the rate of soil detachment to the tangential stress of the bottom of the flow, the average flow velocity and the scouring flow velocity. The coefficient of the equation are experimentally determined in a sample area characterised by chestnut, light chestnut and mountain cinnamonic soils, respectively; all of which are located on slopes of the Large Caucasous. As a result, an overall error equal to 29% is maintained (but not documented) by the authors.

In the second paper *Fractal analysis of roughness profiles in agricultural lands*, F. Catani & S. Moretti investigate erosion rate due to rainfall intensity. Within the framework of a project aiming at evaluating the role of ground roughness on soil erodibility in cultivated land, the authors exploit radar (X-Sar/Sar-c) data to estimate ground physical proprieties such as soil roughness and moisture. They then attempt to correlate the roughness parameter with the erosion rate due to rainfall in-tensity. The experiment assumes scale invariance properties of the roughness profiles. Lastly, the authors point out the relevance of the investigation in order to forecast the impact of human activity on soil and landscape characteristics.

In the paper *Model of sandy beach erosion by storm waves involving sea-level rise*, D. Zhang and S. Tosaki report a prototype-scale experiment with the aim to investigate erosion of sand beaches generated by storm waves. By using four kinds of uniform and non uniform beach profiles, as boundary conditions, different storm waves were generated while sea-level (water depth) was risen. The breaker-induced vortices reaching the bottom lifted the sediment into suspension which was then transported offshore by the mean offshore flow field. In this way, single to quadruple bars were formed, and the beach eroded. The experimental model demonstrated that erosion rate is dependent on beach profile geometry, sediment particle size and sea-level depth. In particular, the change of sea level controls the depth of the breaker-induced vortices which lead to sediment removal. Basing the results of the experiment in a spatial-temporal geomorphological model it would be possible to predict sandy beach erosion.

In the article *On the fractal character of landscape in Central Italy*, F. Catani and R. Fanti attempt to assess the potential of the fractal dimension (D) as parameter enabling the nature of the geomorphologic processes of a region to be detected. In order to carry out this investigation, two sample areas are selected in Tuscany and Lazio regions. For each area, an elevation model (DEM) is obtained and traditional morphometric parameters (slope, aspect, profile convexity, etc.) are derived. In addition, by analysing the changes in elevation at different correlation lags, fractal parameters are also determined. The authors come to the conclusion that landscape exhibits a multifractal behaviour. They also argue that by investigating the spatial variability of the fractal dimension, it would be possible to identify the domains where a specific geomorphological process dominates.

CONCLUDING REMARKS

To summarise, the contributions submitted at the session of Theoretical Geomorphology cover a rather wide spectrum of topics including the analysis of drainage network, soil erosion, beach erosion, taxonomy in geomorphology and small-scale mapping. However, the greatest interest concentrates on the characteristics and evolution of drainage network. The topic is approached either by means of fractal measures, and self-similarity concepts (Veneziano & alii; del Monte & alii, Tokunaga), or exploiting the recent availability of digital terrain model coupled with algorithms that enable stream and divide lines to be automatically generated (Nakayama & Nogami).

Other issues, such as fluvial sediment transport, soil erosion and landscape classification, are investigated though the fractal theory (De Boer, Catani & Moretti, Catani & Fanti).

As a result, it is apparent that today many geomorphologists agree that most properties and fields related to geomorphological processes are highly variable. Among others, these include fluvial processes, degree of soil erosion and sediment transport. Conventional methods of representation often fail to reflect this fundamental feature of the irregularity of such fields. Consequently, many authors argue that the fractal theory, simple-scaling and multi-scaling models have an intrinsic capability of representing variability and intermittence over a wide range of physical scales, through only a few invariant properties and scaling exponents.

However, it is not fully clear if such methods are increasingly more applied among geomorphologists because of their effective potential or simply due to the fact that today they are rather fashionable.

Geomorphological mapping of very wide regions appears guided by a much more (perhaps too much) traditional approach to geomorphological problems (Orlova & Piotrovsky, Stetsyuk).

Lastly, it is apparent that cost and time constraints limit the use of laboratory experiments such as those carried out to evaluate beach erosion (Zhang & Tosaki).