Acta Geogr. Croatica	Volumen 29	29-36	Zagreb, 1994.

UDK 551.435.9 (497.5)
Primljeno *(Received)*: 20.12.1994
Prihvaćeno *(Accepted)*: 25.3.1995.

Izvorni znanstveni članak
Original Scientific Paper

ANALYSIS OF SPATIAL CHARACTERISTICS IN DISTRIBUTION OF SINK-HOLES, AS AN GEOMORPHOLOGICAL INDICATOR OF RECENT DEFORMATIONS OF GEOLOGIC STRUCTURES

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The paper offers a model based on Fry s method dealing with determination of strain ellipse, applied to the analysis of topological changes in distribution of sink-holes, developed in the rocks that have undergone different deformation types and tested on several examples in the area of the north-west part of the Outer Dinarides, where predispositions for the model application have been realized.

Analiza prostornih značajki i distribucija ponikvi, kao geomorfološkog indikatora recentnih deformacija geološke strukture

U članku se opisuje model temeljen na metodi determinacije elipsoida deformacije, Fry (1979), primjenjen u analizi topoloških promjena u distribuciji ponikava, oblikovanih u stijenama koje su pretrpjele različite tipove deformacija. Model je testiran na nizu primjera u području sjeverozapadnog dijela vanjskih Dinarida, gdje su ostvareni temeljni uvjeti za primjenu modela.

INTRODUCTION

Interpretention of character and of direction concerning the latest deformations of geologic structures within the karst regions is sometimes made event more difficult due to the missing of younger, clearly noticable lithostratigraphic marks or due to the problems in recording, recognition and interpretation of the relevant number of structural-tectonis elements at the outcrops of beds, in the zones of extreeme and manifold rock deformations.

In such circumstances, trying to find out about the character and direction of the latest movements at the local and regional level, we look for help within the framework of relief analysis, namely, within the single relief elements such as valley shapes, orientation and shape of water sheds, position of terraces, outline of coasts and particularly in analysis of the karst relief shapes, whereof within the mesomorphological ranks the most frequent are sink-holes.

The paper offers a model based on Fry's metod dealing with determination of strain ellipse, applies to the analysis of topological changes in distribution of sink-holes, developed in the rocks that have undergone different deformation types and tested on several examples in the area of the north-west part of the Outer Dinarides, where predispositions for the model application have been realized.

Fry's Method and How It Functions

Application of Fry's method in determination of strain ellipse, Fry (1979), is made possible by the laws of particle movements within the body subjected to deformation in connection with the character of statistical distribution of particles within the particular body.

So will Poisson's distribution of particles within the body before a deformation, featured by grouping of particles into clusters, remain of the same type after a deformation, whereas statistically homogenous distribution of particles within the body before a deformation will have a non-homogenous distribution of particles after a deformation, and all this in such a way that particles will draw apart in direction of the highest extension and they will draw near in direction of the highest compression, (fig.1).

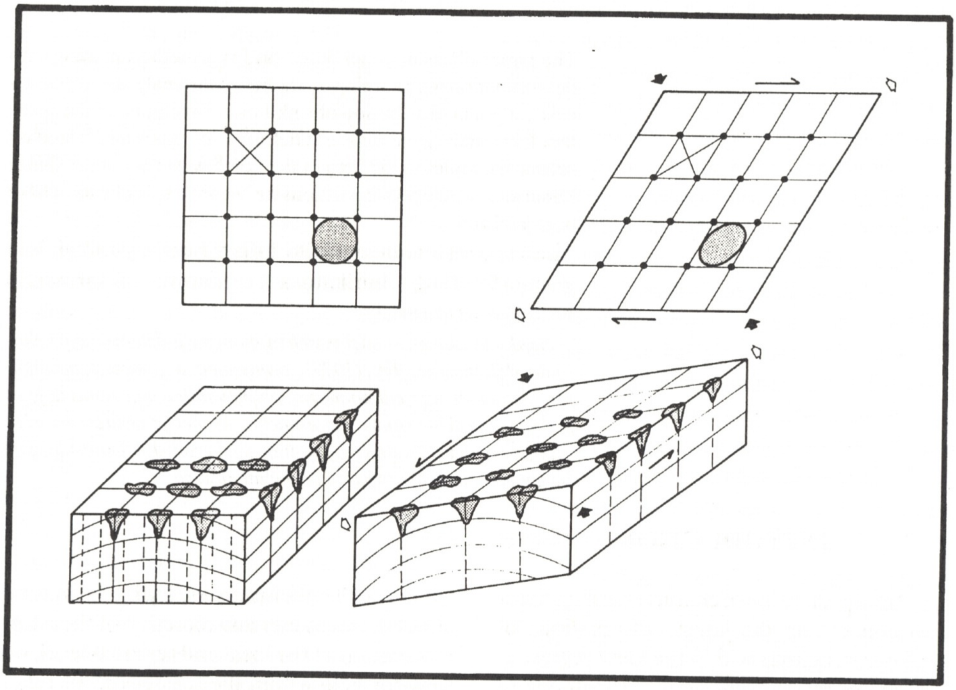

FIG.1. Principle indicating redistribution of particles during shear deformations, on basis of which congruent re-distrinution of initial sink-holes density shaped on geologic bodies that have undergone similar deformation type is assumed. Darts show the direction of extension, compresion and shering.

Slika 1. Princip koji ukazuje na redistribuciju točaka tijekom deformacija smicanja. Promjene u topološkom rasporedu ponikava podudaraju se s tipom deformacije geološkog tijela. Strelice pokazuju smjer kompresije (crne), ekstenzije (bijele) i smicanja (linijske).

In other words, if there is an aggregate of homogenously distributed particles, then the centres of other particles regarding the center of reference particle will be distributed according to the size of particles and aggregatyon type, providing the space between the neighbouring particles cannot be less than 2 r. As a deformation of the body goes on, the space between the particles changes according to strain ellipse diameter changes.

Fry's method is much more suitable than other more complex methods since it is also possible to settle the problem graphically, by manifold translations of all particles regarding the surrounding ones, for the value of the given vector. In this way we obtain elliptical condensing of particles surrounded by the void area (void area resulted from the fact that two neighboiring centres cannot be closer to one another than is the value of 2 r), conforming to the shape and orientation of the strain ellipse.

PREDISPOSITION FOR THE APPLICATION OF THE FRY'S METOD ON THE SPATIAL ANALYSIS OF SINK-HOLES

The application of the Fry's metod aiming to determine general deformation of rock complex, i.e. to determine orientation of movements assumes that the sink-holes will

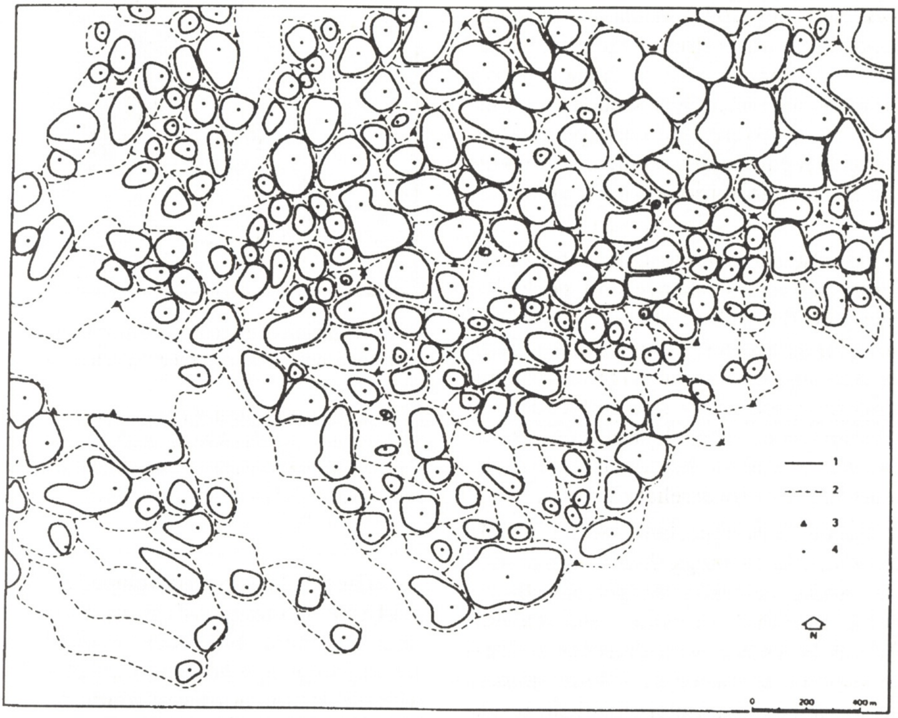

FIG. 2. An example of homogenous distribution and good aggregation of sink-holes, as one of several predispositions for application of Fry's method on determination of strain ellipse for the topological analysis of sink-holes (Bondesan et al)

Slika 2. Homogena distribucija i dobra agregacija ponikava jedna je od osnovnih pretpostavki za primjenu modela (prema Brundsen et al.)

change their topological position within the rocks in which they have been developed and wich have been subjected to deformation, according to the earlier descibed laws (fig.1).

For this we need the more homogenous spatial distribution as possible, the more uniform shape parameters as possible (shape of water shed with a small ellipsticity coefficient, uniform size of "water shed" perimeters, sinkhole depths....) and as dense aggregation of sink-holes as possible (fig.2).

Further on, the application of the metohad presumes the validity of the latest postulates on the morphogenesis of sink-holes itself, Aubert (1966), Beck (1984), Cucci et al (1975), Day (1985), Kemmerly (1982), Sauro (1991), Sweeting (1972), Williams (1985), Mihljević (1992) which stresses the prime influence of more or less homogenously distributed network of intersections or points of contact, of fissure (and fault) penetration systems that particularly on these very points intensify corrosion processes to the utmost extent.

It is also necessary to assume that deformations (structural changes) of geological bodies in the subsurface of lithosphere (emerging as changes in the position of particles, lines and level surfaces) reflect congruent alterations also at the level surface defined by the intersection of geological body with terrain surface, and so they directly affect the change of geometrical relief elements.

Finally, it is important that the terrain from which the topologic distribution of sinkholes would be taken, be geologically explored, i.e. that structural and tectonis relations be known, with detection of local and regional character of deformations in oder to compare tham later on with the results obtained by use of this method.

EXAMPLES AND DISCUSSION

The first region selected for testing of this model (limestone area with well-developed sink-hole karst between Ličko Petrovo Selo and Bihać) happens to be according to the latest geotectonis classification of the Dinarides, Herak (1986) at the contact of two geodynamic entities: Dinaricum, and to the north-east located Supradinaricum.

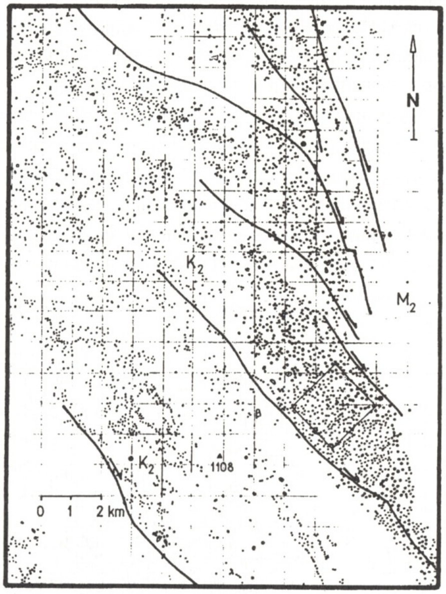

FIG.3. A region of extreme sink-hole karst, shaped in tectonic enviroment of recently active right horizontal faults

Slika 3. Područje izrazito boginjavog krša između Ličkog Petrovog Sela i Bihaća, oblikovanog u tektonskim uvjetima najmlađe aktivnosti dekstralnih transkurentnih rasjeda u nizu (en echelon).

The relief has been developed in carbonate Upper Cretaceous deposits whereas tectonis structure has been marked by a succession of righ horizontal echelon faults, with orientation northwest-southeast (fig.3), which apparently thin out, namely they got covered by Miocene deposits within which the bottom of Bihać basin has been shaped.

Orientation of layers in the limestone complex of beds is congruent with orientation

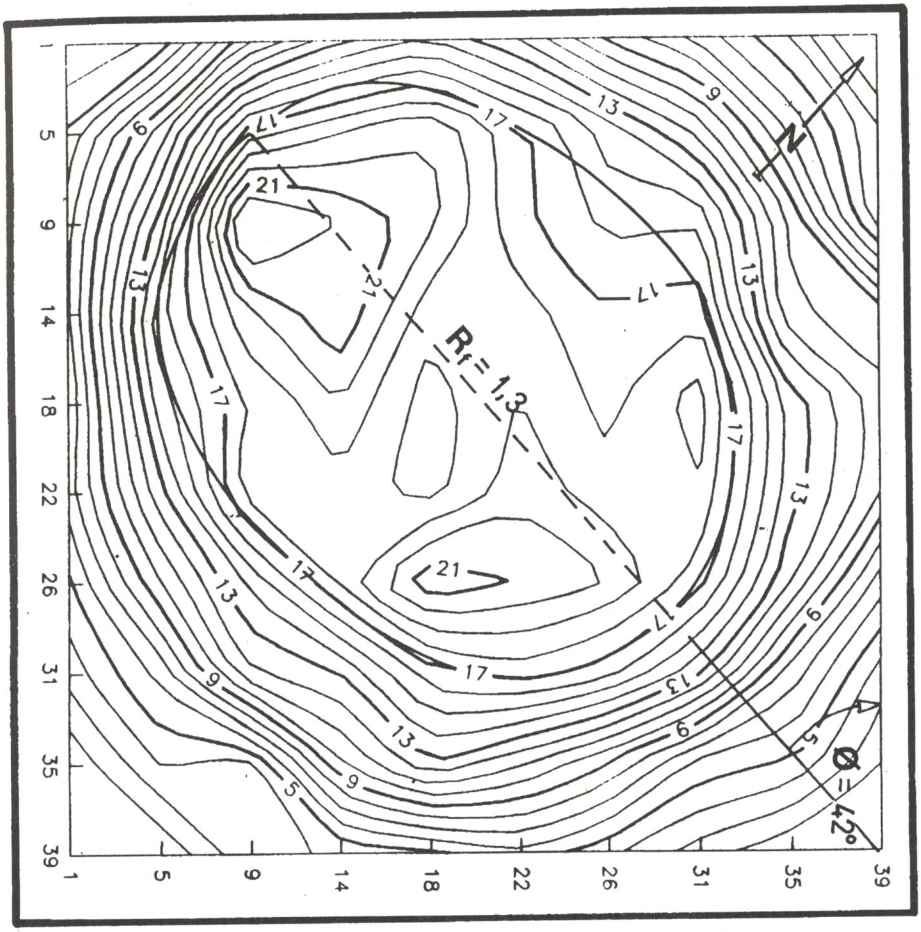

FIG.4. Orientation (ø=42 and shape (R=1,3) of strain ellipsoid obtained by translation of 40 particles (sink-holes centres)

Slika 4. Orijentacija (Ø=42) i oblik (R_f) elipsoida deformacije dobivenog 40-terostrukom translacijom centara ponikava (područje između Ličkog Petrovog Sela i Bihaća).

of right faults traces, falling towards southwest under the angle approximately less than 20 degrees.

With regard to the direction of recent global stress (north-south) we may expect that along the mentioned series of faults, lying at some 45 degrees towards the said stress direction, the right horizontal activity would be more undelined, resulting in shear deformations between the right horizontal fault routes. Also, the sample area is a typical sink-hole karst region implying relatively homogenous distribution and well-packed aggregation of sink-holes.

By means of the program package ARC INFO, we performed some 40 translations of the surrounding particles (sink-hole centres), regarding the central reference particle. Within the orthogonal network of squares (dimension: 40 x 40) into which number of sink-holes has been entered, an interpolation of isolines showing the sink-hole density has been made (fig.4).

The diagram indicated that the initially homogenous distribution of sink-holes appearing as concentrically shaped isoline before translation, has been later on statistically re-distributed, showing concentrically-elliptical form of isolines, conforming in shape and orientation to the strain ellipse that could have been expected regarding the direction of movement along the right horizontal faults, namely, to shear deformation of bedded rock between the routes of the mentioned faults.

The next region where testing of the model has been performed is a wider area around mountain group "Ćićarija" and the ridge of Učka.

The relief has been shaped in carbonate deposits of Cretaceous and Palaeogene and in flysh deposits. Tectonic structure of Ćićarija is featured by maniford reverse relations, i.e. by a seriesof reverse faults,with approximateorientation nortwest-southeast, limiting some structures and structure blocks, whereas the Učka ridge has been shaped in an overthrust structure, also marked by a number of right horizontal faults, developed during the Neotectonic era, as the consequence of restructuring due to the alredy mentioned change in global stress.

In such circumstances, reverse faults too, display nowadays in some places an underlined component of right horizontal movement, which has been also proved in the region of Kostrena (Rijeka fault),by observation of the horizontal striation at the uncovered parts of paraclases on reverse faults, Del Ben et al (1991).

Therefore, it may be expected, as in the previous example, shearing of the rock complex, which would be reflected in topological redistribution of partices, i.e. in orientation of strain ellipse. We also noticed that ellipsticity coefficients (Rf) are bigger than in the former

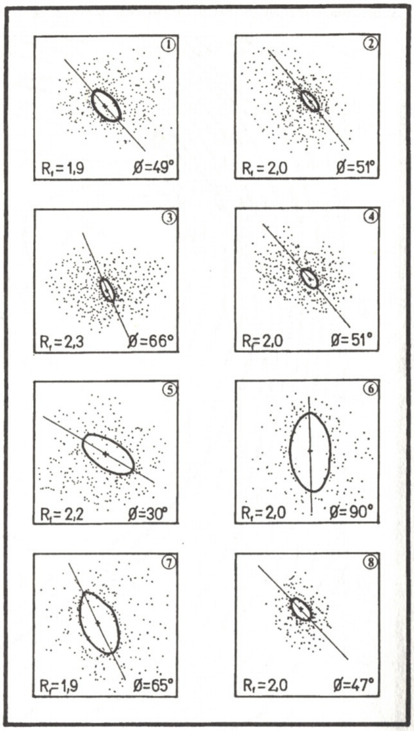

FIG.5 The obtained strain ellipsoids on wider area of the mountain group "Ćićarija" and of the Učka ridge (Rf - ellipsiticity coefficient,ø - orientation) (Difference in orientation of ellipsoid regarding fig.4, in same tectonic environment is the result of different initial direction in translation of sink-holes, concerning the deformation direction)
Slika 5. Elipsoidi deformacije dobiveni višestrukim translacijama ponikava na području Klane, (1,2) Rupe, (3,4) Ćićarije (4,5,6,7) i dijela Učke. (Rf - koeficijent elipsticiteta, Ø - orjentacija elipsoida).

example, whereas the orientation (save for the example 6) is more or less the same. (fig.5). This could be explained by the generally same direction (but different intensity) of global stress, namely, by the similar type of global deformations, in the region of the nortwest Dinarides.

Several rather rarely observed deviations in orientation of strain ellipse, obtained by manifold translations of sink-hole centres, than the "theoretically right orientation" is due to several facts. The first one is that not all predispositions for the application of the same method were met always and everywhere.

Secondly, deformation types act sometimes in combination, namely, deformations are not always homogenous. Thirdly, in some zones, strains of only local significance may appear, and they may deviate from the deformation trend of rocks in general. In this sense, a selection of scale of topographic maps and air-photographs used in analysis is of topical importance, since the rule is: the larger the scale the clearer is the character of regional deformations.

CONCLUSION

Having applied the idea of Fry's strain ellipse, for the topological analysis of sinkholes, it was found out by manifold translations of sink-hole centres it is possible to determine the orientation and shape of strain ellipse developed as a result of different deformation types of rock complex, limited by fault routes of different mechanism of shifts. On the example of the west part of the Outer Dinarides mountain range, we saw that deformation gets more and more intensive towards southwest, which was concluded on basis of bigger ellipsticity coefficients of strain ellipsoid in the mentioned direction.

Cartain deviations in orientation could be explained by the facts that not all predispositions for the application of the same method are always and everywhere completely met, due to differences in lithostructural complex of deposits in which sink-holes have developed, and which were subjected to the particular deformation type, due to the combination of different deformation types and due to the selection of scale, on basis of which the analysis would be performed and which more or less points out the local or the regional character of deformations.

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Sažetak

Analiza prostornih značajki i distribucija ponikvi, kao geomorfološkog indikatora recentnih deformacija geološke strukture

Darko Mihljević

Primjenom metode determinacije elipsoida deformacije Fry (1979) na topološki raspored ponikava, ustanovljeno je da se pomoću višestrukih translacija centara ponikava za zadani vektor, može načelno odrediti orjentacija (ø) i oblik (Rf) elipsoida deformacije nastalog kao rezultat različitih tipova deformacije stijenskog kompleksa, praćenog rotacijom linearnih elemenata ruptura, na čijim su presjecištima ili točkama dodira ponikve uglavnom i oblikovane. Topološke promjene praćene su unutar i duž trasa dekstralnih transkurentnih rasjeda u nizu (en echelon), a dobiveni elipsoidi deformacija podudaraju se s očekivanim tipom deformacija koje se javljaju unutar i duž trasa spomenutih rasjeda. Na primjerima iz sjeverozapadnog dijela Vanjskih Dinarida uočeno je da se deformacije stijenskog kompleksa pojačavaju u smjeru jugozapada, što je zaključeno na osnovu povećanih koeficijenata elipsticiteta (Rf) dobivenih elipsoida deformacije u spomenutom smjeru.

Dobiveni rezultati u skladu su s općom zakonitošću da se deformacije stijena pojačavaju u zoni regionalnog podvlačenja stijena u dubini litosfere i navlačenja pri površini.

Određena odstupanja u obliku i orjentaciji elipsoida, u odnosu na očekivane, objašnjavaju se činjenicom da nisu uvijek i svugdje ostvareni svi potrebiti preduvjeti za primjenu samog modela, zatim različitošću litostrukturnog kompleksa u okviru kojeg se mogu javiti lokalni pritisci koji odudaraju od osnovnog trenda, i konačno izborom mjerila podloga s kojih će se preuzeti topološki raspored ponikava, i koji će odražavati manje ili više lokalni odnosno regionalni karakter deformacija.

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