# SOME KARST FEATURES OF TECTONIC ORIGIN AS AN INDICATOR OF RECENT TECTONIC ACTIVITY ON THE NORTHEAST PART OF THE ISTRIAN PENINSULA

# NEKATERE KRAŠKE OBLIKE TEKTONSKEGA NASTANKA KOT POKAZATELJI RECENTNE TEKTONSKE AKTIVNOSTI V SEVEROVZHODNEM DELU ISTRE

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**Izvleček** UDK 551.24(497.12/.13)

**Darko Mihljević: Nekatere kraške oblike tektonskega nastanka kot pokazatelji recentne tektonske aktivnosti v severovzhodnem delu Istre**

Na območju Učke in Ćićarije so bile analizirane anomalije nekaterih reliefnih oblik. Te lahko kažejo na smer in intenzivnost recentne tektonske aktivnosti. Avtor skuša razložiti morfološki razvoj posebnih morfoloških oblik, ki so se razvile kot rezultat recentne tektonske aktivnosti vzdolž smeri glavnih prelomov različnih tipov. Prikazana je temeljna vloga recentne tektonske aktivnosti na razvoj reliefa v velikem in srednjem merilu.

Ključne besede: tektonika, recentna tektonika, morfologija krasa, tektonske morfološke oblike, Hrvaška, Istra

**Abstract** UDC 551.24(497.12/.13)

**Darko Mihljević: Some karst features of tectonic origin as an indicator of recent tectonic activity on the northeast part of the Istrian peninsula**

On the area of Učka and Ćićarija the anomaly of some relief forms has been analysed. They could indicate the direction and intensity of the recent tectonic activity. We tried to interprete the morphological evolution of the specific morphological forms which have been developed as a result of recent tectonic activity along the traces of principal faults of different types. We have pointed out the basic role of the recent tectonic activity on the relief formation, in macro and mezo scale.

Key words: tectonics, recent tectonics, karst morphology, tectonic morphological features, Croatia, Istria peninsula

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## INTRODUCTION

Within the structural geomorphology, more and more we come across the already asserted morphoneotectonic research, aimed to register and interpret the recent or the present-day tectonic activities of certain region on one side, and its influence upon the today's shape, distribution, density, deviations and finally the evolution of particular macro and mesomorphologic relief forms, on the other side.

Although we may follow the influence of recent or present-day tectonic activities on changes and anomalies in relief forms apart from its affiliation to a certain predominant morphogenetic type (fluvial, derrasion, karst relief etc.) and apart from its affiliation to the basic morphographic categories (plain, lowland, upland relief; hills, mountains) the most suitable, however, for morphoneotectonic research are hilly or mountain karst regions since the effects of structural transformation are preserved for the longest period and are most clearly pronounced in the karst mountain relief.

From the latest studies dealing with effects of active structures on the shaping and changes in relief assembly, on the wider area of the mountain part of Istria and the Kvarner Bay, we may point out the works by Bognar (1992), Benac (1989), Faivre (1992), Mihljević (1992), Mihljević and Prelogović (1992), Prelogović (1989).

## HOW ACTIVE STRUCTURES AFFECTED SHAPING OF THE MOUNTAIN PART OF ISTRIA

The term "mountain Istria" implies a mountain area enclosed by the structural entities of Ćićarija and Učka. It is built of carbonate Cretaceous and Paleogene deposits, clastic Paleogene deposits and Eocene flysh. Many reverse relations resulted from the extremely compressive tectogenic regime, stimulated by an exchange of stiff limestones and plastic deposits of marls, flysh). Fig. 1 shows a map of faults, classified into 6 categories according to the fault type and rank.

The first category includes reverse faults, bordering the main overthrusts, with gently laid paraclases, which is reflected in their convex outline.They define the basic orographic structure of Ćićarija and Učka.

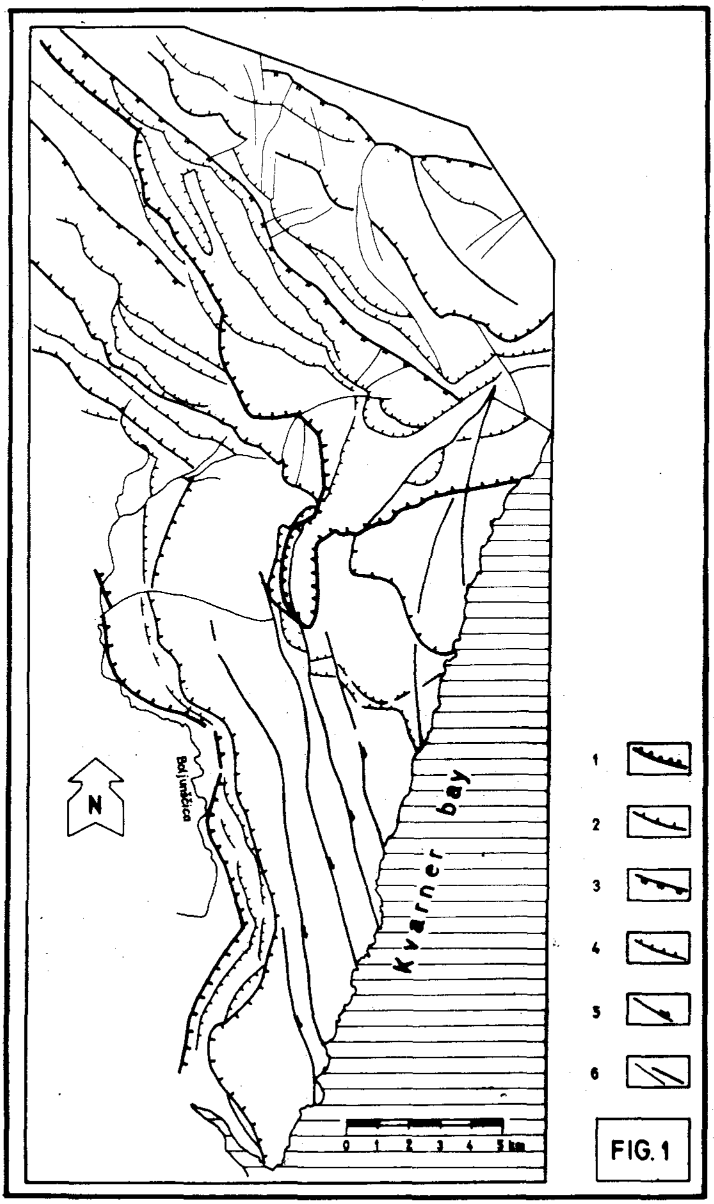


*FIGURE 1. Map of faults*

*1. Main faults bordering the principal thrusts (reverse faults of gently inclined paraclase) 2. Major faults within the structures of Učka and Ćićarija (reverse faults of gently inclined paraclase) 3. Steep reverse faults with northeast vergence (bordering particular structures) 4. Reverse faults with gently inclined paraclases within the structures of Učka and Ćićarija 5. Dextral transcurent faults 6. Unclassified faults*

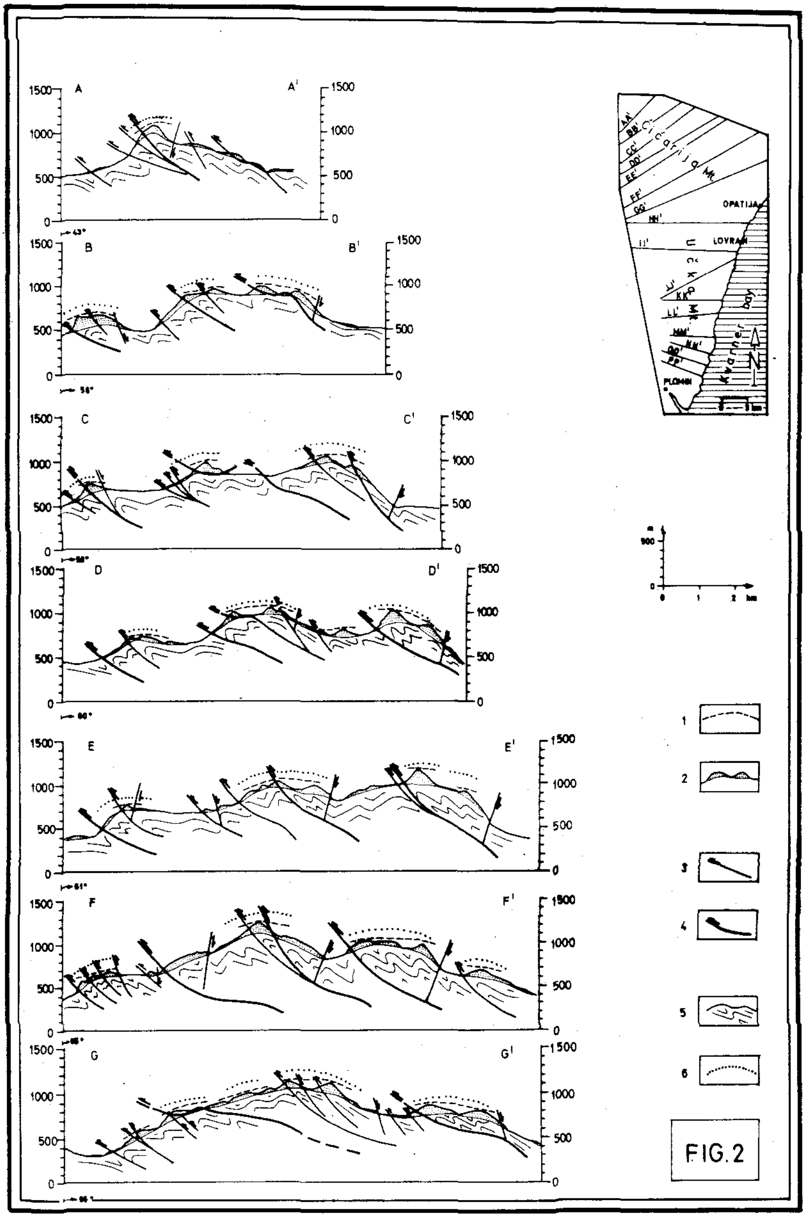


*FIGURE 2. Structural-geomorphologic profiles across southeast part of Ćićarija*
*1. Denudation surfaces 2. Relief partly affected by denudation processes 3. faults with specified limb shift 4. Main reverse faults bordering the principle overthrusts 5. Folded beds beneath the surface 6. Outlines of principle overthrusts*

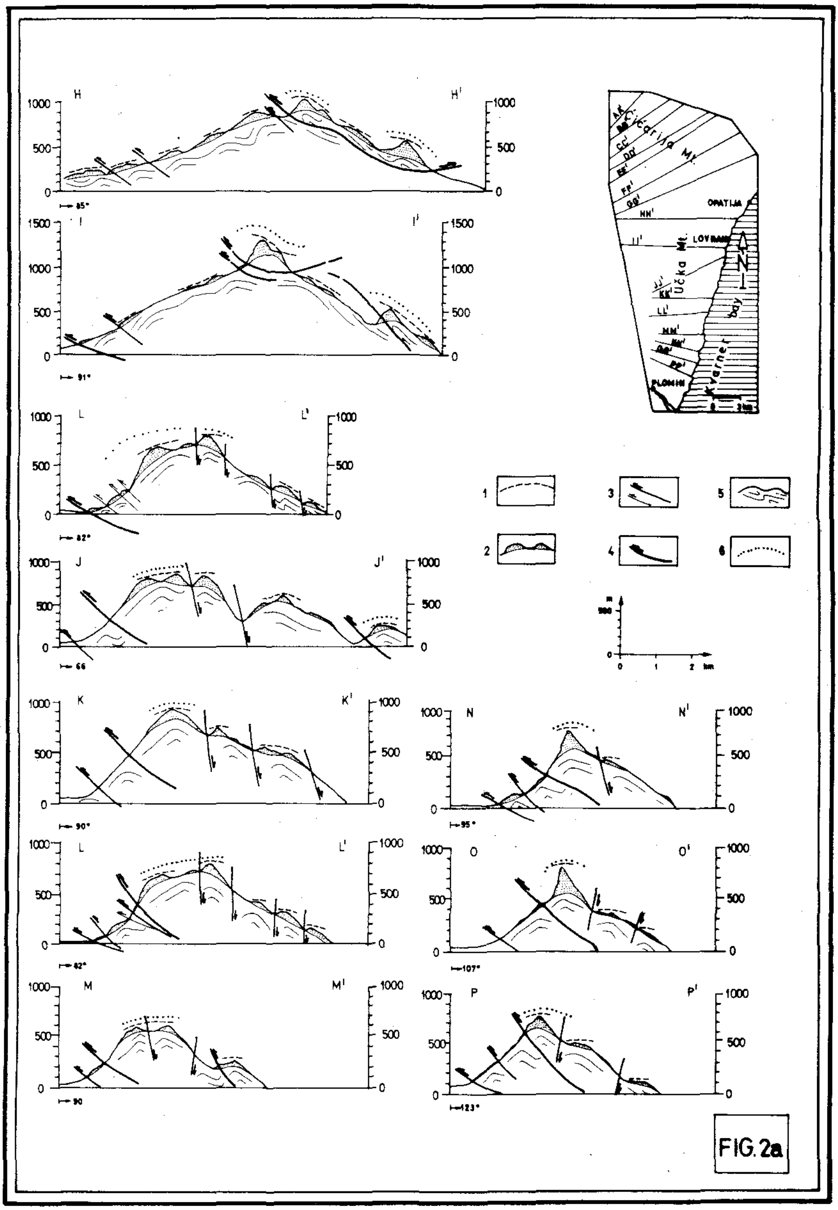


*FIGURE 2a. Structural-geomorphologic profiles across Učka (See fig. 2. for explanations)*

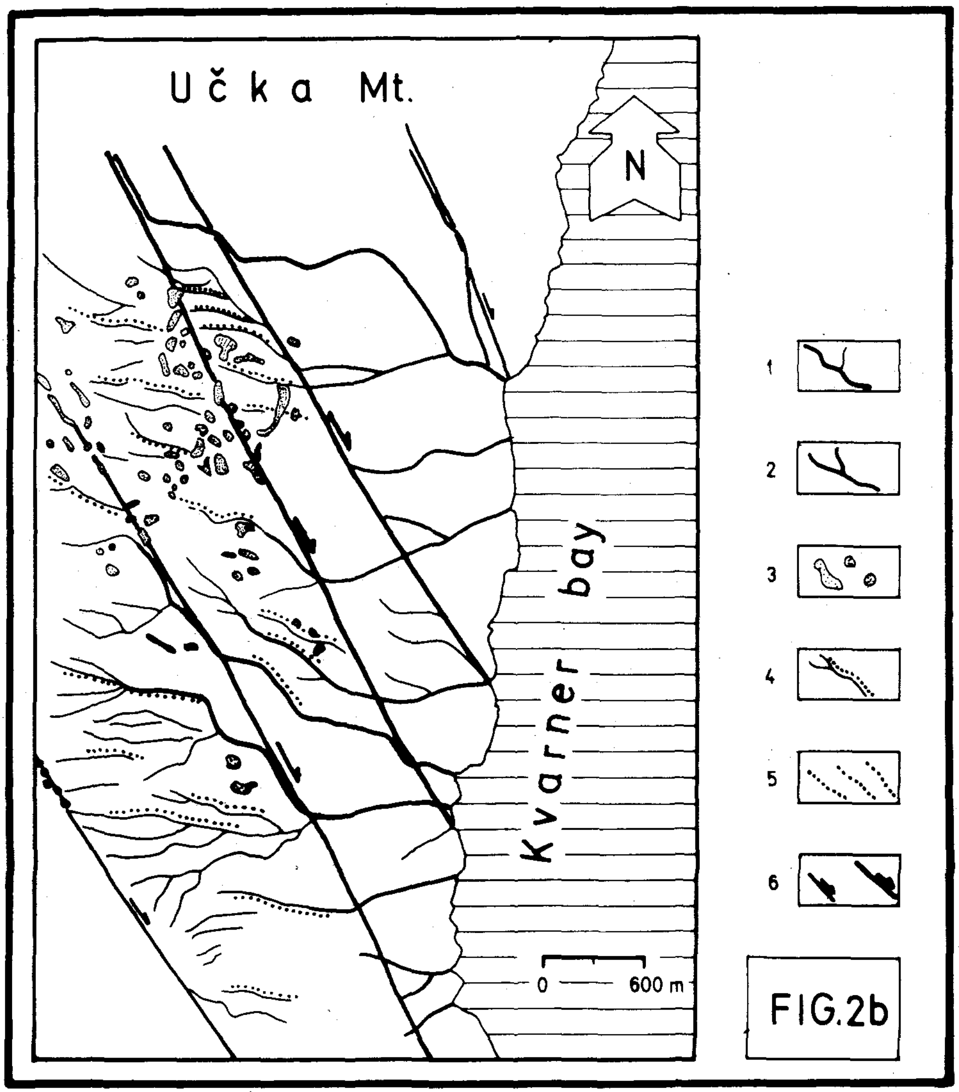


*FIGURE 2b. Relief indicators of dextral transcurent faults*
*1. Major steplike valleys 2. Valleys of lower rank 3. Karst dolinas filled with quaternary deposits (mainly terra rossa) 4. Smaller valleys of the same direction as shear joints 5. Shear joints 6. Dextral transcurent faults*

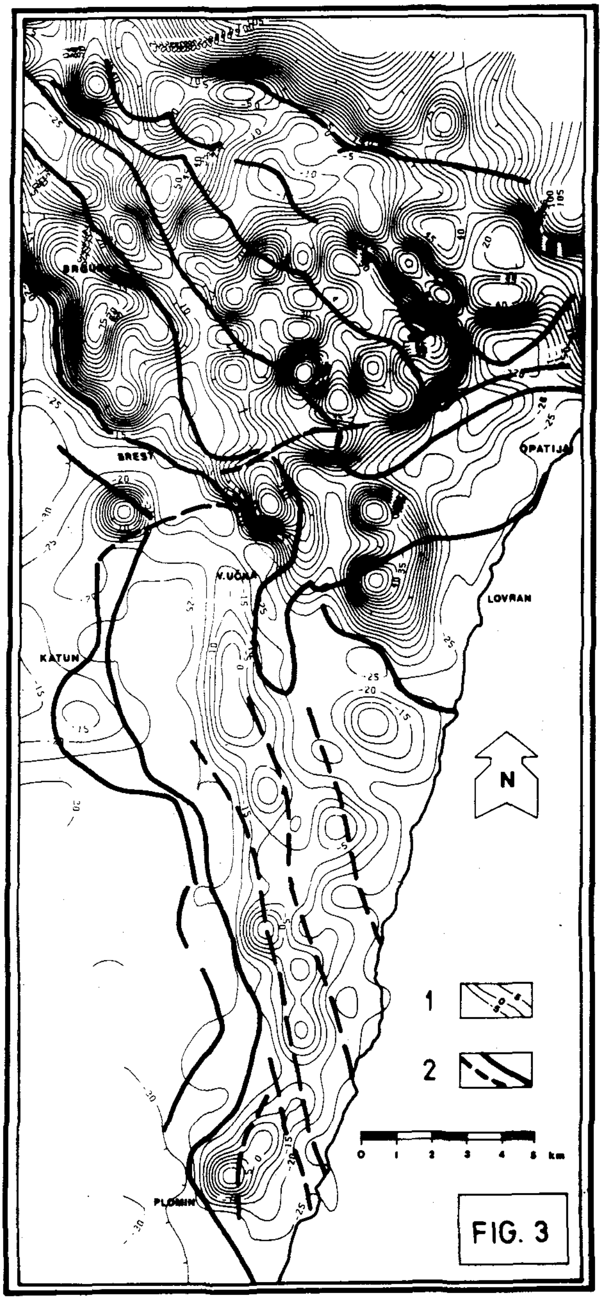


*FIGURE 3. Dolinas density map as an indicator of recent active fault traces 1. Isolines of dolinas density (number/sq.km) 2. Principal faults*

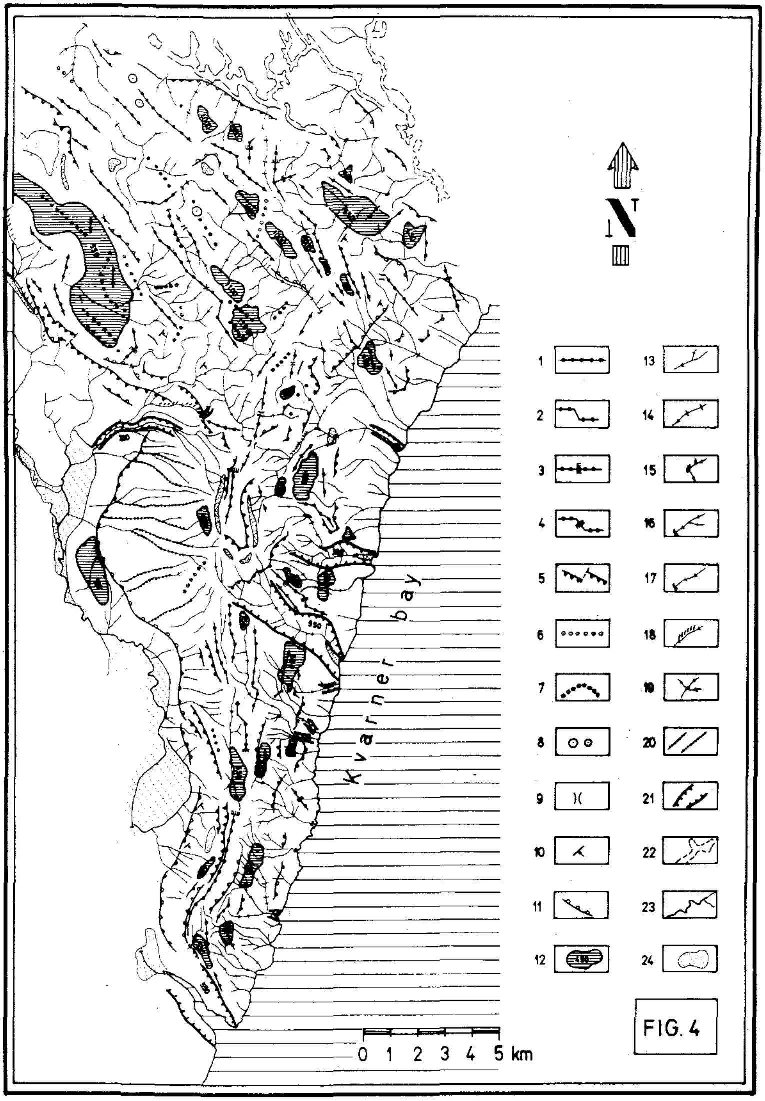


*FIGURE 4. Map of the morphotectonic relief elements*

*1. Linear ridge 2. Planar discontinuity of ridge 3. Altimetric discontinuity of ridge 4. Altimetric and planar discontinuity of ridge 5. Planar discontinuity of escarptment 6. Linear alignment of karst dolinas 7. Arc shaped alignment of karst dolinas 8. Bigger karst dolinas 9. Coll 10. Reverse slope (dip of layers opposit to the slope inclination) 11. Abrupt changes in slope inclination (bulges are directed towards inclination increase) 12. Denudation surfaces with marked average altitude 13. Direction of valley outflow 14. Anomalies in the longitudinal profile of valley talweg 15. Abrupt valley turn 16. Blind valley 17. Hanging valley 18. Valley assimetry 19. Barbed confluence 20. Rectilinear valley 21. Canyons (with marked maximum incision depth) 22. Paleokarst valley 23. River bed 24. Intensive accumulation areas*

The second category are reverse faults within the separated principal structures of Učka and Ćićarija. They define the boundaries of the morphostructural entities within principal morphostructures. Their past activity and partly the activity of today has determined the basic step-like orographic outline of Ćićarija, reflected in a succession of ridges, parallel to the orientation of basic structures and their heights increase towards north-east.

The third category of faults are normal or reverse faults with inclination towards north-east and are a result of compartmental fault type.

The fourth type of faults are manifold reverse faults of lower rank, developed in the front part of more significant higher rank faults, reflected in relief in step-like slope deformations and alternate occurrence of lower ridges and more shallow karst valleys.

The fifth category of faults include right transcurrent faults, and we shall discuss their effect on relief later in the text.

Finally, the sixth category are the faults of non-identifiable type and rank, which however, might be explained within the Ćićarija region as diagonal (tear) faults and separation faults (compartmental faults), and their activity is reflected in planar discontinuity or ridge alignment.

The basic tectogenic mechanism of reverse faulting in the region of Ćićarija, is possible to explain in the sense of a Richore concept on tectonic steps or ramps, especially because there is an alternation of competent and incompetent layers. Main faults (the first category) cut the layers in the direction of tectonic transport. At first anticline forms are shaped and then further towards tectonic transport syncline forms.When the internal resistance of masses in transport direction along the main fault plain is overcome, the main fault breaks in the front part of an overthrust.

Fig. 2 shows structural geomorphological profiles. Dotted lines show contours of the main overthrusts. On the profiles AA', CC', FF', GG', we may see a described fault break, as a consequence of compression (folding) of masses whe coming accross a tectonic ramp. A relief reflection of such tectonic style is noticeable on a step-like increase of the ridge height towards north-east,as on a wavy profile outline of the south-west slopes.

Fig. 2a shows structural geomorphological relations within the structural entity of Učka. We noticed manifold reverse relations on the west part of Učka and transcurrent relations on the east slope. In relief, their activity may be noticed by a pronounced assymetry of the west (much steeper) and of the east slopes. Within the zones of manifold reverse faults, we noticed terraces at various levels (profile HH') and shaping of so called tectonic bulges (profile LL'). The east Učka slopes decrease step-like towards the sea, resulting from the activity of the right transcurrent faults, which in an echalone diagonally cut the basic structure of Učka.

Fig. 2c shows a relief manifestation of the quoted activities. If it were not for these activities, the orientation of gulleys and valleys on the east Učka slopes would be vertical to a direction of water shed. However, valleys have a sigmoidal outline and are generally oriented under the angle of 45 degrees, regarding the water shed. When temporary torrents and gulleys on the eastern Učka slopes come across the fault, they change their direction, according to the fault orientation to the moment when a gravity force outdoes the inert flow along the fault. Since we deal here with an echelon of the right transcurrent faults, the quoted relations are many times repeated, resulting in a described outline of karst valleys and gulleys. Besides, a detailed analysis of gulleys showed that the deeper gulleys are cut in the sections in which a direction of their orientation overlaps with a fault route.

Another relief phenomenon bound to the activities of the quoted faults is reflected in a retrograde development of low rank valleys, exactly to the direction of fault route. The next indicator of a recent fault activity is a development of sink holes and karst pocket valleys with terra rossa in a fault direction. Finally, we noticed a development of shorter gulleys and parts of lower rank valleys, according to a direction of shear joints between the two neighbouring faults.

Fig. 3 shows a distribution and a density of sink holes in the region of Učka and Ćićarija. At first sight we may see a considerable difference in density of sink holes between the structures Učka and Ćićarija. An increased density of isolines represents a gradient of change in the number of sink holes. The biggest gradients of change coincide with the routes of active faults. We may also notice changes of gradients perpendicular to orientation of the basic structures which may denote the presence of tear faults. Within the Učka structure, the gradients of density indicate an activity of the right transcurrent faults.

Fig. 4 displays the separated morphotectonic relief elements showing the activity of the youngest faults. In the region of Ćićarija we may see escarpments and an abrupt change in slope inclination in direction of fault routes. We may also notice the aligned sink holes and an asymmetry of valleys parallel to the main structures. Planar discontinuities in the orientation of ridges and escarpments, and of the deeply cut valleys of an arc-outline perpendicular to the orientation of the main faults indicate to a possible activity of tear faults and a compartmental faulting type.

## CONCLUSION

Having analyised the faults of different types and dimensions, as well as specific karst relief forms, we separated the faults that had a large impact on the relief on mountain part of Istrian peninsula. Especially remarkable are morphotectonic relief elements, pointing to the recently active faults, reflecting in relief as steplike valley anomalies, and in shaping of smaller valleys, of the same direction as shear joints.

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## NEKATERE KRAŠKE OBLIKE TEKTONSKEGA NASTANKA KOT POKAZATELJI RECENTNE TEKTONSKE AKTIVNOSTI V SEVEROVZHODNEM DELU ISTRE

Povzetek

Na območju "gorske Istre" (Učka in Ćićarija) so bile analizirane anomalije nekaterih reliefnih oblik. Priložena karta kaže prelome, razdeljene v šest kategorij. Podobno so bile analizirane reliefne oblike, nato pa izdvojeni tisti prelomi, ki so bistveno vplivali na razvoj reliefa. Posebej pomembni so tisti morfotektonski reliefni elementi, ki kažejo na smer in intenzivnost recentne tektonske aktivnosti oziroma na današnje aktivne prelome. Ti se kažejo kot stopnjaste anomalije v dolinah in v obliki manjših dolin. V prispevku je torej prikazana temeljna vloga recentne tektonske aktivnosti na razvoj reliefa v velikem in srednjem merilu.