GEOMORPHOLOGICAL CHARACTERISTICS OF MARIJA GORICA HILLS

by

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Introduction

Marija Gorica Hills have been investigated by several authors, from different aspects and mainly as a part of wider areas (Roglić J., 1963., Prelogović E., 1970., Basch O., 1980.). As there is no detailed geomorphological work on Marija Gorica Hills, therefore, the task and the purpose of this investigation has been the establishement of relief structure, as well as morphogenesis and evolution.

Geomorphological position

The micromorphological entity of Marija Gorica Hills is a part of macromorphological region of Yugoslav perialpine area. On account of its structural and relief individuality, it represents a type of, so called, independent hills *(Fig. 1.)*.

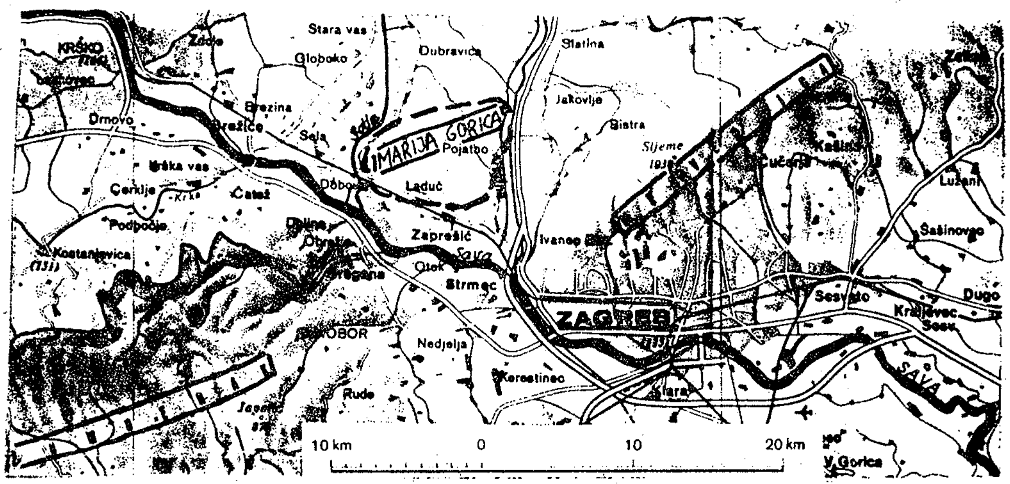

Fig. 1. Orientation map of Marija Gorica hills

As the relief structure is generally conform to geological structure, Marija Gorica Hills represents positive and concordant morphostructure. In tectonic sense, the word is about horst-anticline, elongated NE – SW, between Kupljenovo at NE and Harmica at SW. Maximal lenght of the area is about 10 km. From the aspect of vertical dissection it enters the class of gentle to moderate dissected relief, marked by dynamics values within the span of 100 – 150 m/km^2.

The area is separated, by strong fault zones, of the neighbouring morphostructures. The hills are characterized by assymetric position, and the highest parts are determined at SW and W (Sv. Križ, 310 m) *(Fig. 2.)*.

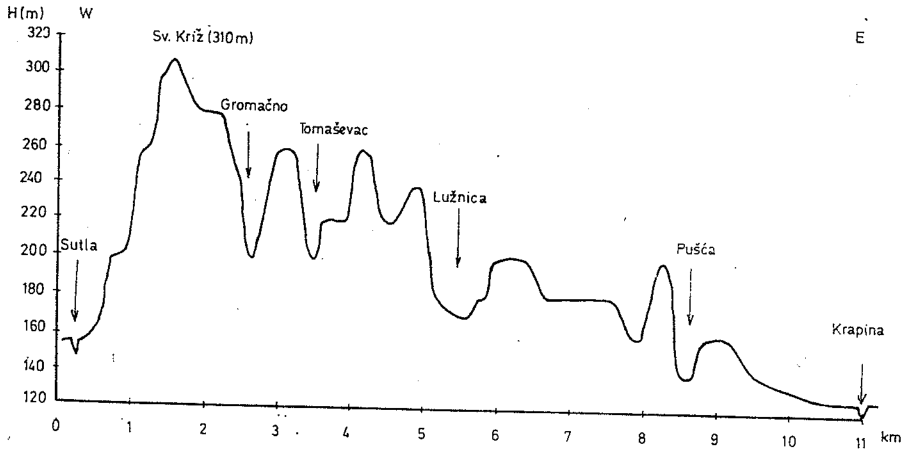

Fig. 2. Asymmetric transversal cross-section

Here exist a steep slope contact toward the Sutla and Sava river valleys. At E and NE part of the area, the slopes are gentle and gradual. SW and W boundaries are defined by tectonically predisposed escarpments toward the Sutla river valley at W (between Harmica and Bela Gorica) and S (toward the Sava river valley along the sector Harmica – Laduč). N boundary of the region is marked by the fault system intersecting the Sutla river valley. It extends along the sector Bela Gorica – Prlinšćak valley-left tributary of Pušća stream – Kupljenovo. At NE, the morphological boundary is clearly defined by contact zone of hilly area and Krapina river valley. The boundary is conventionally represented by the line Laduč– D. Pušća – Kupljenovo (although it is difficult to define the strict boundary zone toward the younger subsidence of the downstream sector of Pušća brook, i. e. Sava river terrace deposits).

From the morphostructural aspect, the area enters in the category of denudational-accummulational relief. Morphogenetically, it represents a typical derasional-erosional hilly area. Domination of tertiary and quaternary "softy" clastic deposits, besides prevailed climate and tectonic con-

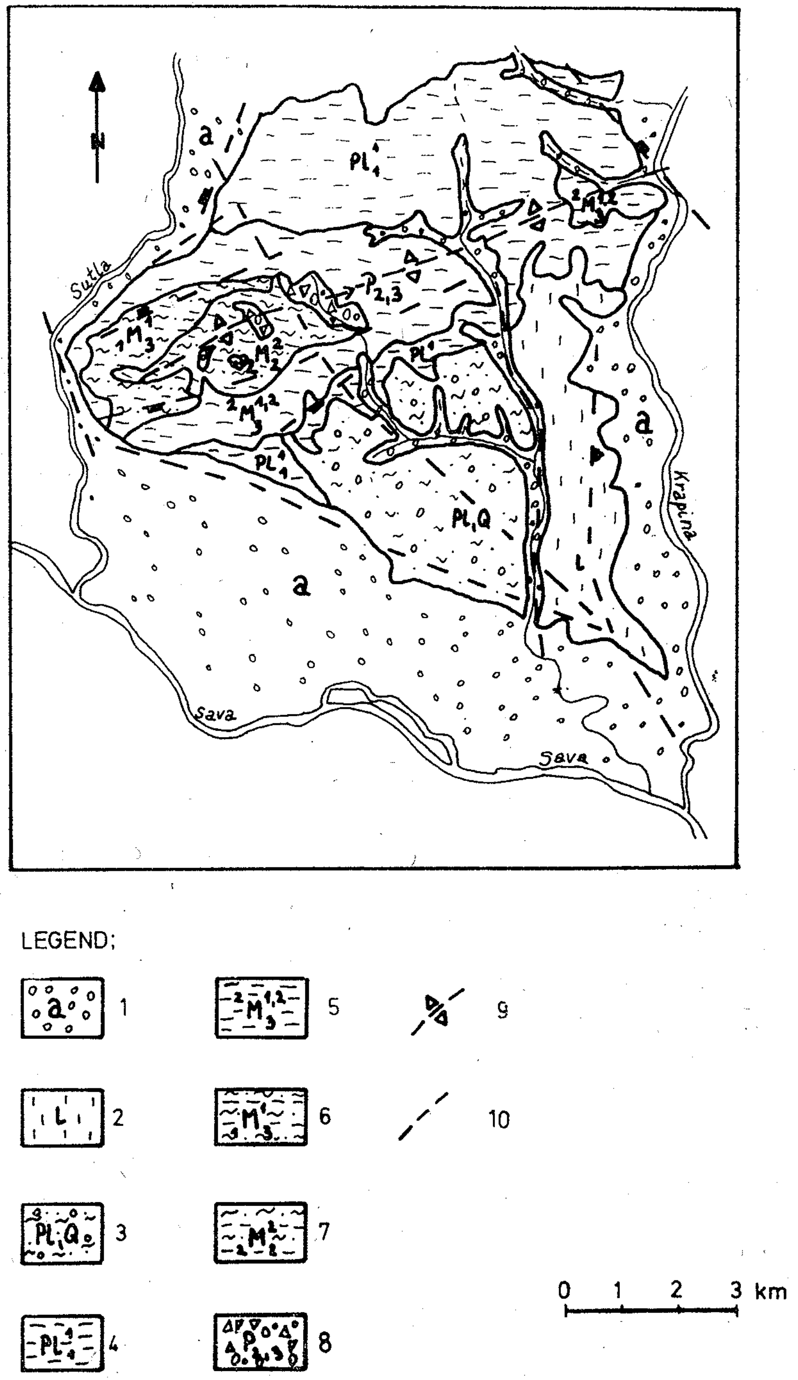

Fig. 3. Geological sketch

Quaternary. 1. alluvium — gravel, sand, clay, 2. loess-like sediments — clayey silt; Pliocene-Quaternary, 3. gravel, sand, clay; Pliocene, 4. marl, marly clay (lower Pont); Miocene, 5. clayey marl (lower Sarmat), 7. clayey marl, sandstone (upper Torton); Paleozoic, 8. quartz conglomerate, brecciaconglomerate, sandstone (middle and upper Perm), 9. anticline axis, 10. more important faults ditions, caused the development of slope and fluvial processes. Morphographicaly, it is expressed by existence of radial, branched out network of erosional brook valleys and derasional valleys, accompanied by a system of ridges with clearly expressed round tops and intercalated saddles. The area is, therefore, a typical hilly region.

Principal geological features and phases of evolution

For understanding the recent structure and relief features it is necessary to give an outline of geological and tectonic structure, as well as to mention some more significant events that have taken place during the earlier geological past *(Fig. 3.)*.

Preneogene age

In this long lasting period, the movements of the Pannonian mass rims, consolidated during the Hercynian orogenesis, as well as dominant varistic structure characterized by NE – SW direction, have got the basic geomorphological importance. In the core zone of the hills prevail the oldest determined rocks of middle and upper Permian genesis. They have been accummulated at the end of Hercynian orogenesis, and are denoted by mollase character. In their lithological structure dominate sandstones, quartz and breccia conglomerates (Basch O., 1980.). They could be sporadically determined at the surface (by means of erosion activity) of the highest parts of the area (at Marija Gorica) as well as in deeply incised valleys at the anticline structure wings (Curak, upstream tributary of Lužnica brook). Upper Tortonian deposits are directly sedimented over these rock complex, so an existance of great sedimentation hiatus during complete Mesozoic and, partly, Neogene age is obvious. There is a presumption, in spite of heterogenous sinking during Mesozoic, that some block structures (as Marija Gorica hills as an entity) have existed for the long time as intrabasin uplifted areas. Similar features prevailed in some other areas of continental part of Croatia.

Neogene - older pleistocene

There have been performed new, very strongly expressed reactivation of relict fault zones orientated NE – SW, accompanied by general sinking and marine transgression of regional relevance. It is a period of increased spliting of palaeogeographical contures, when begins a development of new, initial forms, that have been in later Tertiary, by means of fault activity rejuvenation, gradually developed (Basch O., 1980.). It is a time of forming the anticline structure "Marija Gorica – D. Stubica", as well as neighbouring syncline structures of Krško polje and "Samobor – Stubica" depression, as well as horst structure of Medvednica and Žumberak. In the core of Marija Gorica Hills over Permian rocks lay sediments of upper Tortone and lower Sarmate. They contain carbonate and clayey marl and sandstones. As a consequence of water salinity diminishing and desintegration over broader area of Parathetys, Pannonian and Pontian sediments (marls, marley sands, gravels, sands and clays) would be determined only at the sides of Marija Gorica structure (at N and SE part of the region), where gradually pass toward the neighbouring areas of Krško and "Samobor – Stubica" synclines. During the transient period of upper Pliocene and older Pleistocene described movements represent one of the most intensive tectonic phases in the S part of Pannonian basin. It is an introduction toward the youngest stage of structural and geomorphological development of the area.

Younger Pleistocene - Holocene

According to the periglacial conditions of the investigated area during Pleistocene, there has been performed an accumulation of silty material over the convenient, aplanated terrestric areas. Slightly more intensive humidity degree of the area has been expressed in increased share of clayey fraction, so that clayey loess-like sediments prevail over S and SE slopes of the region. They are represented by clayey silts, yellowish-brown coloured, containing gray, clayey horizons. There is a specific absence of carbonate component (Bognar A., 1978., Bash O., 1980.) in these sediments as a consequence of more intensive humidity contents of loess and loess-like sediments, as well as primary prevailed humid climate of the area during sedimentation. The surface parts of these deposits have been changed under the influence of pedogenetic processes, adopting the pseudogley characteristics. The lack of vegetation cover during Pleistocene maintained the intensive derasional processes, which have been dominant in the morphological development of the area (during more humid intervals prevailed linear-erosional activities).

During middle Pleistocene, by reactivation of Dinarically orientated faults (NW – SE) between Krško and Podsused, probably begins an intensive sinking of SW parts of NE – SW orientated positive structures. In the same way, the continuation of Marija Gorica structure from Harmica toward SW has been destroyed (as well as uplifted area between Podsused and Sv. Nedelja). These intensive tectonic movements, by means of lowering the local base level, have strenghtened the linear-erosional processes. The intensive incision has been continued even during postglacial by reason of changed climate conditions, that is increased humidity caused by penetration of Atlantic air masses.

Holocene development is marked by generation of derasional and fluvial relief forms. During historic period, various types of antropogene actions have significant geomorphological importance.

Geomorphological analysis

The Marija Gorica Hills, morphogenetically, represents well expressed type of derasional-erosional hilly area. Therefore, the main morphogenetic role have derasional and linear-erosional processes. As a concequence of considerable tectonic influence on its development, the area possesses well expressed morphological individuality. It is dissected by numerous consequent and subsequent derasional and erosional valleys, forming a typical hilly relief type. Intensity of derasional-erosional processes, as well as their influence on evolution and relief characteristics, could be presented, in a way, by analysis of drainage basin morphometry (Mc Cullagh P., 1979.).

Within the investigated area, three typical drainage basins could be defined *(Fig. 4.)*: Pušća, Lužnica and Pojatno. All of them are incised in homogenous lithologic structure, built by "softer" Neogene and Quaternary sediments. Hypsometric curve for all the basins show similar features. Its shape is not far from ideal, diagonal line, what is an indicator of approximatively uniform share of basin surface levels within corresponding height intervals, i. e. the type of undulating, hilly relief, without outstanding applanated surface levels or deeply incised valleys. The hypsometric integral value (HI) varies within similar frames – from 0,35 (Pojatno) to

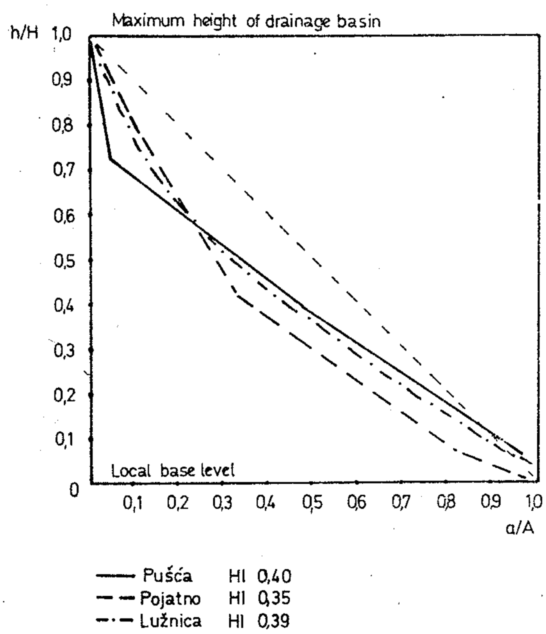

Fig. 4. Hypsometric curves and hypsometric integrals (HI) of drainage basins
A = total surface of the basin, a = proportion of the surface above any given contour, H = difference between local base level and the highest point in the basin, h = difference between any given contour and base level

0,40 (Pušća). It means that the investigated area was under the influence of intensive erosional activity, as well as even 65% of primary material volume (Pojatno) have been eroded. The HI value could, conventionally, express a degree of morphological development (according to Davis). So, this area would be marked by mature stage of its morphological evolution.

It is obvious that, besides uniform lithological conditions, prevailed uniform morpho-climatic occasions, as well. Of course, it is not to be neglected the influence of neotectonic movements, that undoubtedly played a remarkable morphogenetic role.

Within the complex of derasional processes in morphological modelation of the area were dominant deluvial and proluvial processes as well as solifluction *(Fig. 6.)*. As slope processes are influenced by various factors (lithological features, infiltration possibilities of rock complex, drainage coefficient, slope inclination), their corresponding space differences would cause a differentation of derasional processes and corresponding forms of relief.

Destructional deluvial and proluvial processes are caused by precipitation and snow-melt waters activity, down the slope by means of gravitation. The abundance of precipitation in this part of W Croatia (cca 1200mm) as well as lithological structure, defined exclusively by predominant clayey deposits (carbonate and clayey Neogene marls and clayey loess-like sediments), as well as geomorphological relations influence, caused an intensive slope destruction by deluvial and proluvial activities. These processes are especially important during the parts of year with increased humidity (spring, autumn) and respectively during very humid years. The result of just mentioned morphological processes represents an increased development of gullies and derasional valleys as typical slope relief forms.

The most of well expressed gullies are determined in the highest, W part of the area (Sv. Križ, 310 m). They are deeply incised with "V" shape of their transversal profile. This fact, as well as generally steep inclination, is an indicator of morphological youth of the area. At the foot parts of slopes, as an erosional local base level, destructed material has been accumulated, forming deluvial cones and proluvial fans. A large proluvial fan is formed at the end of branched gully system near village G. Laduč. It extends at the length of almost 300 m, covering a part of Sava river flood plain.

Derasional valleys of troughy and oval shape are broadly extended over the most of investigated area. They are result of an older phase of gully development and are generated by collapse and slipping of steep hillslopes, that become broader. Very broad, oval derasional valleys are developed in NW part of the hills near Marija Gorica, Celine and Bela Gorica. Numerous small amphitheatral derasional valleys, dellas, and, so called, derasional circuses have intensified relief dissection, forming an undulating hilly relief.

An important morphogenetic phenomena are land-slide and gelisolifluction processes – that is a motion of rocky material over the sliding surface by means of gravitation. The main role in land-slide formation plays a sliding surface, in the most cases connected to clayey strata or deposits abundant in colloidal particles (Bognar A., 1983.). Well expressed land-slide phenomena dominate at SW slopes of the area. This fact is caused by steep slope inclination, lithological structure, as well as Sutla river lateral erosion influence to slope destabilisation and land-slide activation. The slopes are generally marked by convex profile, the fact that shows their morphological youth. Gully development, slope shape and inclination, as well as land-slide phenomena can indicate younger uplifting movements. The slopes with potential land-sliding activation are very often at SE and E part of the hills. This is the case especially with valley sides of Curak-Lužnica, Mačkovac and Pušća brooks. As a consequence of intense morphological processes it could be registrated a phenomena of road spliting on the clayey slopes (e. g. at the village of Trstenik, in the Curak valley). As a broadly extended phenomena there is "folding" of sliding material within, so called, "land-slide tongue", formed by processes of compression. Sporadically, it could be found (S of Trstenik) subsequent subsidence of sliding material, by means of suffosion activity. All of determined land-slides are included in, so called, "carpet" land-slides (Bognar A., 1983.). Great number of dellas and derasional valleys are genetically connected to development of just mentioned "carpet" land-slide type.

Linear erosion is of great importance in erosional, brook valleys. Its influence is not so extended as derasional ones, but possesses a morphogenetic significance. All significant streams are incised in the E slopes of the area, flowing toward SE. The valleys are tectonically predisposed, marking the faults of N–S and NW–SE orientation. They have influenced the dissection of elementary horst-anticline structure on smaller blocks. Brook valleys are, partly, deeply incised. The most significant is a gorge of Curak stream, NE of Trstenik. The brook is deeply incised into Palaeozoic quartz and breccia conglomerates. Additional assymetry of Curak–Lužnica, Prlinšćak and Pušća transversal valley profiles shows at strong radial uplifting movements characterized by various intensity values. On the contrary, an abruptly developed strong meandering and intensive marsh-land formation along rims of the valleys is obvious in the downstream sector of Pušća stream, S of Dubrava, as well as over the stream sector Lužnica, E of Trstenik. The ridges are not so high any more. All these phenomena show an existence of local subsidence area.

Along the valley sides, two erosional levels could be, generally, differed. They are determined in the Prlinšćak and, partly, in the Pušća valley, as well as along the brook valleys of Pojatno and Curak. These levels are indicators of polyphase morphogenetic character of the area. It could be differentiated two phases of strong erosional valley incision, and the recent one, as well as single phase of valley broadening. It is well expressed in the Prlinšćak valley *(Fig. 5.)*., where, after primary incision phase into the highest level, follows its derasional lowering (by two oposite derasional valleys, and, as a result is formed a saddle with higher derasional cone summit).

It is possible to presume that the age of the first incision phase was during Riss – Würm interglacial, or in the period of interstadial $W_1 - W_2$. Derasional phase of destruction would refer at younger Würm, while the youngest phase has been followed in postglacial. Phases of stronger incision have been probably influenced by the combination of climate conditions and tectonic movements, prevailing at the end of Riss – Würm interglacial over the broader area of middle Danube basin (Pécsi M., 1976., Bognar

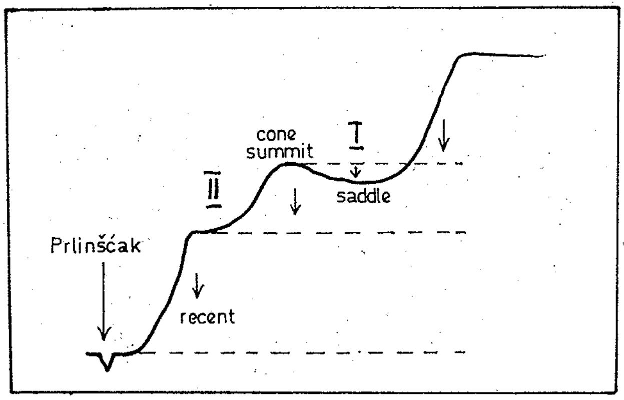

Fig. 5. Erosional levels in Prlinšćak brook valley

A., 1982.) and respectively, at the end of Würm period (S foothills of Medvednica mountain; according to Bognar A. and oth., 1976.). It is tested by the following facts. Along the separate valley sector there has been determined disagreement of levels developed on the opposite valley sides, or an absence of corresponding levels at one valley side. It is a case with Curak valley, where the righthand valley side levels are considerably higher (by about 10 m) than left ones. In the Pušća valley, level fragments at the right valley side are generally continuous, but not exist near village D. Pušća at lefthand valley side. It is the word here about subsequent tectonic dislocation and differentiated uplifting of individual block structures. The recent relief and tectonic structure of the area is, therefore, plausibly formed during the youngest geological time (Pleistocene – Holocene).

An indicator of neotectonic and even recent tectonic movements is a morphometric analysis according to V. P. Filosofov's methode (1960)[1]. There have been constructed the maps of erosional basis surfaces of second and third order. On the basis of their analysis and comparison, the synthetic neotectonic map is constructed *(Fig. 7.)*. The maps of erosional basis surfaces of third order point out the existence of an anticline oval structure orientated NE – SW. Densely ordered isobasites at W and, especially S part of the structure indicate the strong uplifting movements. E part

[1] As a basis have been used orohydrographical maps in scale 1 : 25 000. They contain all basic morphographic and morphometric features necessary in construction of special maps.

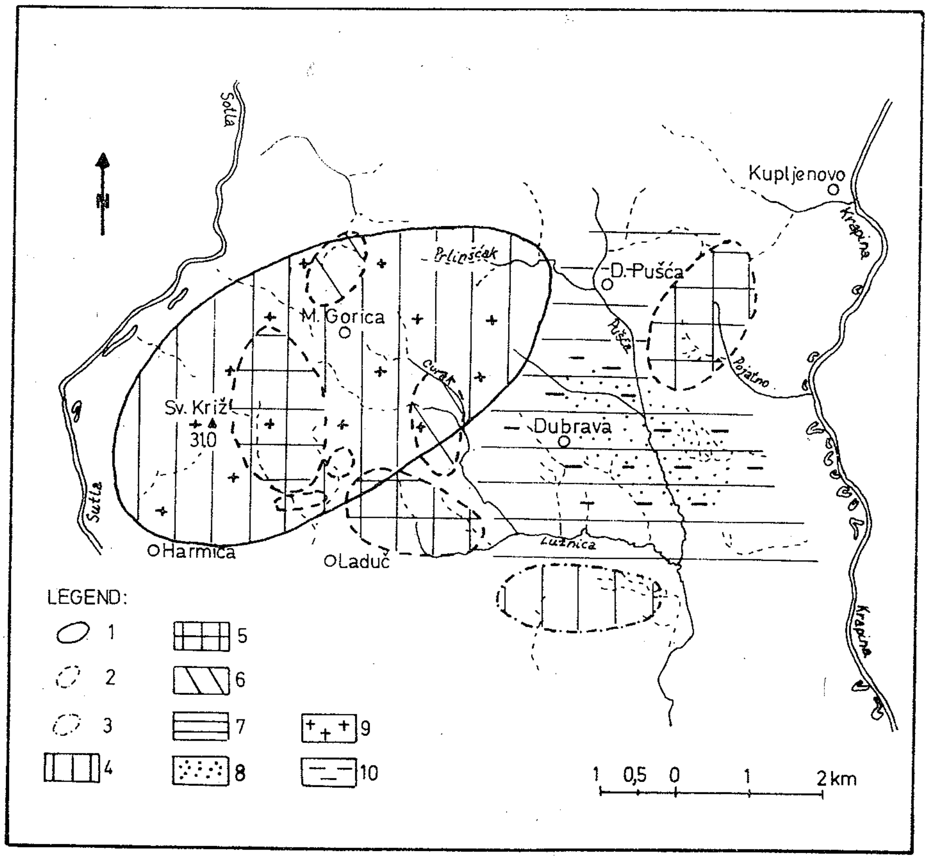

Fig. 7. Neotectonic map of Marija Gorica hills

1, anticline structure, 2. local anticline structure, 3. presumed local anticline structure, 4. area of neotectonic uplifting, 5. area of intensive neotectonic uplifting, 6. area of slight neotectonic uplifting, 7. area of neotectonic subsidence, 8. older sunken structure, 9. inherited structure, 10. non-inherited structure

of the structure is marked by broader distance of isobasites, as a result of slight sinking tendency. These relations probably express the situation during transient period of Pliocene--Pleistocene[2]. Additional data have been gathered by comparing the maps of erosional basis surfaces of third and second order. W part of the anticline structure shows inherited features, characterized by emphasized uplifting movements. The E part of the area shows much more complicated situation. There exists an abroupt

[2] The valleys of the same order mostly represent forms of equal age. According to Filosofov, the erosional basis surfaces in the valleys of second and third order are related to the tectonic movements of Pliopleistocene age, and erosional basis surfaces of third and higher order mark summary movements of Quaternary and Pliocene age. Comparing the maps of different erosional basis surfaces, it is possible to presume the vertical movements of terrain during the time.

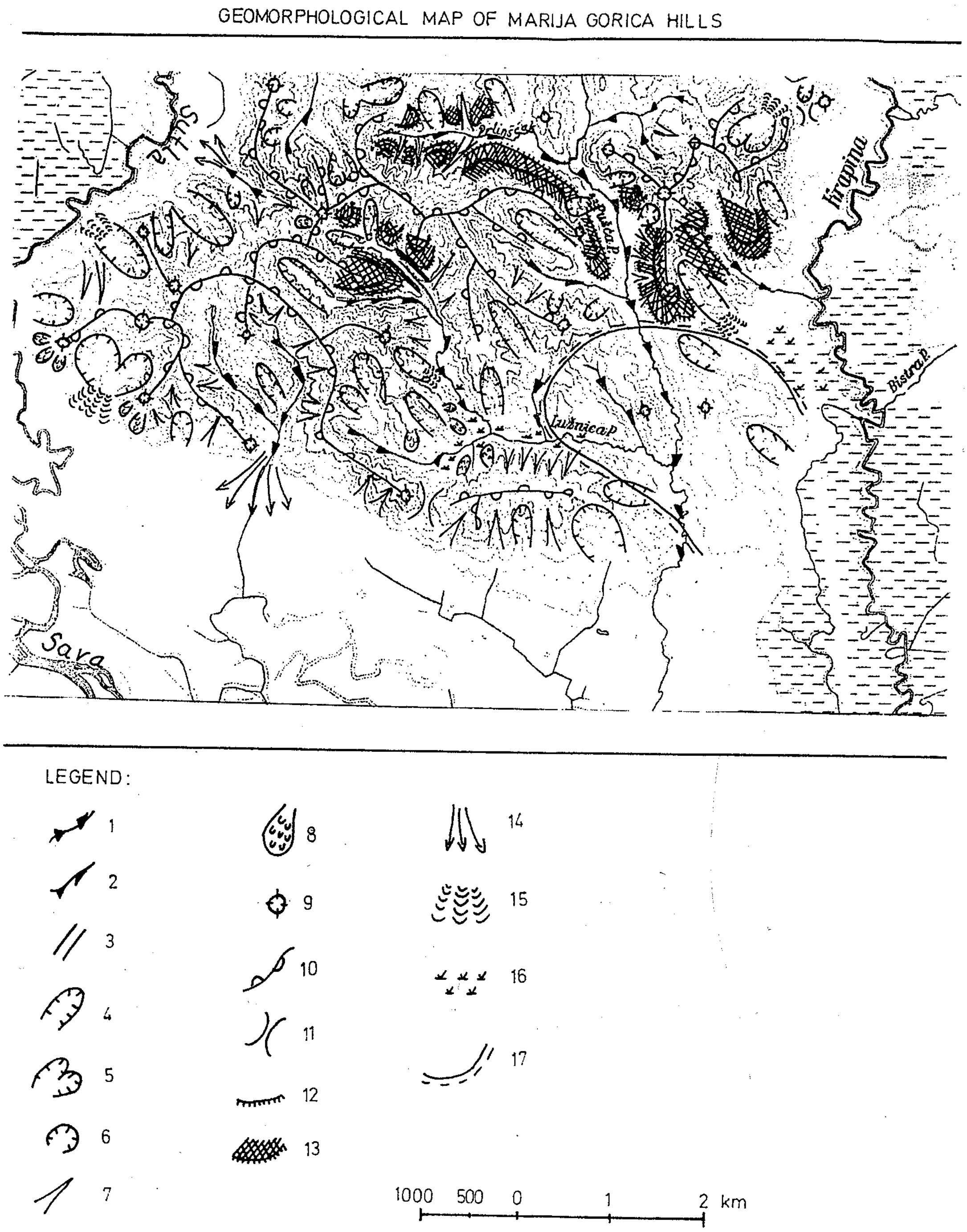

Fig. 6. Geomorphological map of Marija Gorica Hills

1. symmetric valley, 2. asymmetric valley, 3. defile, 4. derasional valley, 5. derasional circus, 6. della, 7. gully, 8. landslide, 9. derasional cone summit, 10. round formed ridge, 11. saddle, 12. erosional step, 13. erosional level, 14. brook fan, 15. proluvial fan, 16. marsh, 17. boundary of recent subsidence

and sharp bending of the second order isobasites along the direction N – S and NW – SE, so they cross isobasites of the third order under considerable angle. Consequently, the word is about the genesis of a young, non-inherited structure, by means of just mentioned fault activation. Relatively great distance between isobasites of second order is an additional indicator of subsidence movements. Pliopleistocene structure is defined only at basis surface of the third order and is obviously sunk during younger Pleistocene. At that time, tectonically predisposed valleys of Pušća and Lužnica have been probably formed, as well as structure spliting at individual blocks, marked by tendency of stronger or gentler uplifting or subsidence.

In these way gathered results are concordant to above mentioned suppositions about younger Pleistocene valley incision. Development of the valleys has been significantly influenced by tectonic movements, respectively, differential movements of individual blocks.

Synthetic neotectonic map gives an information about the existance of local anticline structures, as well as the areas influenced by more or less intensive neotectonic uplifting or sinking. There is determined, generally, an uplifting tendency of rim, W and S parts of the area, while in the downstream sector of Pušća and Lužnica valleys, prevails neotectonic subsidence. This situation is clearly reflected in space, by means of, already determined, prevailing morphological processes and corresponding relief forms.

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