GEOHAZARDS - RECENT PHENOMENA AND PROCESSES OF FLUVIAL RELIEF

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Natural disasters considered as a primary factor in development of the relief, in the second half of the 18th century, are not sufficiently investigated in geomorphological studies of uniformitarian understanding and in geomorphological analyzed approaches in defining of morphological genesis and evolution. In uniformly concept the privilege is given to the M.W. Davis concept of morhological evoluation of pineplen which is mainly based on three stages of exogenous development.

Besides in this paper the integrative approach was studied, sublimating relief evolutionary analysis, whose proponent was A. Penk. Davis's and Penk's concept are based on endogenous and exogenous processes and phenomena, but with different interpretations of evolution and their disruption.

Recently with frequent climatic fluctuations which cause natural disasters, natural hazards are more often involved in the complex analysis of the genesis and evolution of relief. Proponents of geohazard activities current emanation of tectonic activity and exogenous processes and phenomena consider for initiators of the current transformation and simultaneously generate new types of relief plastic. Some examples of these processes will be studied in this paper.

Key words: *relief, morphological genesis and evolution, pineplen, uniformity, morphological analysis, river thalweg, natural disasters, natural hazards*

INTRODUCTION

Land relief features may be considered to be the outcomes of natural dualism of internal tectonic and external egzodynamic processes and phenomena. In that natural genetic integration, uniform processes (Hutto, 1975) and sudden natural disasters occur (Cuvier, 1800). Those processes and disasters affect morphology of a part or of the entire surface of the planet.

Geomorphic uniformity advocates sucession of natural processes and phenomena commonly known as exogenous processes. They are continuous, complementing, and they act in the same direction of the pineplenisation. The pineplenisation can be accelerated and decelerated as the result of natural processes, so that the pluvial precipitation increase is followed by accelerated fluvial erosion and loose detritus' transportation and acceleration. On the other side, isohyetic decrease temporary reduces and uniforms all the processes. Uniformity predetermined some geomorphologic studies of landform evolution, such as morphologic cycles (W.M.Davis, 1902).

However, the upholders of natural disasters prefer the sudden and powerful land metamorphosis, no matter whether exogenous or endogenous geohazards are involved. The advocators of geohazards consider instantaneous emanation of tectonic and exogenous processes and phenomena as initiators of current transformation and generation of new

embossed plastic types. In nineteenth and twentieth century, this funded the basics of relief evolution and divided geomorphologists on erozionists and those who advocated that the relief originated from instantaneous cataclysms (neptunists, plutonists and fluvialists).

UNIFORM AND GEOHAZARD PERCEPTIONS OF GENESIS AND EVOLUTION OF THE RELIEF

Uniform perceptions of relief development

Constant, persistent and uniform phases of relief development based on morphological cycles belong to the natural geomorphologic uniformity. The advocator of the uniformitarianism, William Morris Davis, differentiated between three stages of morphological cycles. Those are a younger, juvenile stage of development, the older mature relief development stage and the senile development stage. According to the conception, there was a gradual movement from the yuvenility to the senility.

According to Davis, the initial stage begins after the occurance of vertical tectonic movements that raise a peneplain. As a consequence, the erosion processes are significantly intensified since the gradient of rivers rapidly increases. Also discrepancy of longitudinal thalwegs occures. Furthermore, those processes are forming deep V-shaped valleys and indicating landslides of lateral slopes and watershed sides.

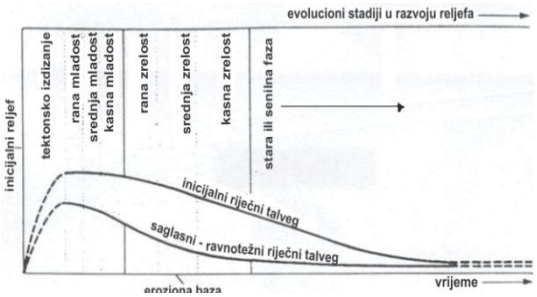

Fig. 1. Davis's development cycles of relief

Source: M. Vresk (1997)

Lateral regressive dissection causes sides of the channels to evolve from older juvenile stage to the stage of narrowing orographic watersheds between them. The regression disorganizes surface river network so that concave slopes gradually transform to convex ones. This relief development stage is the older stage of mature relief which is transition stage to the senile development stage.

Simultaneously with previous processes, processes of eroded detritus transportation and accumulation occur. Accumulation processes at longitudinal thalweg occur lawfully, in form of zje sedimentary waves, where larger waves are moved upstream, smaller ones downstream while the smallest sedimentary waves move most distant from the place of formation. As the result of the process, eroded detritus alluvium at the stream bed and in near is formed and it contributes to the alignment of initial peneplains. That is the final senile stage of fluvial morphostructure development where the transformation the initial one occurs.

In this way, one uniform stage of relief development is completed. The relief formed is of polymorphic and polygenetic type. If the morphologic evolutionary cycle is interrupted, the stage can be renewed. The interruption of process usually comes as a result of new endogen processes which are the base of the initial relief for new fluvial processes.

Depending on predominant physical processes and phenomena that occur in drainage basin, tectonic initiators of Davis cycles' interruptions can be replaced with various exodynamic processes. Davis' cycles can have its full meaning only when considering certain parts of surface of the planet Earth, that can be even smaller that the surface of

medium developed basin. In one part of the basin, longitudinal thalweg can be adjusted according to recogni-zable Davis' cycles, while in another part of the same basin they need to be neither coherent nor recognizable.

Newly created exodynamic mophostructures can be analyzed according to predominant agents and modifiers which destructed primary morphostructure. This is morphological chronology or according to W. Penk (1924) morphological analysis. Even though both the theory of Davis and the theory of Penk, are based on endogenization and exodynamism of processes and phenomena, they differ in perception about evolution and its interruptions. Davis' perception of peneplains and Penk's perception of morphologic analysis of relief are based on uniformity of exodynamic processes and phenomena which are interrupted by sudden tectonic processes.

Geohazards-natural disasters and catastrophes in transformation function of relief

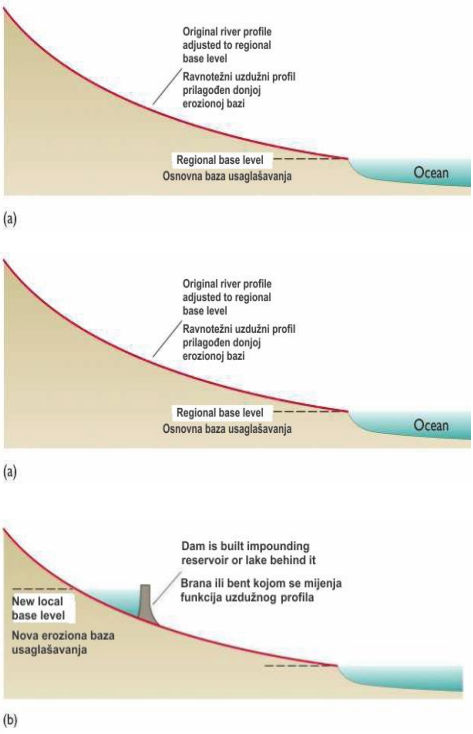

Fig. 2. Interrupted final phase of river thalweg equilibrium with anthropogenic barrier-bent (figure a), the occurrence of new erosion base of the new harmonization of the thalweg (figure b) and the creation of accumulation in front of bent, and a deep erosion behind the bent (figure c)

Shortcomings of uniform perceptions of relief development are not only present in interaction of endogenesis and exogenesis where endogenesis initiates exogenesis, but also in a fact that exogenetic chronology is not necessary to be interrupted or initiated by exodynamic processes. However, it can be interrupted or initiated by new and intensive exodynamic processes that cause existing initial morphologic phases to alternate with those that take part in formation of new morphologic expression.

New exodynamic processes and phenomena are sudden, tense, and geohazardous. They initiate the emergence of new juvenile stage of uniform relief development. The processes firstly interrupt, and then accelerate uniform relief development. It is very important to mention that uniform theorists have never gave up the idea about the role natural disasters play in formation of morphological habitat of Earth's surface. According to them, this represents a key factor for understanding the planet's morphological history and its future projections.

The natural disasters theory had been raised in eighteenth century through the writings of G. Cuvier. Cuvier initiated new views for the geomorphologic evolutionists among which C.F.A von Hoff and C. Lyell are of special importance.

Geohazards (Varnes, 1984) are defined according to the probability of potentially hazardous natural processes and phenomena occurrence. Among the most important geohazards that induce changes on relief are tectonic geohazards. The most significant tectonic geohazards are volcanism and earthquakes while landslides can be induced by exogenic processes related to meteorological and hydrological changes.
Negative exodynamic geohazards can be further accelerated by an anthropogenic factor. The most important among them are the cuts on unstable hillsides intended for construction of urban and infrastructural objects. It can initiate destructions of slopes of which the most common are colluvial, deluvial, and proluvial escarpment and landslides (Figure 3).

Changes in the level of morphological compatibility of fluvial thalweg caused by construction of waste dam are also considered to be anthropogenic initiating factors since regressive erosion and fluvial alluvium accumulation are coordinated according to the dams. They actually represent a new erosion base according to which new fluvial thalweg moves. Upstream, the fluvial alluvium accumulates, while downstream the deep erosion is forming and causing riverbed to move according to the end erosion base of the water course termination point.

Fig. 3.The landslide initiated by cutting the unstable colluvial slopes in the Željezno Polje

Anthropogenic bents cause the river thalweg to change from the balanced and uniform evolutionary morphologic habitat to the gradual one which can be seen in Figure 3. This example justifies the interruption process of Davis' exodynamic uniform cycles with the uniform external modifiers that are immediate, surprising, very strong and dynamic. The most common external modifiers are pluviometric which can triple the amount of monthly precipitation. Natural disasters are predominant among all exodynamic processes so that all climatic fluctuations that cause frequent weather variations are attributed as having leading role in landscape transformation. Among the supporters of the theory that climatic elements have dominant role in transformation of relief, J. Büdel who referred to climatology as to climate geography has the prominent place.

Some examples of pluviometric geohazards in Bosnia and Herzegovina

Natural disasters with the function of reforming reliefs from previous shapes into their recent states are recorded by the new floods with catastrophic consequences. The catastrophic floods were conditioned by pluviometric disasters during May, 2014. Examples of these processes are apparent on several locations in Bosnia and Herzegovina. One of the examples used for this paper confirms the function of geohazards in initiation and evolution of new relief forms. It occurred in the basin of the river Željeznica, the left tributary of the river Bosnia in its central basin. The entire basin of the river Željeznica is located in rural areas which are conjoint with region of Željezno Polje. In the last eighty years, there were evident anthropogenic transformations of the basin of the river Željeznica in the region of Željezno polje. This transformation is defined by using cartographic method. The

transformations occurred in the rural areas where the number of residential and other buildings was continuously increasing from the number of eighty in the year 1930 to the number of 1221 nowadays.

Fig. 4. Geohazard in the Željezno Polje in which during only one day, the accumulative fluvial deposits on the pediments raised erosional base for 10m, according to which the recent harmonization is accomplished.

Fig. 5. Geohazard in the Željezno Polje, which accumulating the deposits raised the pediment in only few hours on account of lowering the existing morphological antiforms.

The transformations of the rural areas together with other infrastructure induced splitting of Paleozoic molasse pediments on smaller parts which significantly changed morphologic evolution. Joint with agrarian processes, the processes substituted natural forest landscapes with anthropogenic ones which could not resist latest fluvial hazards. Severe weather with enormously high five-day quantity of rainfall caused increased inflows to the river streams.

Natural hazards are conditioned by particular systematic distribution of cyclonic action centers. One of the especially important cyclones in this case is Genoa cyclone. This cyclone generated turbulent thermal convection of warm air over central part of Western Balkans. From the north side, the thermal convection was limited by stable and colder air so that its activity was repressed and therefore dominant at the southern and eastern parts.

Those weather conditions were preceded by increased weekly amount of precipitation which occurred in the beginning of May. There was especially high amount of water flowing through the river basins. The coefficient of flow was five times greater than the average one, especially in the case of river systems with lower taxonomic range.

Water level increase was also affected by evapotranspiration caused by complete air saturation by humidity. River streams saturated in water-bearing geologic surface with the intensive horizontal morphologic discreetness greater in medial than in transversal part accelerated the stream of the water in stream bed. All those factors caused intensive streaming of river tributaries. That was more evident in the basins with scarce phyto production such as the basin of the river Bosnia.

Fig. 6. Landslide initiated with the road communication in Željezno Polje.

Stream processes significantly modified the fluvial forms which moved directions of surface streams. Besides that, the significant changes in morphology of stream beds were conditioned by erosion and accumulation processes and phenomena. Besides typical fluvial processes, intensified proluvial, colluvial and alluvial processes induced denudation and the significant changes in morphology of stream beds. New fluvial processes caused the transformation of existing and initiation of new downhill forms. The existing stream beds and bottomland slopes in hydrographic system of the river Željeznica were modified so that at the ends of the bottomland slopes there were transformation from convex to concave forms. Also, stream bed accumulation elevated the erosion base which was evident in Figures 4, 5, and 6.

DISCUSSION

Based on new perceptions and experiences, it is indisputable that relief is affected by tectonic movements at different hypsometric levels. Afterwards, it is exposed to all forms of exodynamic destructions which are conditioned by predominant physical factors such as isohyetal and fluvial. Their effect is stronger when the existing predisposed relief has more complex form.

Since isohyetal and fluvial factors and modifiers perform indirect and direct destruction of hypsometric tumps as well as the transportation and longitudinal sedimentation of diverse detritus, they can be assigned with the predominant role. These processes lower the morphologic hills. However, tranAsportation and accumulation of destructed detritus cause the backfilling of valleys and alignment of the hillsides. The processes are not simultaneous, do not last equally long and therefore do not have the same destruction, transportation and accumulation effect at lower morphologic hillsides.

All other conditions being equal, exodynamic processes depend on the geologic structure, energy of primary relief, expositions, hillside slopes, horizontal and vertical articulations, vegetation, anthropogenization, and etc. The destruction of the basic tectonic form can be lowered if there is a stable geologic basis, lower energy and hillside falls, eastern exposition, weaker articulation, greater phyto production as well as landscape naturalness. In other cases it can be accelerated and therefore cyclically uniformly expressed. The differences can occur in the same river system where different physical factors exist. Since exodynamic processes and phenomena differ from each other no matter whether they occur in the same river stream or not, there is no uniform model of surface forms reformation. They all appear in distinct physical conditions.

River valleys can be classified according to the degree of morphologic construction, morphologic development, predominant genesis and its morphologic complexity. The same river valley can show the elements of mono-morphology in the segments of longitudinal

thalweg and the elements of poly-morphology in another one. Some cross-section segments have elements of monophases, other elements of polyphases, while some river system segments show elements of monogenetics and others of pologenetics. Based on predominant types of elements, the valleys that are monomorphic, monogenetic, monophase and that have uniform morphological appearance have simple definitions. On the other side, the complex valleys are polymorph, polygenetic, polyphase and also can have elements of gorges, canyons and structural basins. The same river system can have almost all stated forms in its longitudinal profile segments.

In addition to those analyses, there are the elements of morphologic thalweg construction whereby the river valleys are classified to: balanced, straight gradient valleys, gradual and inverse gradient valleys. Balanced and straight gradient valleys are predominantly formed in uniform geologic structure and are in evolved development stage. They are classified as simple river valleys. On the other side, classified as complex river valleys are gradual and inverse gradient valleys formed in diversified geological substrate.

Besides deep erosion processes, geohazards also denude decomposed surface detritus. Newly formed predisposed furrows transfer the detritus to the lower levels, most often to the river valleys. After that the harmonization process of thalweg or valley slopes starts.

With regressive cuts of rockfall sloping foothills and valley slopes, the new cuts are formed so that the hillsides are dissected on the smaller morphological shelves; series of smaller foothill pineplens. The total amount of eroded, transported and deposited detritus at lowest levels of relief structure corresponds to the hypsometric deficit of morphologic antiforms from higher hypsometric levels where erosion and transportation processes occur.

Geohazards cause sudden interruption of exodynamic uniform relief evolution and initiation of new relief forms that have not existed before. Geohazards also take part in formation of new evolutionary exodynamic processes which otherwise would not emerge or evolve if there were gradual uniform development stages.

Geohazards are affected by physical processes and phenomena so that fluvial processes are affected by bad weather conditions such as downpours. The amount of precipitation during the downpours can exceed the three-month maximum amount of precipitation.

The consequences of geohazards depend on the physical factors of the base where the precipitation occurs. The most important factors are geologic and pedogeographic structure, relief energy and hillsides' slopes. Also, anthropogenic processes can influence the intensity of fluvial geohazards. Those factors are usually related to the changes in physical properties of the base, especially the changes in anthropogenic substitution of forest with cultural landscape. If such changes occur, the fluvial destruction of the hillsides and their transportation towards the accumulation basis occurs. The accumulated detritus then further increases the basis.

CONCLUSION

Tectonic and endodinamic causes of cycle interruptions in the development of the relief can be replaced by others, various exsodinamic processes. All this collectively depends on the prevailing physical and geographic processes and phenomena in the observed basin. Morphological cycles of reducing existing morphostructures with destruction of exodinmic phenomena and processes based on the concept of W.M. Davis (1902) may have its full meaning only in certain parts of the earth's surface, that sometimes can even be smaller than the surface of medium-developed basin. In one part of the basin

longitudinal alignment of thalweg may take place according to a recognizable cycles, which are not necessarily coherent nor recognized in another part of the same river basin and river system.

This newly formed exodinamic morfosculpture can be analyzed with the prevailing agents and modifiers, with whom the primary morphostructure was destructed. This is a morphological chronology, which according to W. Penk (1924) is termed as morphological analysis. Both assumptions about the evolution of relief are based on processes and phenomena of endogenization and exodynamism, except that they have a different understanding about evolution and interruptions of the same.

Deficiencies of uniformitarian perceptions of the relief forming, among other things, are not only in endogenesis and exogenesis interaction, wherein the first initiating another, than in the fact that exodinamic chronology in most cases, does not have to be interrupted nor initiated solely by endodinamic processes. This can be interrupted and initiated with new intensifying exodinamic processes. Existing initial morphophases alternate with others, forming a new morphological expression.

Natural disasters, in function of relief transformation from previous forms in their present condition are recorded in recent catastrophic floods conditioned by pluviometric disasters in May 2014, in Bosnia and Herzegovina. For an explanation of geohazards influence in initiation and evolution of the new relief morphophorms as an example was the drainage area of Željeznica, the left tributary of Bosna river in its central basin used. Total drainage area of Željeznica is inhabited by rural settlements (ruronim Željeno Polje). In this area, in the last 80 years using cartographic method, evident anthropogenic transformation of draniage area of Željeznica is defined. Spatial transformation included rural villages, whose total number of different residential facility and other facilities grew steadily from 85 registered in 1930. to 1221 today.

Spatial rural transformation together with other infrastructure dissected previously molasse pediments with anthropogenic terraced folds to smaller shelves, what the morphological evolution significantly altered. These processes, together with agrarian process, substitute the natural forests with anthropogenic landsat, which have become nonresistant for the last fluvial hazards. The storm, natural meteorological phenomenon opposite to the standard climate, with enormously high amount of rainfall in a short time, five days, caused the extremely increased flow of water to the river systems.

Torrential processes significantly modified existing fluvial morphophorms, what transformed surface flows in new directions. In addition, many significant changes in the morphology of riverbeds which are conditioned with riverbed erosive and accumulative phenomena and processes appeared. Apart from typical fluvial processes on the change of riverbeds influenced reinforced denundation processes including, in particular, colluvial, proluvial and alluvial. The new fluvial processes caused the transformation of existing and initiated new morphological slope forms. Existing riverbeds and valley slopes in the hydrographic system of the Željeznica river have been modified with new morphological forms. Thus, the valley slopes at its ends transformed from a convex into a concave shape, and the riverbed reservoirs pushed the erosional base, which was recorded in annexes 4, 5 and 6.

In conclusion, the new exodinamic processes and phenomena can be sudden, stressful or hazardous. They significantly initiate occurrence of a new juvenile stages of uniform relief development. Stressful exodinamic processes, first interrupt and then accelerate the development of uniform relief. It is very important to note that the uniform model never

completely rejected the role of natural catastrophes in development of morphological habitus on earth's surface, which is the key to understand the morphology of the past and its projection into the future time.

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