THE THEORY OF GEOMORPHOLOGICAL CYCLES OF WILLIAM MORRIS DAVIS

TEORIJA O GEOMORFOLOŠKIH CIKLUSIH WILLIAMA MORRISA DAVISA

Andrija Bognar

Abstract

UDC: 551.4:929 Davis W. M.
COBISS: 1.02

The theory of geomorphological cycles of William Morris Davis

KEY WORDS: relief, development, theory, geomorphological cycle, evolution, peneplain

Up to this day there have been no theory, which would, by undeniable facts, present and prove the whole geomorphological development of the Earth relief. The history of geomorphology is familiar with five theories of the global approach, which represent the revolutionary progress in geomorphological idea development, but none of them has given an appropriate answer, explanation or acceptable interpretation of our planet's relief evolution. The first one, so called theory of geomorphological cycles, is connected with the name of the American geomorphologist William Morris Davis. In the framework of that theory he tried to represent the emergence and the whole evolution of the relief forms in one, for that time very progressive way, but in spite of that, during the 20th century, his theory experienced an exceptionally sharp criticism or was called into question in its entirety.

In this work we shall present the essence of Davis' theory, review and evaluate the most important critical comments. Finally, we shall try to prove that the basic idea of this great geomorphologist is still positive in the light of new knowledge of the theory of plate tectonics.

Izvleček

UDK: 551.4:929 Davis W. M.
COBISS: 1.02

Teorija o geomorfoloških ciklusih Williama Morrisa Davisa

KLJUČNE BESEDE: relief, razvoj, teorija, geomorfološki ciklus, stadij, evolucija, peneplen

Tudi danes še ne obstaja teorija, ki bi z neizpodbitnimi dejstvi prikazala in dokazala celovit geomorfni razvoj izoblikovanosti zemeljskega površja. Iz zgodovine geomorfologije je doslej poznanih pet splošnih teorij, ki sicer predstavljajo revolucionarni napredek v razvoju geomorfološke misli, a niti ena ne daje povsem sprejemljivega tolmačenja zakonitosti razvoja reliefa na našem planetu. Prva med njimi je teorija o geomorfoloških ciklih, povezana z imenom ameriškega geomorfologa Williama Morrisa Davisa. Z njo je poskušal celovito razložiti nastanek reliefnih oblik in njihov razvoj na za tisti čas zelo napreden način, vendar je ta teorija v 20. stol. doživela izjemno močne kritike ali bila v celoti postavljena pod vprašaj.

V prispevku je predstavljeno bistvo Davisove teorije ter pregled in ovrednotenje najpomembnejših kritičnih pripomb. Na koncu poskuša avtor dokazati, da je vsemu navkljub osnovna misel tega velikega geomorfologa na nek način pozitivna v luči novih spoznanj teorije o tektoniki plošč.

Address – Naslov:
Andrija Bognar, Ph. D.
Department of Geography – Geografski odsjek
Faculty of Science – Prirodoslovno-matematička fakulteta
Trg Marka Marulića 19/II
Zagreb
Croatia – Hrvaška
Phone – telefon: +385 (0)1 4828297
E-mail – el. pošta: andrija.bognar@zg.hinet.hr

1. Introduction

Up to this day there have been no geomorphological theory, which would, by undeniable facts, present and prove the whole geomorphological development of the Earth relief. The history of geomorphology is familiar with five such theories, which represent a very significant step forward; moreover, we can say a revolutionary progress in geomorphological idea development. They haven't provided a complete answer about global relief development, but showed themselves as appropriate for explanation and interpretation of particular cases and parts of developmental regularity. The first of those theories is connected with W. M. Davis (1899), the second one with W. Penck (1924), the third one with K. K. Markov (1948), the fourth one with I. P. Gerasimov and J. A. Meščerjakov (1970), and, finally, the fifth one with L. C. King (1962).

In the framework of his theory W. M. Davis tried to represent the relief form development and the whole Earth's relief evolution in a very progressive way. In this connection he developed his theory from a simple and logical equation based on three basic keystones: structure + stage (span of time) + cycle (process).

2. Basic statements (postulates) of the theory

The initial stage in the Earth's relief cyclic development is represented by a gently undulating area, denuded to the sea level, the so-called **peneplain**, defined as almost plane surface – plain. The plain is broken down by valleys with gentle and homogenous slopes (Fig. 1).

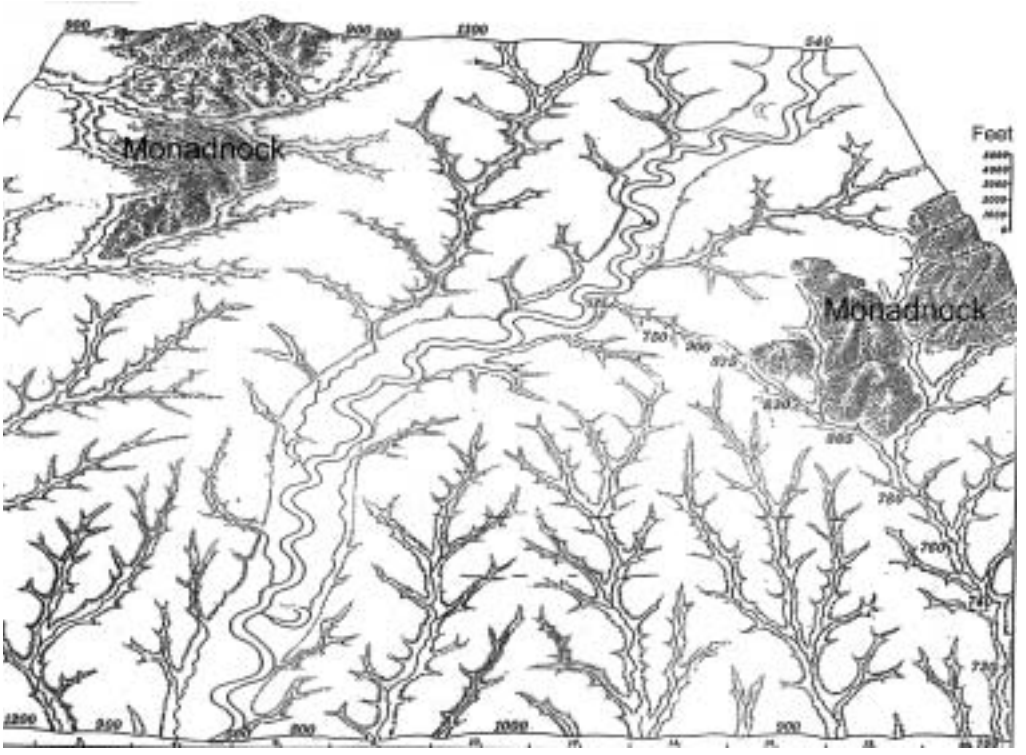


Figure 1: The beginning level (penepleain) of the relief evolution is, according to W. M. Davis, in the penultimate stage in relief evolution.
Slika 1: Začetni stadij razvoja reliefa (peneplen) je po W. M. Davisu hkrati tudi končni stadij v geomorfološkem ciklusu razvoja reliefa.

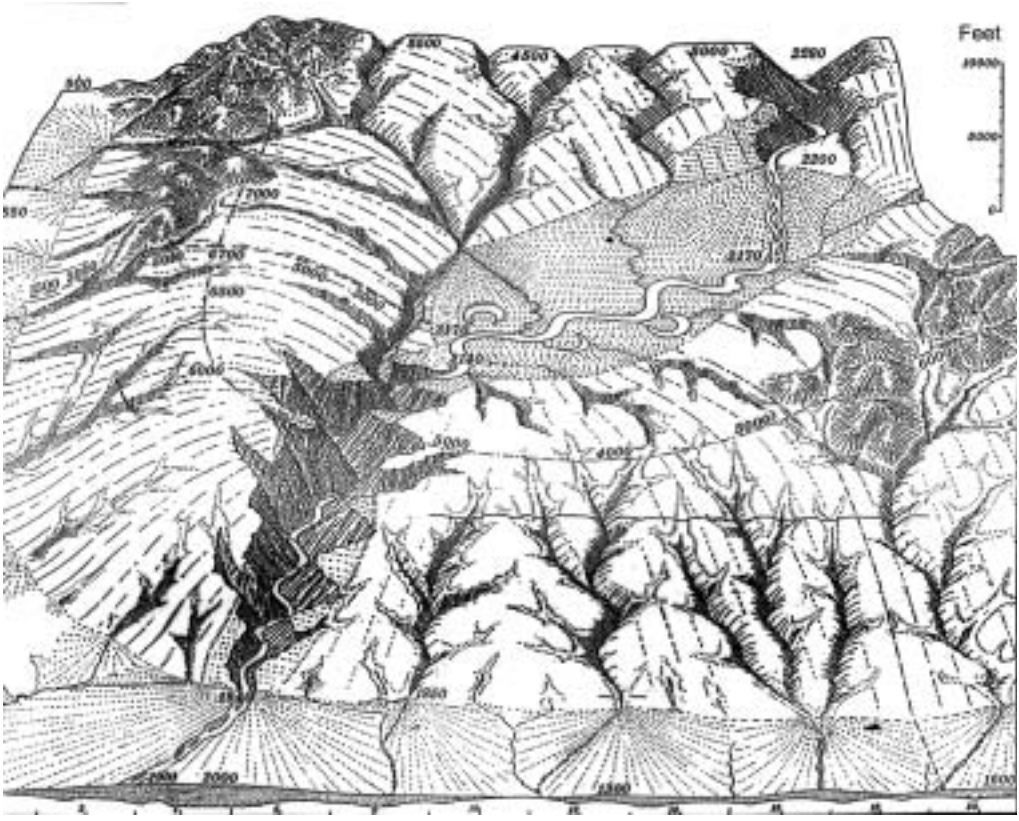


Figure 2: The youngest stage of relief evolution according to W. M. Davis.
Slika 2: Mlajša juvenilna faza razvoja reliefa po W. M. Davisu.

Let's suppose, Davis said, that vertical tectonic movements raise a peneplain. As a consequence, the gradient of rivers rapidly increases and the erosion processes are significantly intensified. Deep V-shaped valleys and high raised uneroded parts of the peneplain, which represent the intervalley ridges, clearly show that, since the beginning of the uplift, only a short span of time has passed. Youth of the dominant morphological forms, V-shaped valleys, predominance of the chiefly convex slopes indicate a close correlation between denudation and relief and large uneroded areas of the former plain. That's why, as Davis said, the area is in **a younger, juvenile stage of development** (Fig. 2).

Later, if there is slowing down of tectonic activity (termination of raising), denudation, naturally, continues to act. The tributary valleys are being cut what results in further dissection of the peneplain remnant. Among deeply cut valleys, very pronounced linearly elongated and arched mountain ranges are being formed. Their summits still keep the base peneplain level. A high mountain dissected area supports so called **older juvenile stage of the relief development** (Fig. 3)

As the relative altitude differences between the sea and mountain area, i. e. the valley bottom (thalweg) is still significant, denudation, although less intensive, still lasts, i. e. goes on. The intervalley ridges are becoming rounded and lower and marked with so called normal slopes[1].

[1] Here we speak about the slopes with the convex and concave parts on the transversal profile.

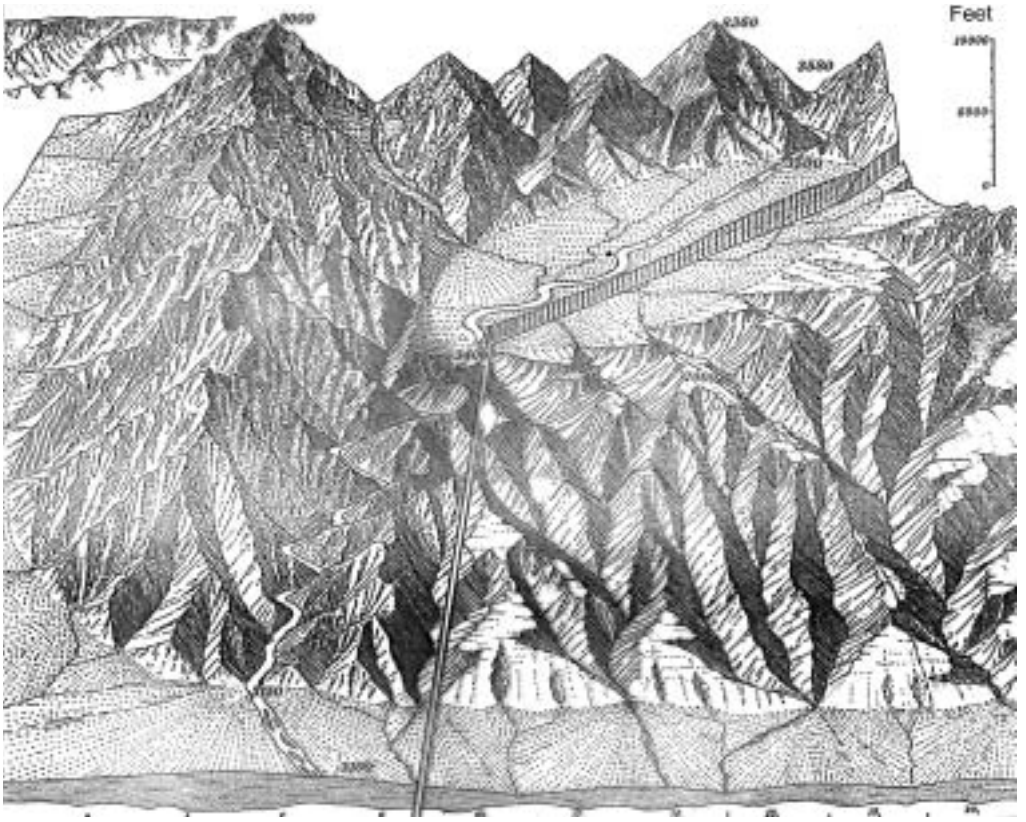


Figure 3: The younger stage in relief evolution according to W. M. Davis.
Slika 3: Starejša juvenilna faza razvoja reliefa po W. M. Davisu.

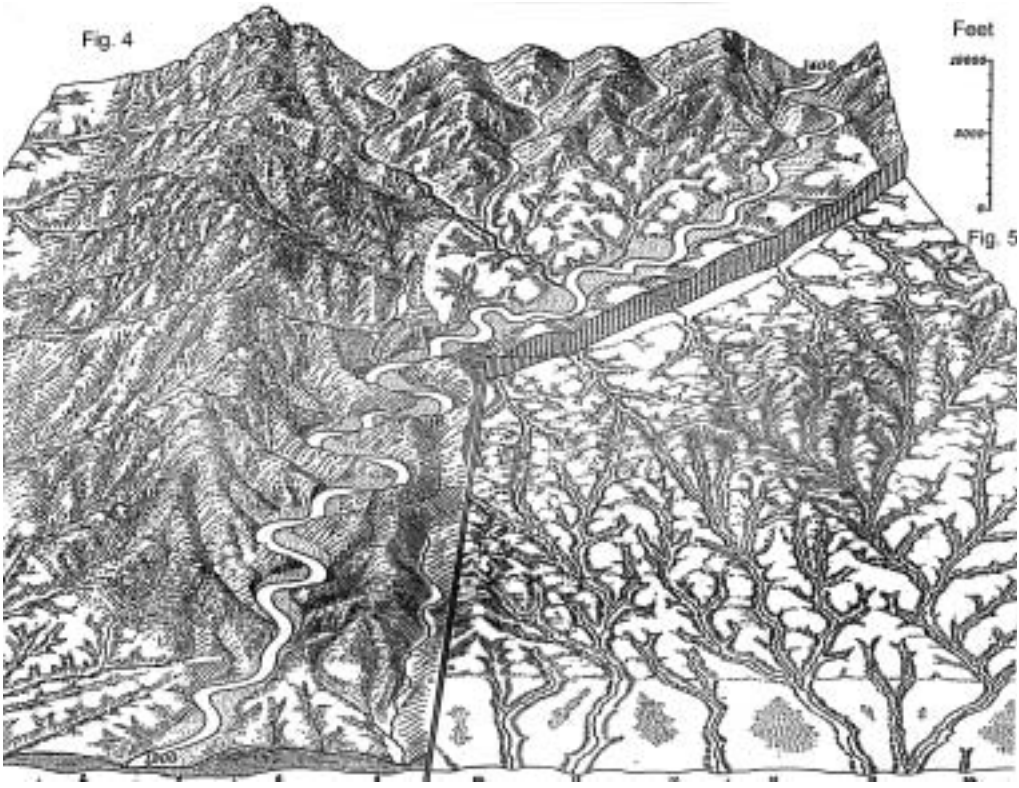
The gradient of the valley bottoms is being homogenised, the rivers are not cutting down any more and the valley bottoms are widening due to the lateral erosion. The transversal profiles of the valleys assume the bowl-shaped forms. That relief is in **the younger mature relief stage**. (Fig. 4).

The older mature relief development stage follows (Fig. 5). The valley gradients are homogenous; the rivers are meandering on wide valley-bottoms. The valley slopes are gentler and intervalley elevations have been lowered significantly. The area has the character of a mountain region. Finally, denudation gradually ceases, and there is no significant relief dissection. After the juvenile and mature relief development, the area assumes the early stage characteristics again. **The relief is in the senile development stage**. In this way, according to W. M. Davis, one erosion cycle has finished (Fig. 1).

The presented gradual relief evolution during one Davis' morphological cycle seems quite clear. His assumptions seem so logical and natural and one needn't be surprised that the American geomorphological school has considered, till recently, the study of geomorphological cycles an acceptable evolutionary pattern.

3. Theory criticism

However, the errors of the theory are evident. First, relief evolution cannot be cyclic, except very rarely on specific smaller areas. Interior and exterior forces interact very differently in space and time. It means that each relief form, with regard to its origin, can be considered complex and has, more or less, the fea-



Figures 4 and 5: The younger and older mature stages in relief evolution according to W. M. Davis.
Sliki 4 in 5: Mlajša in starejša zrela faza razvoja reliefa po W. M. Davisu.

tures of the endogenic and exogenic process influence. It also means that in larger areas of heterogeneous and changeable geologic structure the classical cyclic development is not possible, and that those cycles have never been able to establish themselves to the very end. The idea of cycle means repetition, return to the primary condition and the end of cyclic evolution. We can't speak about that in relief and relief form development because the influence of endogenic and exogenic forces is simultaneous and does not alternate in the course of time. Accordingly, we can't speak about the phenomenon of the states qualitatively new during formation and development of relief forms.

Davis has been criticized with good reason, especially his statement that the time of denudation activity is the most important factor. According to him, the time of denudation can be figured out of relief forms. Namely, he thought that there is a strong connection between the duration of denudation and forms (a so called morphological correlation principle). However, that principle does not exist (it is valid and applicable only in certain circumstances). In the relief form development besides denudation, we cannot neglect the role of lithological structure, climate, extent of the area, geological structure and tectonic movements.

In the case of the same denudation process, the area consisting of »softer« rocks will be destructed faster, so the change from youth to mature and senile stages will be faster than in the areas consisting of more resistant (harder) rocks.

Moreover, very often the area made of »softer« rocks (clay) is, during its whole evolution, characterized by relief forms connected with only mature or senile development stage; while the areas made of more resistant rocks may preserve the character of the youth stage of evolution till the end the relief forms (especially those areas where limestones predominate).

The extent of the area is also an important geomorphological factor. In the case of the same denudation rates, and even uniform lithological structure, smaller areas are faster destructed than larger ones. A solitary mountain structure formed in granite will be denuded faster than a larger group of mountains. The same will happen in the case of smaller and larger islands.

It is not necessary to point out the decisive role of climate. The occurrence of whole geomorphological evolution cycle is not possible because, in particular climatic zones, denudation changes in character and its intensity, as well as its efficacy. In spite of the structural uniformity of its forms, relief shows very different characteristics[2] in particular climatic zones. This fact cannot be called into question although the Davis' followers have worked out, besides the fluvio-denudation cycle, the cycles of glacial, desert and marine denudation. It cannot be called into question because the independent, purely denudational relief cycle does not exist, just as particular climate zones cannot be divided by sharp lines.

Geomorphological critics have stated that the failure of Davis' theory can be explained as follows:
1. Relief evolution was explained by a cyclic process,
2. The role of lithological and geological structure, tectonic movements and the area largeness in relation to the duration of denudation interval were neglected,
3. The unique (complete) and integral process of the relief geomorphological development was divided into mutually independent morphological processes; only separate erosion, glacial, desert and abrasion cycles were considered as proved, which means that the basic dialectic pattern was called into question; and that pattern says that everything depends upon everything, in other words, that particular processes could be explained precisely only in the framework of the unique geomorphological development process.

To the contrary of the statements of Davis' theory that the terminal peneplain of small relative relief is strictly the result of the cyclic relief development, research has proved that Davis' peneplain is only one of the possible manifestations in the Earth's relief final development. Peneplains could be formed by abrasion, and also, aside from the stream linear and lateral erosion, on various hypsometric levels, and if some area of the layer horizontal structure and of various rock material resistance is destructed by denudation to some resistant and permeable layer. Finally, a fossil peneplain can be exhumed by denudation.

In the light of the mentioned criticisms it is evident that Davis' cyclic theory can be applied only in certain situations. According to the interpretations of the 1920s and 1930s' geomorphology, relief evolution is a very complex, nearly unsolvable mystery.

W. Penck stood up against Davis' agnostic view based on the study of the nature of matter and its movements and on the uniformity of geomorphological evolution. According to W. Penck, relief evolution can be compared with the equation, which can determine an unknown development process out of the known forms and exterior forces and their influence. That process, Penck declared, depends upon the Earth's crust vertical movements. Penck called his method »a morphological analysis«. He tried to explain the development process by the relief form analysis. Contrary to Davis, who emphasised the role of the exterior forces on relief formation and evolution, in Penck's interpretation the stress is on the endogenic processes.

Such Penck's approach lead him logically to an excessively emphasised autodynamic point of view, according to which, »if the endogenic preconditions are identical there is no possibility that in particular areas with different climate we'll find different denudation forms with different evolutions« (1924). Such wrong comprehension of nature dialectics is a big mistake of Penck's view; just because of that he gave only partial solutions, which cannot explain the relief evolution integrality. Penck's interpretation is, therefore, narrower than that of Davis. We must add that Penck, besides the endogenic processes, has considered only river erosion and slope denudation as significant factors in relief formation, completely neglecting the role of ice, sea and wind.

[2] We must add that it depends on the tectonic movement intensity and their relation towards denudation effects.

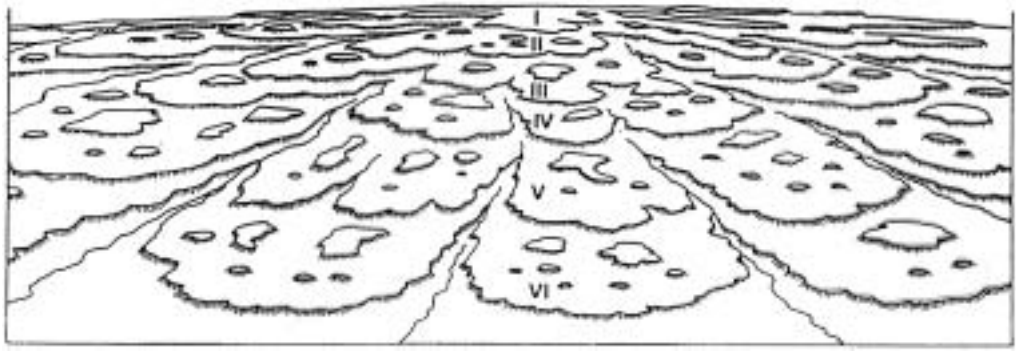


Figure 6: »Piedmonttreppen« or marginal erosional surfaces according to W. Penck (1924).
Slika 6: Robne uravnave (predgorske stopnje) po W. Pencku (1924).

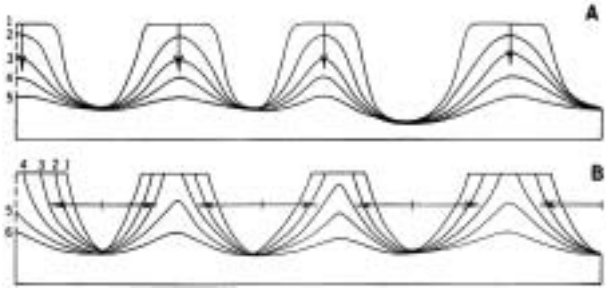


Figure 7: Relief development according to W. M. Davis (A) and according to W. Penck (B).
Slika 7: Razvoj reliefa po W. M. Davisu (A) in W. Pencku (B).

Contrary to Davis, who inaccurately separated the relief evolution in two, artificially separated stages of epeirogenic uplift and denudation, Penck pointed out that those two processes must not be separated, even for didactic reasons. They must be analyzed mutually connected, because in nature they allways happen simultaneously. That's why Penck recommended: we must work with as short time intervals as possible in order to explain as precisely as possible the interdependent activity of uplift and denudation. Such analysis Penck called **a differential method**. It is based on the slope formation interpretation, because the interdependent activity of the endogenic and exogenic processes is clearly expressed in the slope profiles. This statement is correct, but the analysis of Penck's work is not the topic of this study. Nevertheless, we must notice that Penck's conception, according to which the transversal slope profile is a function of the interdependent activity of uplift and denudation (fluvial erosion and slope-wash), is basically correct, but it is applicable only in the areas of humid climate, and neither as a method of morphological analysis in arid areas, nor in the case of glacial and karst denudation.

Applying the method of morphological analysis, Penck came to the following results: if a long tectonic rest follows a rapid uplift, we have the only case in which the relief evolution according to Davis' interpretation may happen, i. e. the peneplain can be formed. It is possible that sometimes, as the consequence of greater rock resistance, isolated hills as rock remnants, the so-called monadnocks can be found. In any other case, relief evolution, as the consequence of the uplift intensity and duration changes, will essentially differ from Davis' interpretation. Those deviations can be determined by a differential method. For example, if a certain area begins to rise up (a part of sea bed raises above sea-level or some lowland area begins to uplift), it is possible that the uplift is so weak that it can be completely compensated by denudation. Accordingly, undissected low relief remains and it is very similar to Davis' peneplain (**Endrumpf**), but distinct from it, this one is the expression of a balanced relation between the uplift and denudation values. Therefore, it represents the starting point of any further relief development. Penck called it the initial or primary plain (**Primärrumpf**). Only the convex slopes of valleys and isolated rock remnants – monadnocks make it different from Davis' peneplain. Penck also mentioned various examples of the planation level evolution. According to him, Davis' peneplains mark large areas of old cratons in Africa, Australia

and Brazil. They are formed as the result of the exogenic destruction at the end of Archeozoik. After that, they experienced epeirogenic movements of less intensity. Distinct from cratons, the planation levels in the Alpine-Himalayan and Andean mountain zones represent the remnants of the base-level planation development – **Primärrumpf** (Fig. 6/7).

4. Peneplains and marginal planation levels

In 1902, Davis used the notion »peneplain« for the first time, denoting large areas of the Earth's crust nearly levelled by fluvial erosion. They were formed at the level of the erosion basis during the penultimate stage of relief denudation in various humid areas. The emergence of Davis' peneplain is connected with lowering of intervalley elevations during the phases of long tectonic rest.

Later, the notion of peneplain was widened and had more extensive contents that in Davis' interpretation. Numerous peneplains in various areas were described so, according to W. D. Thornburry (1954), Davis himself had to warn the researchers to be careful when using that notion.

The greatest discussion about the theory was provoked by the question if we can even assume such a long period of tectonic rest, which would enable denudation processes to shape the relief up to the penultimate phase of its final development stage. The possibility of the cyclic relief development was also called into question. According to Davis' interpretation, an erosion cycle supposed a cyclic relief development, which included denudation and the period of relief uplift and revitalization. According to geomorphological criticism, the main reason of Davis' theory failure was in antidialectic interpretation that relief evolution was a cyclic and reversible process. But, if we deny the cyclic relief development, the notion of peneplain itself is a fiction.

Many of those who modified Davis' theory, considered that peneplain development might also happen in the conditions of slow uplift if its speed is less than denudation intensity. In interpretation of the stepped denudation planation level development in mountain systems there are also certain modifications[3] of Davis' explanation of their morphogenesis.

Many American followers of Davis also explained the peneplain development with certain modifications. According to W. D. Thornburry, only those are consistent with Davis' interpretation, who apply the notion of peneplain for surfaces levelled by denudation only, which were formed in the summit parts of intervalley ridges in the final stage of erosion cycle, partly by the stream lateral planation and chiefly by slope mass movements. De facto, all that represents a significant complement of Davis' study. In my opinion, all planation surfaces formed under the influence of various factors in various circumstances must have corresponding, but different names.

Some researchers suggested the term panplain instead of peneplain. There are more and more works in which the authors declared that in the temperate zone, erosion processes could never denude the relief to peneplain. Those forms can exist in the temperate zone, but only as remnants of an older geologic era with the prevailing tropical climate. On the other hand, taking into consideration the previous opinion, some do not exclude the possibility that in the temperate zones, peneplains can be formed under the forest cover (Baulig, 1956), and generally under a dominant influence of fluvial erosion (Bulla, 1954).

Numerous Russian researchers supported the view that in mountains, because of frequent periodical uplifts, denudation cycle has not enough time to level the relief to the final stage so the typical peneplains can-

[3] Davis supposed a longer period of rest in the mountain system development, which results in peneplain formation in penultimate phase of the older stage. Periodical uplifts evolution follows. In »quieter« periods, at the margin of mountain systems, partial peneplains – denudation planation levels are formed near the erosion base. Where the tectonic rest phases were not long enough for the complete destruction of the previous peneplain and higher parts of the mountains, according to Davis, the older peneplains are being transformed into smaller step-like parts in the mountain system.

not be formed. Smaller planation surfaces they called denudation planation levels (Dumitrasko, 1954; Čemjekov, 1964 and other).

Many researchers explained the emergence of peneplains by a long denudation activity of an exterior force – process. Some researchers considered peneplains as polygenetic forms, which develop with time by mutual activity of many factors (Penck, 1924; Meščerjakov, 1964; Klein, 1959 etc.). Moreover, the polygenetic planation levels also differ in space. Besides denudation surfaces, the plains of accumulation and accumulation-denudation origin are also connected with such planation levels (Meščerjakov, 1954; Spiridonov, 1961). Pécsi (1967) called the first ones deplanation, and the second ones aplanation surfaces. In his latest theory of pediplanation L. King (1962) assumed denudation planation by pedimentation process in arid and semi-arid areas under the conditions of tectonic rest. Planation surface develops by mutually parallel slope retreat, which finally levels elevations and the final denudation planation level – pediplain is formed.

Besides the peneplain formation interpretation, another one important geomorphological question came into sight during discussions between W. M. Davis and W. Penck: the morphogenesis of marginal planation levels or so-called piedmonts. In his works Davis indicated that high block mountain relief is characterized by a phenomenon of the step-like planation levels. He connected their emergence with the cyclic evolution of the Earth's surface relief. As an example he took the northeastern part of the block mountain system Allegheny in the USA, which is on all sides, especially towards the Atlantic Ocean, surrounded by low, gently undulating relief generally sloping from the mountains towards the ocean. Davis considered this gently undulating area, dissected by consequent valleys, a denudation planation level which is separated with a fall line from the accumulation plain along the ocean shore. The summit parts of the mountain system Allegheny, of approximately similar heights, are the remnants of an older, elevated denudation planation level, which, according to Davis, indicates that during morphological evolution the mountain system was lowered to the peneplain stage, and, afterwards, transformed again into a mountain system by general epeirogenic uplift. As the uplift in the marginal parts of the mountains was less intensive, denudation was able to lower them into a marginal planation level (a partial peneplain), while the central parts of the mountain system were still in the mature development stage.

A new cycle of exogenic modelling was disturbed by new epeirogenic movements, which resulted in the uplift of the marginal planation level along the fall line. Because of breaks in their longitudinal profiles, the rivers were forced to cut in, what caused the emergence of many rapids and waterfalls.

According to Davis' interpretation, the formation of the marginal planation levels or partial peneplains is evidence of periodical uplift followed by cyclic denudation. As numerous marginal planation levels (Piedmonttreppen) have been found in other parts of the world, Davis' opinion at the beginning of the 20th century was generally accepted.

Walter Penck (1924) has explained in his criticism of Davis' polycyclic study about relief development the »autodynamic« interpretation of the marginal planation level origin. In other words, Penck didn't consider Davis' explanation convincing enough. According to Davis, the marginal planation level surfaces, except the lowest one, are in the phase of destruction, which means that they represent the fossil forms. Penck, on the contrary, thought that it is not the question of the fossil forms, but of the relief forms which also develop at the present time and represent, in fact, base-levels. According to him, morphogenesis would be as follows: the initial stage can be Davis' peneplain, and after that, it is uplifted faster including larger and larger areas. As the consequence, the fluvial erosion increases and the rivers cut in, most intensively at the peneplain margins, because there is the largest amount of water available. It causes the formation of breaks in the river course, which represent the local erosional basis. The valley sides gradually move backwards and the valleys are widening on the expense of the higher level. The initial, slightly expressed uplift has no influence on the upstream part of the drainage basin, because denudation compensates the uplift, so the initial planation level or Primärrumpf is formed. It elevates and forms deep valleys. The planation level »draws into« the mountains in the form of broad valley bottoms. W. Penck called such relief form a piedmont or piedmonttreppe of denudational character. If the uplift later accelerates and extends

to larger areas, after some time, the piedmont is elevated to a higher level and new breaks are formed on its margin. In that way a series of new planation levels (Piedmonttreppen) develop. Some of them continually extend on the expense of the higher ones. As the result, in the end, there is a complete planation of the mountain structure and mountain system. Although the subsequent criticism completely rejected the basic theses about the piedmonttreppen development according to Penck, I think that his interpretations need some further research. At the end, I would like to point out that the marginal planation level or Penck's piedmont (piedmonttreppe) must not be led into connection with the notion of pediment which represent the piedmonttreppe formed primarily by erosion and slope processes in specific climatic conditions[4].

5. Davis' theory and global plate tectonics

Relief (a cluster of even and uneven surfaces on the Earth) emerges and develops as the result of interdependence of the interior and exterior forces and processes. The interior forces and processes have a decisive role in formation of planetary, mega- and macro-relief forms, and the exterior ones in formation of the forms of smaller dimensions. The exogenic processes depend largely on climate and considerably influence the character and distribution of relief forms but their activity is decisively directed and controlled by endogenic forces and processes. Lithological characteristics and geological structure of the Earth have a significant indirect influence on relief formation, too.

The development and affirmation of the global plate tectonics theory enabled, for the first time, to explain from the unique point of view the characteristics, genesis and evolution of many important phenomena (appearance and disappearance of the Earth's crust, tectonic movements, volcanism and seismicity) and planetary relief forms (ocean basins, mid-ocean ridges, subduction zones and continent masses with fold-

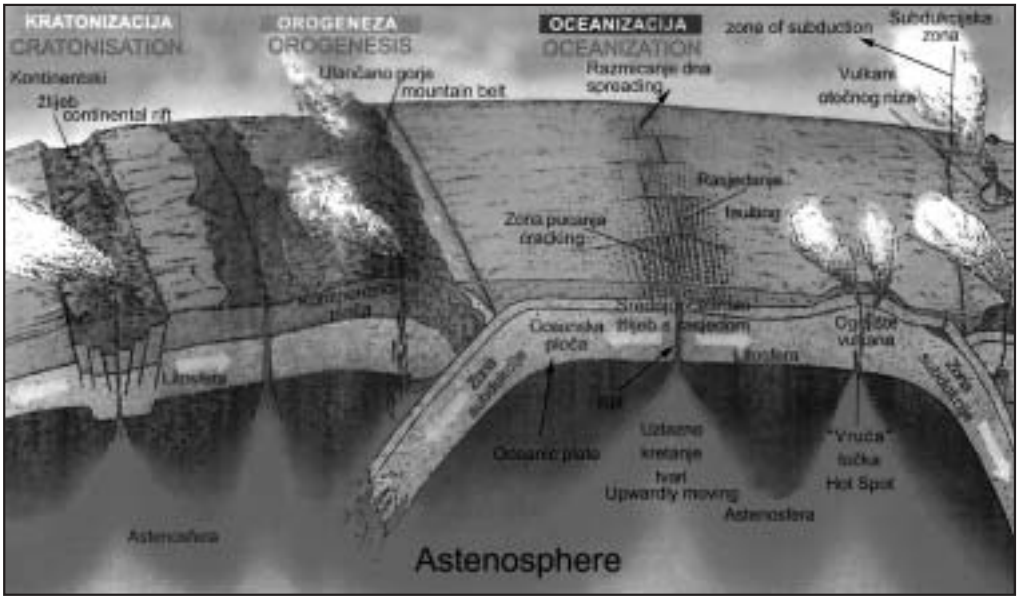


Figure 8: The main stages in evolution of the Earth crust and planetary relief forms.
Slika 8: Glavne faze razvoja zemeljske skorje in planetarnih reliefnih oblik.

[4] The notion piedmonttreppe was introduced into Croatian geomorphological literature by A. Bognar in 1980. It is the synonym of the notion piedmont.

ed mountain systems and cratons). Just because of that, the Earth's surface relief evolution must be connected with its crust development in time and space, and in conformity with the basic statements of the global plate tectonics theory.

The phased evolution of the Earth's crust is considered as proved. There are three basic stages: oceanization, orogeny and cratonization (Fig. 8). We can speak about a unique development of the Earth's structural-geomorphological plan, because the endogenic processes which act inside the Earth's crust, more precisely inside the lithosphere and asthenosphere, are mutually connected and have general planetary characteristics. Formation and development of the largest relief forms on the Earth are connected with particular stages of the Earth's crust development: the ocean basins, mid-ocean ridges and subduction zones with the oceanisation stage, folded mountain systems (the Alpine-Himalayan mountain system, the Andes and the North American mountain systems) with the orogeny stage, and craton formation with the cratonisation stage. Consequently, they must be comprehended as an expression of the interdependent activity of the endogenic forces and processes inside various stages of the unique geotectonic development of the Earth and its crust.

If we compare these patterns with three Davis's stages, we come upon the undeniable fact that he recognised the phased relief evolution isolating its juvenile, mature and senile development stages. If we examine the effects and general trends of their development, each of those stages is in harmony with the corresponding stage of the planetary relief evolution interpreted in the framework of the global plate tectonics, with no regard to the basic differences in interpretation of the driving forces and mechanisms of the leading geomorphological processes of endogenic and exogenic character. Ultimately, Davis' idea about a repeated phased relief evolution is valid, because in the framework of the global plate tectonics theory there is some talk about the Earth's crust development revitalization, and therefore about the relief development revitalization. Namely, by a renewed mobilization of the process of spreading in the area of the carbonized parts of the continental masses (East African Rift, the Baikal rift and the Central Asian Highlands, the Rocky Mountains with the basin-and-range topography), a repeated development of the new Earth's crust begins. Of course, not in cyclic, reversible sense, as Davis interpreted, but observing differently in time and space. Finally, it should be mentioned that, in the framework of his theory, Davis studied only the relief evolution of the continental parts of the Earth.

In addition, the idea of peneplain as the expression of the final, senile relief development is also valid. Namely, peneplains are, in the framework of the global plate tectonics, dominant relief forms of the final stage of the Earth's crust development – cratonization.

6. Bibliography

Baulig, H., 1956, Peneplains et pediplains. Bulletin de la Sociète Belge d'Études géogr. 25, pp. 25–58. Gand.

Bognar, A., 1991, Osobine i zakonomjernosti oblikovanja strukturnog reljefa Zemlje. Geografski horizont 1 (1991), pp. 1–13. Zagreb.

Bulla, B., 1954, Altalanos termeszeti földrajz II. Tankonyvkiado, Budimpešta. 554 pp.

Büdel, J., 1957, Die »Doppelten Einebnungsflächen« in den feuchten Tropen. Zeitschrift für Geomorphologie 1. pp. 201–225. Berlin.

Čemjekov, J. F., 1964, Proishoždenije i razvitija povjerhnostej denudacionogo viravnivanija v skladčatih oblastjah. V zborniku Problemi povjerhnostej viravnivanija, pp. 151–164. Nauka, Moskva.

Davis, W. M., 1902, Geographical essays. Boston. 777 pp. (ponatis 1954, New York).

Dumitrasko, N. V., 1954, O genezise povjerhnostej viravnivanija. Voprosi geografii 2. Geografgiz, Moskva.

Gerasimov, I. P., J. A. Meščerjakov, 1964, Morfostruktura i morfoskuljptura zemnoj poverhnosti. V zborniku Problemji geografii, pp. 225–231. Nauka, Moskva.

King, L. C., 1962, The morphology of the Earth. Oliver and Boyd. 699 pp. Edinburgh-London.

Klein, C., 1959, Surfaces poligénétiques et surfaces polycycliques. Bulletin de l'Association de géographes français, pp. 282–283. Paris.

Markov, K. K., 1948, Osnovnije problemi geomorfologiji. Geografgiz, Moskva.
Meščerjakov, J. A., 1964, Poligenetičeskie povjerhnosti viravnivanija. V zborniku Problemi povjerhnostej viravnivanija, pp. 9–22. Nauka, Moskva.
Pécsi, M., 1967, A foldfelszini kulso (exogen) folyamatok osztalyozasa es nevezektani ertelmezese. Foldrajz Közlemenyek 15, pp. 190–210. Budimpešta.
Pécsi, M., J. Szilárd, 1969, Az elegyengetett felszinek fobb kutatasi es nomenklaturai problemai. Közlemenyek, Magyar Tudomanyos Akademia, Földrajztudomanyi Kutato Intezet, pp. 153–176. Budimpešta.
Penck, W., 1924, Die morphologysche Analyse. Ein Kapitel der physikalischen Geologie. 327 pp. Stuttgart.
Ramsay, A. C., 1846, On the denudation of south Wales. Memoires, Geological Survey of Great Britain, 1, pp. 297–335. London.
Spiridonov, A. I., 1961, Problema povjerhnostej viravnivanija v SSSR. Bl. Mosk. obč-va ispt. pripod. Otdelen. geol. vp. 2. Moskva.
Thornburry, W. D., 1954, Principles of geomorphology. John Willey, 618 pp. New York.
Tricart, J., 1961, Les characteristiques fondamentales du système morphogénétiques des pays tropicaux humides. L'Information Géographique 25, pp. 155–169. Paris.

7. Summary in Slovene – Povzetek

Teorija o geomorfoloških ciklusih Williama Morrisa Davisa

Andrija Bognar

1. Uvod

Vse do dandanes nimamo takšne geomorfološke teorije, ki bi z neizpodbitnimi dejstvi prikazala (dokazala) celovit geomorfni razvoj Zemlje. Zgodovina naše znanstvene vede pozna pet takšnih teorij, ki glede na dotedanji razvoj pomenijo pomemben korak naprej, pravzaprav lahko rečemo revolucionarni napredek v razvoju geomorfološke misli. Sicer niso dale celovitega odgovora na vprašanje o razvoju globalnega reliefa, temveč so se pokazale koristne le za razlaganje posamičnih primerov in delov razvojnih zakonitosti. Prva med njimi je povezana z imenom Williama Morrisa Davisa (1899), druga Waltherja Pencka (1924), tretja Konstantina Konstantinijeviča Markova (1948), četrta z imeni I. P. Gerasimova in J. A. Meščerjakova (1970) in peta z imenom Lesterja Kinga (1962).

W. M. Davis je s svojo teorijo o cikličnem razvoju reliefa poskušal prikazati razvoj reliefnih oblik oziroma celoten razvoj reliefa Zemlje na izrazito napreden način. Utemeljil jo je z, na prvi pogled, enostavno in logično enačbo, izhajajočo iz treh osnovnih stopenj: struktura + stadij (čas) + ciklus (proces).

2. Temeljne postavke teorije

Začetno stanje v cikličnem razvoju zemeljskega površja predstavlja rahlo valovita uravnava – **peneplen** – z eksogenimi procesi znižana do morske gladine, definirana kot skoraj povsem uravnjena površina – ravnik (hrvaško ravnjak[1]). Razčlenjujejo ga doline s položnimi pobočji z blagim in enakomernim naklonom (slika 1).

Davis je predpostavljal, da se peneplen dvigne z vertikalnimi tektonskimi premiki, kot posledica pa se strmec dolin hitro poveča, erozijski procesi pa močno okrepijo. Globoke doline s prečnim prerezom v obliki črke V in visoko dvignjeni, neerodirani deli peneplena v obliki meddolinskih slemen, zanesljivo kažejo, da je od dviga peneplena minilo relativno kratko časovno obdobje. Na tesno povezanost denudacije in

[1] Ravnik (hrvaško ravnjak) lahko definiramo kot (nepopolno) uravnjeno površje. Bognar v svojem delu (1984) z morfografskega vidika razlikuje nižine (nizine) z reliefno energijo manj kot 5 m/km^2 in ravnice (ravnice) z reliefno energijo manjšo od 30 m/km^2.

reliefa kaže mladost dominantnih morfoloških oblik (V-dolin), prevlada konveksnih pobočij in velike neerodirane površine prvotnega ravnika. Ravno zaradi tega se, kot pravi Davis, območje nahaja v **mladem, juvenilnem razvojnem stadiju** (slika 2).

Ko sčasoma pride do umiritve tektonske aktivnosti (območje se neha dvigati), seveda denudacija deluje naprej. V površje se zarezujejo doline ob stranskih pritokih, zaradi česar se ostanek peneplena še naprej razčlenjuje. Med globoko zarezanimi dolinami se izoblikujejo dobro razvita, podolgovata in v obliki loka zavita slemena, ki imajo vršne dele še vedno v **prvotni višini peneplena**. Visokogorsko, močno razčlenjeno površje kaže na t. i. **starejšo juvenilno razvojno fazo** (slika 3).

Ker je relativna višinska razlika med morsko gladino in goratim območjem, oziroma med slemeni in dolinskimi dnemi, še vedno precejšnja, denudacija poteka naprej, čeprav že z nekoliko zmanjšano intenzivnostjo. Slemena med dolinami postajajo vse bolj zaobljena in se znižujejo, med njimi in dolinami pa prevladujejo t. i. normalna pobočja[2].

Strmec *dolinskih dnov* se vse bolj izenačuje, doline se ne poglabljajo več, temveč širijo, tako da prečni prerezi dolin dobivajo skledasto obliko. Takšen relief je značilen za **mlajšo zrelo razvojno fazo** (slika 4).

Sledi **starejša zrela razvojna faza** (slika 5). Podolžni profili dolin so izenačeni, reke tečejo v okljukih po širokih dolinskih dneh, dolinska pobočja so položna, slemena med dolinami pa so se že znatno znižala. Relief ima vse značilnosti sredogorja. Denudacijski procesi končno povsem prenehajo, nadaljnjega bistvenega razčlenjevanja reliefa ni več. Po juvenilni in zreli razvojni fazi dobiva površje spet značilnosti začetnega stanja; je v **starem razvojnem stadiju**. S tem se po W. M. Davisu erozijski ciklus zaključi (slika 1).

Prikazan razvoj reliefa v toku enega Davisovega morfološkega ciklusa se na prvi pogled zdi zelo jasen. Davisove predpostavke izgledajo tako logične in naravne, da se ni treba čuditi, kako je ameriška geomorfološka šola vse do najnovejšega časa sprejemala nauk o geomorfoloških ciklusih kot povsem sprejemljivo evolucijsko zakonitost.

3. Kritika teorije

Toda, *napake v teoriji so zelo očitne*. Prvič, razen v izjemno redkih primerih na manjših območjih, razvoj reliefa ne more potekati ciklično. Endogeni in eksogeni procesi so namreč prostorsko in časovno odvisni drug od drugega in to na zelo različne načine. To pomeni, da je treba imeti z vidika nastanka vsako reliefno obliko za kompleksno, da bolj ali manj očitno vključuje učinke endogenih in eksogenih procesov. Na večjih območjih s heterogeno in spremenljivo geološko zgradbo torej razvoj klasičnih erozijskih ciklusov ni mogoč in se ti niso mogli nikoli razviti. Pojem ciklus namreč predpostavlja ponavljanje, povratek na izhodiščno stanje in zaključek evolucije v zaprtem krogu. To pa med razvojem reliefa in posamičnih reliefnih oblik ni mogoče, saj se vplivi notranjih in zunanjih sil s časom ne izmenjujejo, temveč potekajo istočasno. Zaradi tega lahko v toku nastajanja in spreminjanja reliefnih oblik govorimo samo o nastajanju *kvalitativno novih stanj*.

Davisu so kot eno od bistvenih napak v teoriji upravičeno očitali, da upošteva *čas delovanja denudacije kot najpomembnejši dejavnik*. Po njegovi teoriji naj bi bilo možno iz reliefnih oblik ugotoviti čas trajanja denudacije, saj je menil, da obstaja tesna povezava med dolžino trajanja denudacije in oblikami (t. i. *zakon morfološke korelacije*). Takšnega zakona namreč ni, v resnici sploh ne obstaja (velja lahko le kot pravilo v določenih okoliščinah). Pri nastajanju reliefnih oblik ne smemo ob denudaciji prezreti *pomena kamninske zgradbe, podnebja, velikosti ozemlja, geološke zgradbe in tektonskih premikov*.

V primeru enakovrednega denudacijskega procesa se bo površje na »mehkejših« (manj odpornih) kamninah hitreje zniževalo in s tem si bodo hitreje sledili mlad, zrel in star razvojni stadij kot na območjih iz »trših« (odpornejših) kamnin.

[2] S tem so mišljena pobočja, ki imajo v prečnem profilu konveksne in konkavne dele.

Pogosti so celo primeri, da je za površje na »mehkejših« kamninah (gline) v smislu izoblikovanosti površja ves čas razvoja značilna prevlada reliefnih oblik, značilnih za zrel ali star razvojni stadij, medtem ko se na območjih s prevlado odpornejših kamnin lahko ves čas ohranijo reliefne oblike, značilne za mladi razvojni stadij (posebno, kadar v kamninski zgradbi prevladujejo apnenci).

Pomemben geomorfni dejavnik je tudi velikost območja. V primeru enako intenzivne denudacije se celo v razmerah povsem homogene kamninske sestave manjša območja hitreje spreminjajo kot velika. Osamljena gorska tvorba iz granita bo hitreje denudirana kot iz enake kamnine zgrajena večja gorska skupina; podobno velja tudi v primeru manjšega ali večjega otoka.

Odločilne vloge podnebja sploh ni potrebno posebej poudarjati. Celovit geomorfni razvojni ciklus ni možen že zaradi tega, ker so kvalitativne značilnosti denudacije in tudi njena intenziteta različne po posameznih klimatskih območjih, natančneje klimatskih pasovih, prav tako tudi njeni geomorfni učinki. Kljub istovrstnosti strukturnih reliefnih oblik so te zelo različne v posameznih klimatskih območjih[3]. Tega dejstva ni mogoče zanikati, čeprav so Davisovi nasledniki poleg njegovega fluvio-denudacijskega izdelali še cikluse ledeniške, puščavske in marinske denudacije, kajti čisti denudacijski ciklus sploh ne obstaja, enako kot ne moremo posameznih klimatskih pasov razmejiti z ostrimi mejami.

Geomorfološka kritika je ugotovila, da lahko neuspeh Davisove teorije pojasnimo z naslednjim:
1. razvoj reliefa je razlagal kot ciklični proces,
2. zapostavljal je pomen kamninske sestave, geološke zgradbe, tektonskih premikov in velikosti območja v razmerju do dolžine obdobja denudacije,
3. enovit in nedeljiv proces geomorfnega razvoja reliefa je razdelil na medsebojno neodvisne posamične morfološke procese, saj je bil prepričan v dokaze o samostojnih erozijskih, glacialnih, puščavskih in abrazijskih ciklusih. To pomeni, da je zanikal temeljno dialektično zakonitost, da je vse odvisno od vsega, oziroma da se lahko posamični procesi pravilno razlagajo samo v okviru enotnega geomorfnega razvojnega procesa.

V nasprotju z Davisovo teorijo, da je končni peneplen z majhno reliefno energijo izključno rezultat cikličnega razvoja reliefa, so poznejša preučevanja dokazala, da je Davisov peneplen samo eden od možnih končnih rezultatov razvoja zemeljskega površja. Peneplen lahko prav tako ustvari abrazija, obenem pa lahko nastane neodvisno od linearne in bočne erozije vodnih tokov na različnih nadmorskih višinah tudi v primeru, ko se neko območje iz vodoravnih, različno odpornih kamninskih skladov z denudacijo zniža do nekega odpornejšega in prepustnejšega kamninskega sloja. In končno, denudacija lahko ekshumira tudi fosilni peneplen.

V luči navedenih kritičnih pripomb je očitno, da se lahko Davisova teorija o cikličnem razvoju reliefa uporabi le v določenih situacijah. Po geomorfoloških tolmačenjih iz 20. in 30. let 20. stol. je v resničnem svetu razvoj reliefa zelo zapletena, pravzaprav nerešljiva uganka.

Davisovemu agnostičnemu tolmačenju, ki je temeljilo na preučevanju narave materije in njenega spreminjanja ter na enotnosti geomorfološke evolucije, se je uprl Walter Penck. Po njegovem mnenju se lahko razvoj reliefa primerja z enačbo, v kateri se iz poznanih (ugotovljivih) oblik in zunanjih sil ter njihovega vpliva lahko ugotovi neznani razvojni proces, ki pa je po Pencku v prvi vrsti odvisen od vertikalnih premikov zemeljske skorje. W. Penck je svojo metodo imenoval »morfološka analiza«. Z analizo reliefnih oblik je poskušal sklepati o razvojnem procesu in ga pojasnjevati. V Penckovih tolmačenjih je poudarek na endogenih procesih, za razliko od Davisa, ki je poudarjal vlogo zunanjih sil pri oblikovanju in razvoju reliefa.

Takšen Penckov pristop je povsem logičen, vendar pa je pripeljal do pretirano mehanistično avtodinamičnega stališča, po katerem ob »istovetnih endogenih predpogojih ni mogoče, da bi se v področjih z različno klimo razvile drugačne denudacijske oblike, ki bi se med seboj razlikovale po načinu nastanka« (1924). Takšno zmotno tolmačenje dialektike narave je velika napaka v Penckovih stališčih, na njihovi osnovi pa je lahko ponudil samo parcialne rešitve, s katerimi ni mogoče pojasniti celovitosti razvoja reliefa. Penc-

[3] Dodati je treba, da je to odvisno od intenzivnosti tektonskih premikov in od njihovega odnosa do učinkov denudacije.

kova izhodišča so torej ožja od Davisovih, treba pa je še dodati, da je Penck kot pomembna dejavnika razvoja reliefa poleg endogenih procesov upošteval samo še rečno erozijo in denudacijo na pobočjih, povsem pa je zanikal vlogo ledu, morja in vetra.

Za razliko od Davisa, ki pri razvoju reliefa napačno izdvaja dve, med seboj umetno ločeni časovni razdobji (tektonsko dviganje in zatem denudacijo), Penck poudarja, da teh dveh procesov ne smemo ločevati niti iz didaktičnih razlogov. Analizirati jih je potrebno v medsebojni povezanosti, saj tudi v naravi niso ločeni, temveč se dogajajo istočasno. Zato Penck priporoča, da ne smemo delati z velikimi, temveč čim krajšimi časovnimi intervali s ciljem čim natančnejšega tolmačenja medsebojne odvisnosti hkratnega učinkovanja dviganja in denudacije. Takšno analizo je Penck imenoval **diferencialna metoda**. Utemeljil jo je s tolmačenjem oblikovanja pobočij, saj se prepletenost učinkovanja endogenih in eksogenih procesov prepričljivo kaže v pobočnih profilih. Ta njegova trditev je precej sprejemljiva in točna, vendar bi s podrobno analizo zašli predaleč, saj to ni predmet te študije. Je pa treba pripomniti, da je Penckova razlaga, po kateri je prečni profil pobočij funkcija soodvisnosti delovanja tektonskega dviganja in denudacije (fluvialna erozija in pobočni procesi) v osnovi sicer pravilna, vendar pa velja samo za humidna območja in je ni mogoče uporabiti kot metode morfološke analize v aridnih območjih, ne velja pa tudi v primerih ledeniške in kraške denudacije.

Z metodo morfološke analize je prišel Penck do naslednjih rezultatov: do razvoja površja po Davisovem tolmačenju, t. j. do stadija peneplena, lahko pride samo v primeru, ko hitremu tektonskemu dvigu sledi dolgo obdobje tektonskega mirovanja; v takšnem primeru lahko kot posledica večje odpornosti kamninskih mas nastanejo osamljene vzpetine kot osamelci ali t. i. monadnocki. V vsakem drugem primeru se kot rezultat menjavanja intenzivnosti in časa trajanja tektonskih dvigov razvoj reliefa bistveno razlikuje od Davisovega tolmačenja. Ta odstopanja je mogoče ugotoviti z diferencialno metodo. Npr. kadar se neko območje začne tektonsko dvigati (ali se morsko dno dvigne nad višino morske gladine ali se začne dvigati ravninsko območje), je možno, da je dviganje tako počasno, da ga denudacija zmore kompenzirati in površje ostane v nizki legi in nerazčlenjeno. Takšno površje je podobno Davisovemu peneplenu (*Endrumpf*), vendar je za razliko od njega odraz uravnoteženega odnosa med jakostjo tektonskega dviganja in denudacije. Takšna uravnava predstavlja izhodiščno obliko kakršnega koli nadaljnjega razvoja reliefa, zato jo je Penck imenoval začetna ali primarna uravnava (P*rimärrumpf*). Od Davisovega peneplena se razlikuje samo po konveksnih dolinskih pobočjih in osamelih vzpetinah – monadnockih. Poleg tega Penck omenja še nekatere druge načine nastajanja uravnav. Po njegovem mnenju so Davisovi penepleni nastali na velikih območjih starih kratonov v Afriki, Avstraliji in Braziliji. Izoblikovali so se kot rezultat eksogene destrukcije ob koncu arhaika, zatem pa so doživeli epirogene premike majhne intenzivnosti. Za razliko od kratonov so uravnave v alpsko-himalajskem in andskem gorskem pasu ostanki začetnega stadija uravnavanja – (P*rimärrumpf)* (sliki 6/7).

4. Vprašanje peneplena in robnih uravnav

Izraz peneplen je Davis prvič uporabil 1902 za skoraj popolnoma uravnjeno veliko območje zemeljskega površja, nastalo s fluvialno erozijo. Takšne uravnave naj bi nastale na višini erozijske baze v toku predzadnjega (penultimate) stadija denudacije reliefa v različnih humidnih območjih. Nastanek Davisovega peneplena poteka v obdobjih dolgotrajnega tektonskega mirovanja z zniževanjem višjega sveta na razvodjih.

Pomen izraza peneplen se je pozneje razširil, tako da je dobil veliko širšo vsebino kot v Davisovem tolmačenju. Preučevalci so opisali številne peneplene v različnih delih sveta, tako da je po W. D. Thornburryju (1954) moral sam Davis pozvati k previdnosti pri uporabi tega izraza.

Najbolj živahno razpravo o Davisovi teoriji je izzvalo vprašanje, ali je sploh mogoče predpostaviti tako dolgo obdobje tektonskega mirovanja, da bi lahko denudacijski procesi izoblikovali relief vse do njegove predzadnje faze zaključnega stadija razvoja. Pod vprašajem je bilo tudi, ali je ciklični razvoj reliefa sploh mogoč; po Davisovem tolmačenju erozijski ciklus predpostavlja sklenjen razvojni krog, ki vključuje denudacijo in obdobje, v katerem pride do ponovnega tektonskega dviga in revitalizacije reliefa. Glavni razlog za neuspeh Davisove teorije je po geomorfoloških kritikih v antidialektičnem tolmačenju, da je razvoj reliefa krožni proces, ki se lahko povrne na svoj začetek. Če pa se negira ciklični razvoj reliefa, je tudi sam pojem peneplena zgolj fikcija.

Mnogi preučevalci, ki so dopolnjevali Davisovo teorijo, so menili, da lahko pride do razvoja peneplena tudi v razmerah počasnega tektonskega dviganja, kadar je hitrost dviganja manjša od intenzivnosti denudacije. Določene modifikacije je doživelo tudi Davisovo tolmačenje morfogeneze in razvoja stopničasto razvrščenih uravnav v goratih območjih[4].

Tudi mnogi ameriški privrženci Davisove teorije so vnesli določene modifikacije v tolmačenje razvoja peneplena. Po Thornburryju so se Davisovega duha dosledno držali samo tisti, ki so izraz peneplen uporabljali za denudacijsko uravnano površje, nastalo v vršnih delih meddolinskih slemen v zaključnem obdobju erozijskega ciklusa in to deloma z bočnim uravnavanjem vodotokov in pobočnimi procesi. Vse to dejansko predstavlja precejšnjo dopolnitev Davisovega nauka. Po našem mnenju bi morali za vse peneplenu podobne uravnane površine, toda nastale pod vplivom različnih dejavnikov v drugačnih razmerah, uporabljati ustreznejše, drugačne izraze. Nekateri raziskovalci so tako namesto izraza »peneplen« (angl. peneplain) predlagali izraz »panplain«.

Vse več je avtorjev, ki trdijo, da v zmerno toplem pasu erozijski procesi niso mogli nikoli znižati reliefa do peneplena. Takšne oblike lahko v zmerno toplem pasu obstajajo samo kot ostanki iz nekega starejšega geološkega obdobja s prevladujočim tropskim podnebjem. Kljub temu pa nekateri ne izključujejo povsem možnosti, da bi lahko penepleni nastali tudi v zmerno toplih geografskih širinah pod gozdnim pokrovom (Baulig, 1956) in to pod dominantnim vplivom fluvialne erozije (Bulla, 1954).

Številni ruski (sovjetski) raziskovalci zagovarjajo prepričanje, da v gorskem svetu denudacijski ciklus zaradi pogostih tektonskih dviganj nima dovolj časa, da bi uravnal površje do končnega stadija, tako da tipični penepleni ne morejo nastati. Tamkajšnje manjše uravnane površine so imenovali denudacijski nivoji uravnavanja (mdr. Dumitrasko, 1954; Čemjekov, 1964).

Nastanek *uravnjenega površja – peneplena* mnogi razlagajo z dolgotrajnim denudacijskim delovanjem neke zunanje sile – procesa. Drugi jih imajo za *poligenetske oblike*, ki se sčasoma razvijejo z menjavanjem številnih različnih dejavnikov (Penck, 1924; Meščerjakov, 1964; Klein, 1959 itd.). Poleg tega *se razlikujejo tudi nivoji uravnavanja, ki so tudi s prostorskega vidika poligenetske tvorbe.* Na takšne nivoje uravnavanja se poleg denudacijskih uravnav vežejo še uravnave akumulacijskega in akumulacijsko-denudacijskega porekla (Meščerjakov, 1954; Spiridonov, 1961). Pécsi (1967) imenuje prve deplanacijske, druge pa aplanacijske površine. K temu je treba dodati še novejšo teorijo L. Kinga o *pediplenizaciji* (1962), ki predpostavlja denudacijsko uravnavanje s procesom pedimentizacije, ki poteka v aridnih in semiaridnih območjih v razmerah tektonskega mirovanja. Končna uravnjena površina nastane z vzporednim odmikanjem pobočij, s čimer se v zaključni fazi izravnajo vse vzpetine in nastane končna denudacijska uravnava – *pediplen.*

Poleg pojasnjevanja nastanka peneplena se je ob razpravi med W. M. Davisom in W. Penckom kot eno pomembnejših geomorfoloških vprašanj pojavila *morfogeneza robnih uravnav* ali t. i. *piedmonta.* Davis je namreč v svojih delih ugotovil, da so za sredogorski svet značilni stopničasto razporejeni nivoji uravnav, njihov nastanek pa je povezal s cikličnim razvojem zemeljskega površja. Kot primer je uporabil severovzhodni del hribovja Allegheny v ZDA, ki je na vseh straneh, posebno še v smeri proti Atlantskemu oceanu, obdano z nizkim, rahlo valovitim površjem, na splošno nagnjenem proti oceanu, vstran od osrednjega hribovja. Ta rahlo valovit svet je razrezan s konsekventnimi dolinami in Davis ga je razlagal kot denudacijsko uravnavo, s strmo prelomno stopnjo (Fall line) ločeno od akumulacijske uravnave ob obali Atlantskega oceana. Vršni deli hribovja Allegheny so v približno enakih višinah in Davis jih je tolmačil kot ostanke starejše, dvignjene denudacijske uravnave. To po Davisu kaže, da je bilo nekdanje gorovje v teku morfološke evolucije znižano do peneplena, nato pa naj bi bilo zaradi splošnega epirogenega dviganja ponovno spremenjeno v gorski svet. Ker naj bi bilo dviganje v robnih območjih šibkejše, je te dele denudacija hitro znižala in izdelala robno uravnavo – delni peneplen, medtem ko so osrednji deli gorovja še vedno ostali v zrelem razvojnem stadiju.

[4] Davis je predpostavljal daljše obdobje tektonskega mirovanja v razvoju gorskih sistemov, kar se odraža v nastajanju peneplena v predzadnji (penultimate) fazi starejšega stadija. Sledi občasno tektonsko dviganje. Na robovih gorskih sistemov v tektonsko »mirnejših« obdobjih nastajajo delni penepleni v nivoju erozijske baze – denudacijske uravnave. Kjer tektonske faze mirovanja niso bile dovolj dolge, da bi prišlo do popolnega uničenja predhodnega peneplena in više ležečih vzpetin, po Davisovem mnenju od starejših peneplenov ostanejo manjši, v obliki stopnic razvrščeni uravnjeni deli.

Novi ciklus eksogenega preoblikovanja so prekinili novi epirogeni premiki, zaradi česar se je robna uravnava dvignila vzdolž prelomne stopnje (Fall line). Zaradi nastanka takšnega pregiba (povečanje strmca) na podolžnem profilu so se morale reke vrezati v stopnjo, s čimer so na njih nastali nizi brzic in slapov.

Po Davisovem mnenju priča nastajanje robnih uravnav ali delnih peneplenov o periodičnem dviganju, ki mu vsakič sledi obdobje denudacije. Ker so tudi v drugih delih sveta odkrili številne robne uravnave (predgorske stopnje), je veljalo Davisovo stališče na začetku 20. stol. kot splošno sprejeto.

W. Penck (1924) je podal v svoji kritiki Davisovega policikličnega nauka o razvoju reliefa »avtodinamično« tolmačenje nastanka robnih uravnav, saj so bili Davisovi argumenti zanj premalo prepričljivi. Po Davisu so namreč površine robnih uravnav, razen najspodnejše, v fazi destrukcije, torej predstavljajo fosilne oblike. Nasprotno je Penck menil, da to niso fosilne tvorbe, temveč nastajajo še danes in pravzaprav predstavljajo začetne nivoje uravnavanja.

Po Pencku bi bila njihova morfogeneza naslednja: Začetni razvojni stadij bi lahko bil Davisov peneplen, ki ga potem zajame hitro dviganje vse širšega območja. Kot posledica tega je fluvialna erozija vse močnejša in reke se intenzivno poglabljajo, najhitreje v robnih delih peneplena, kjer imajo največje pretoke. S tem na rekah nastanejo stopnje – pregibi, ki predstavljajo lokalno erozijsko bazo za višje ležeče dele porečij. Dolinska pobočja se postopoma pomikajo nazaj in širijo na račun prvotne uravnave. Sprva šibko dviganje nima nikakršnega vpliva na gorvodni del porečja, saj je denudacija zmožna kompenzirati dviganje. Tako nastane začetna uravnava (Primärrumpf), ki se postopoma dviguje in vanjo se vrežejo globoke doline. Ravnina uravnavanja se v obliki širokih dolinskih dnov »vriva« v osrednje dele gorstva. *Takšno, z denudacijskimi procesi nastalo obliko je W. Penck imenoval piedmont ali predgorsko stopnjo (Piedmonttreppe).* Z nadaljnjim razvojem, pod pogojem, da postaja dviganje vse hitrejše in zajema vse večje območje, se piedmont čez določen čas dvigne na višji nivo, na njegovih robovih pa nastanejo novi pregibi. Na ta način nastane cel niz nivojev uravnavanja (predgorskih stopenj), pri čemer se nekatere stalno širijo na račun višjih nivojev. Končni rezultat tega procesa je popolno uravnanje gorske strukture ali gorstva.

Čeprav je poznejša kritika v celoti zavrnila Penckove temeljne predpostavke o nastanku predgorskih stopenj, menimo, da bi njegovo tolmačenje zahtevalo nadaljnja preučevanja. Na koncu bi želeli poudariti, da robnih uravnav oz. Penckovega piedmonta (*Piedmonttreppe*) ne smemo povezovati s pedimenti, ki so de facto predgorske stopnje, vendar nastanejo prvenstveno s preperevanjem in pobočnimi procesi v specifičnih podnebnih razmerah[5].

5. Davisova teorija in globalna tektonika plošč

Relief (splet ravnih in nagnjenih delov zemeljskega površja) nastaja in se spreminja kot rezultat součinkovanja notranjih in zunanjih sil ter procesov. Notranje sile in procesi imajo odločilno vlogo pri oblikovanju planetarnih, mega- in makrooblik reliefa, zunanje sile in procesi pa pri oblikah manjših dimenzij. Eksogeni procesi v odvisnosti od klime v veliki meri vplivajo na horizontalno in vertikalno izoblikovanost reliefa, *pri tem pa jih odločilno usmerjajo in kontrolirajo endogene sile in procesi.* Velik vpliv na oblikovanje reliefa imajo posredno tudi značilnosti kamnin ter geološka zgradba Zemlje.

Z razvojem in uveljavitvijo teorije o globalni tektoniki plošč je bilo mogoče prvič celovito pojasniti značilnosti, nastanek in razvoj vseh važnejših geo-pojavov (nastanek in izginjanje zemeljske skorje, tektonski premiki, vulkanizem in potresna aktivnost) ter planetarnih reliefnih oblik (oceanski bazeni, srednjeoceanski hrbti, subdukcijske cone, celinske mase z nizi nagubanih gorstev in kratoni). *Zaradi tega je treba razvoj reliefa na zemeljskem površju povezovati z evolucijo njene skorje v prostoru in času, seveda v skladu s temeljnimi postavkami teorije o globalni tektoniki plošč.*

[5] Izraz predgorska stopnja (hrvaško predgorska stepenica) je v tem smislu v hrvaško geomorfološko literaturo uvedel A. Bognar (1980); izraz predstavlja sinonim za pediment.

Kot dokazana velja etapna evolucija zemeljske skorje. Razlikujemo tri osnovne etape, in sicer oceanizacijo, orogenezo in kratonizacijo (slika 8). *Lahko govorimo o enovitem razvoju strukturno-geomorfoloških značilnosti Zemlje,* saj so endogeni procesi, ki delujejo v zemeljski skorji, točneje v litosferi in astenosferi, medsebojno povezani in imajo vseplanetarne razsežnosti. Nastanek in razvoj največjih reliefnih oblik na Zemlji je vezan za posamične etape v razvoju zemeljske skorje: oceanskih bazenov, srednjeoceanskih hrbtov in subdukcijskih con v etapi oceanizacije, nagubanih gorstev v etapi orogeneze (alpsko-himalajski niz ter Andi in severnoameriška gorstva) ter nastanek kratonov v etapi kratonizacije. Razumeti jih moramo torej kot odraz medsebojne odvisnosti med endogenimi silami in procesi znotraj različnih razvojnih etap enotnega geotektonskega razvoja celotnega planeta in njene skorje.

Če te zakonitosti povežemo s tremi Davisovimi razvojnimi stadiji reliefa, je jasno razvidno, da je on prepoznal etapnost razvoja reliefa in ločil njegov mladi (juvenilni), zreli in star razvojni stadij. Ko podrobneje spoznamo učinke in splošne tendence razvoja, lahko vsakega od teh stadijev povežemo z ustrezno etapo v evoluciji planetarnega reliefa, tolmačenega v okviru globalne tektonike plošč, in to ne glede na temeljne razlike v tolmačenju gibalnih sil in mehanizmov delovanja ključnih geomorfnih procesov endogenega in eksogenega izvora.

V končni liniji velja tudi Davisova ideja o ponavljanju etapne evolucije reliefa, saj se tudi v okviru teorije o globalni tektoniki plošč govori o revitalizaciji zemeljske skorje in s tem tudi reliefa. Namreč, s ponovno oživitvijo procesa razpiranja v območju kratoniziranih delov celinskih mas (Vzhodnoafriški tektonski jarek z okoliškimi višavji, Bajkalski tektonski jarek in Srednjeazijsko višavje, Skalno gorovje z nizom medgorskih kotlin), se na novo začne tudi razvoj nove zemeljske skorje. *To seveda ne poteka v cikličnem, krožnem smislu* kot si je to predstavljal Davis, *temveč povsem drugače, tako v prostorskem kot časovnem smislu.* Na koncu je treba poudariti, da je Davis v svojo teorijo zajel samo razvoj kopnega dela Zemlje.

Poleg tega ostaja veljavna tudi ideja o peneplenu kot izrazu končnega, senilnega razvoja reliefa. Penepleni so namreč tudi v okviru globalne tektonike plošč dominantne reliefne oblike zaključne etape razvoja zemeljske skorje – kratonizacije (iz hrvaškega jezika prevedel K. Natek).