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REVIEW ON DENUDATION LEVELS OF THE WESTERN MECSEK MOUNTAINS (SW TRANSDANUBIA, HUNGARY)

Abstract. A denudation level is a well-known and widely used concept to understand landform evolution, which became one of the benchmarks of geomorphology in the last century. But there is still a question: how can we use formerly described denudation levels to identify the main stages of surface development? The literature abounds in methods to measure the absolute age or determine the relative age of denudation levels, but these methods are expensive or cannot be used in the Western Mecsek Mountains due to the lack of correlative sediments. A revision of the established ages and origin of denudation levels based on the recent geomorphic theories is also needed. In this paper we revise the formerly published geomorphic maps as well as local and antiquated terminology on the denudation levels of the Western Mecsek Mountains, using classical geomorphic interpretation supported with GIS. Three denudation levels were mapped and their relative age was determined based on the comparison of their altitudinal relations and the revision of data from previously published papers. These denudation levels, even if reshaped, represent the Early to Late Miocene and Early Pleistocene phases of surface development. Therefore, the review of the relative age of denudation levels helps summarize our knowledge on the surface development in the Western Mecsek Mountains and it can be the base for further geomorphic studies. We expect these data will become a rich source of information to other researchers studying denudation levels of the Carpathians and the Carpathian Basin.

Key words: denudation levels, pediment, geomorphic mapping, GIS, the Western Mecsek Mountains, the Pécs Basin

INTRODUCTION

The concept of planation surfaces includes different kinds of surfaces (A d a m s 1975) such as peneplain (D a v i s 1899), etchplain (B ü d e l 1948), pediment (G i l b e r t 1887; M c G e e 1897) or pediplain (G i l b e r t 1909; M a x s o n, A n d e r s o n 1935). The theory of 'the geographical cycle' (D a v i s 1899), 'the morphological analysis' (P e n c k 1924) and accordingly, the concept of the peneplain and mountains foreland, have been debated and criticised since they were introduced. Hence, generally only the concepts of the pediment and pediplain are conventional (Cui et al. 1999). However, the whole theory of surface planation is one of the benchmarks of geomorphology (Cui et al. 2002), due to its emphasis on the interactions between landscape components (Brierley et al. 2006; Brierley 2010).

The term *denudation* includes all surface processes leading to the lowering of a surface (Gaillardet 2006). Uplift and climate-driven erosion and weathering processes create different denudation levels on the surface through geologic time. These levels can be used to identify denudation processes and the rate of uplift. We consider "a denudation level" as nothing more than a subset of "a geomorphic surface" defined as a set. As far as their shape is concerned, there is no essential difference between the two, except in classification. Denudation levels in the Carpathians and in the mid-mountains of the Pannonian Basin are a base for the interpretation of tectonic movements (Zuchiewicz 1984; Kukulak 2004) and surface development (Starkel 1985; Ielenicz, Simoni 2007; Nedelea et al. 2009) at local and regional scales. Denudation levels of mid-mountain ridges in the Pannonian Basin, such as the Mecsek Mountains, were investigated approx. 150 years ago.

Since geomorphic properties of the study area have been described and interpreted differently through time — according to the above-mentioned theories — there are many discrepancies in the theories describing surface development in this area. For that reason, our aim was to take the first step to create a clear, consistent description of the surface development of the Western Mecsek.

Over the past decades researchers investigated only the surroundings of denudation levels (Sebe et al. 2008) or used them for geomorphotectonic investigations (Kovács et al. 2007; Konrád, Sebe 2010), without detailed research on the denudation levels in the Western Mecsek Mountains. The classical geomorphic maps of the area cover only isolated locations with limited extent; thus their interpretation is problematic due to their local significance. However, the interpretation of denudation levels is critical to understanding the tectonic evolution of the Western Mecsek Mountains and their surroundings.

Explanation of denudation levels changed several times during the development of the international and Hungarian geomorphology. However, the relative ages and the origin of denudation levels and fluvial terrace surfaces have not been revised based on the recent geomorphic theories. Their altitudinal position is also debated. The varying study of the origin of the levels and common use of some antiquated or local terms led to a standstill in Hungarian geomorphology. The inconsistent use of relevant nomenclature, including local terms (e.g. in stratigraphy) made a correlation of denudation levels complicated. Moreover, as the results of earlier studies were published in Hungarian only, they are inaccessible for international readers thus it is still open to debate.

The review of the previous work as well as of local geomorphic and stratigraphic terms helps to clarify the debated issues of denudation levels and may prepare the ground for a wider correlation. The altitudinal position and exact limits of denudation levels can be refined with GIS and morphometric methods to update the older maps.

We first intend to build and analyse a DEM of the Western Mecsek Mountains to obtain high-resolution data about denudation levels and to separate them from each other. Using these data and our previous field experience (Kovács et al. 2007) we review the geomorphic maps and the findings about denudation levels and fluvial terrace surfaces published earlier. Concerning methodology, some GIS-based methods were applied to similar geomorphic problems and successfully used in other sample areas (Bugya 2009; Bugya, Kovács 2008). This paper also summarizes extensive data on denudation levels that was published previously only in Hungarian, thereby remaining largely inaccessible to the international scientific community.

AIMS

This paper aims to:

1. revise the local and antiquated terms, forms and stratigraphic units, and reinterpret them with regard to the most recent terms and stratigraphy (Cohen et al. 2013).

2. revise and improve the former geomorphic maps of the Mecsek Mountains using DEM and morphometric methods. With our findings and the revised publications made accessible to international audience, we expect these data to become a rich source of information to other researchers studying denudation levels of the Carpathians and the Pannonian Basin.

SITE DESCRIPTION

The geological properties of the Western Mecsek Mountains were studied in detail (Böckh 1876; Vadász 1935; Kleb 1973; Konrád, Sebe 2010) over the last 60 years, due to the presence of uranium mines and as a potential disposal site of the high-activity radioactive waste of the Paks Nuclear Power Plant. Geomorphic properties and Neogene surface development of the area were discussed in only a few Hungarian studies (Szabó 1931; Pécsi 1963; Lovász 1970; Szilárd 1975; Fábián et al. 2005; Kovács et al. 2007; Sebe et al. 2008).

With an anticlinal structure, the Western Mecsek Mountains rise above their surroundings with a summit altitude of 592 m a.s.l. at the Jakab Hill, 540 m a.s.l. at the Vörös Hill and 535–611 m a.s.l. at the Misina and Tubes Range (Fig. 1). The Jakab Hill is composed of Upper Permian and Lower Triassic conglomerates and sandstone, the Misina and Tubes Range is built up of Middle Triassic limestone. There is a major strike-slip fault zone along the southern border of the Western Mecsek Mountains and the Pécs Basin, called the Mecsekalja Dislocation Zone

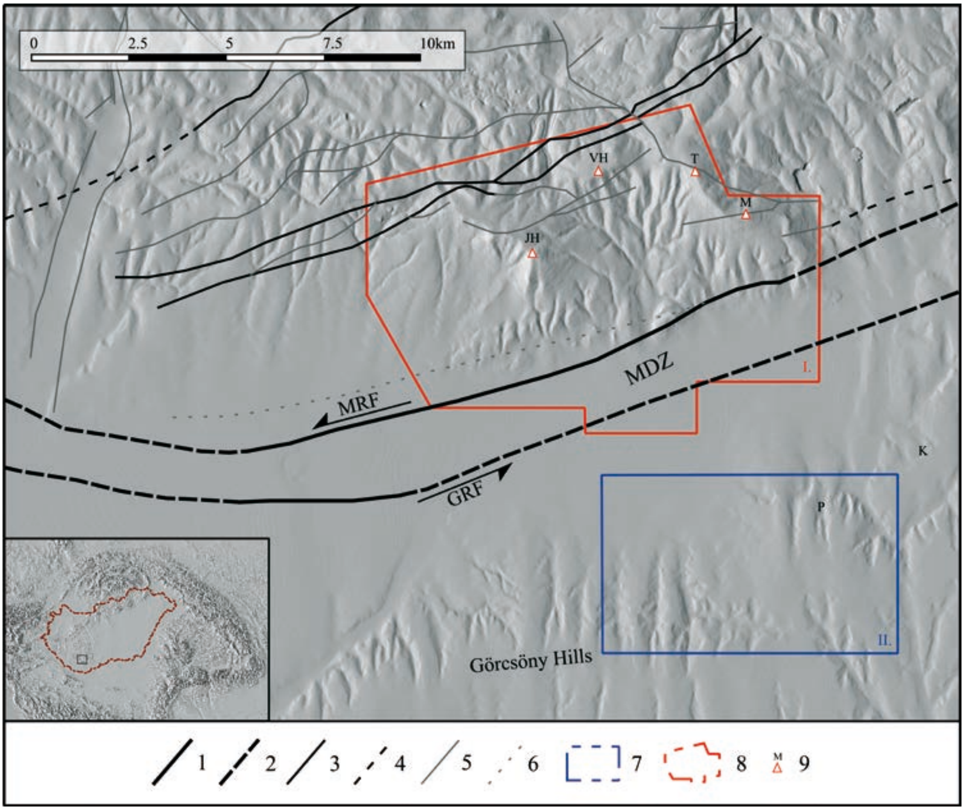


Fig. 1. Location of the investigated area. 1 — observed first-order fault; 2 — compiled first-order fault; 3 — observed second-order fault; 4 — compiled second-order fault; 5 — observed third-order fault; 6 — compiled third-order fault; 7 — boulders of the geomorphic map of Málom; 8 — boulders of the geomorphic map of the Western Mecsek Mountains; 9 — peak, JH — Jakab Hill; VH — Vörös Hill; T — Tubes; M — Misina; P — Posta Valley; K — Kozármisleny fauna site; MRF — Mecsekalja Reverse Fault; GRF — Görcsöny Reverse Fault; MDZ — Mecsekalja Dislocation Zone. Tectonic settings after (Chikán et al. 1984; Sebe et al. 2008)

(Szederkényi 1977; Wéber 1977). The Mecsekalja Dislocation Zone and the Görcsöny Reverse Fault are the tectonic borders of the Pécs Basin that is covered by Holocene fluvial deposits. Colluvial sediments of Miocene and Pliocene, clay and loess series of Pleistocene cover the Görcsöny Hills (250 m a.s.l.). An approx. 13 km long and 3–4 km wide basin (112–120 m a.s.l.) separates the Görcsöny Hills from the Mecsek Mountains. We mapped small-size areas on the southern slopes of the mountains (No. I. on Figure 1) and the northern slopes of the basin (No. II. on Figure 1), which are the most crucial from the geomorphic point of view.

METHODS AND MATERIALS

A 1 : 10,000 scale geomorphic map of the southern slopes of the Western Mecsek Mountains was drawn, using classical geomorphic mapping methods (Demek 1972), legend and tools (Ádám et al. 1963) to determine the origin, position and altitudinal relation of the geomorphic surfaces. Classical geomorphic methods understood as all methods of surveying, mapping and data processing without using modern GIS, database and data processing operations. The new geomorphic map was based on a review of a previously published geomorphic sketch (Kovács et al. 2007) and corrected according to the field observations and photo documentation of the fieldwork. However, earlier results and geomorphic maps were also considered (Szabó 1931; Fábián et al. 2005; Szilárd 1975; Sebe et al. 2008) to construct a more precise geomorphic map. A geomorphic map of the southern foreland of the mountains, by Sz. A. Fábián et al. (2005), was revised to clarify the connection of the fluvial terraces of the Pécs Basin to the denudation levels of the mountains.

A digital geomorphic map was created with Inkscape (0.47) and Gimp (2.6.8) to interpret only the most important forms (denudation surfaces, valley bottoms etc.). Slope features were derived from a DEM and GIS-based analysis of geological formations which compared landforms and bedrock based on 1 : 25,000 and 1 : 100,000 scale bedrock maps (Chikán et al. 1984; Chikán, Budai 2005).

The DEM, based on the contour lines of the 1 : 10,000 scale topographic maps was created with 2.5 m vertical (according to contour increments) and 5 m horizontal resolution, using regularized spline tension (v.surf.rst module of Grass GIS 6.4.3) interpolation (Mitášová, Mitáš 1993; Mitášová, Hofierka 1993). DEM was improved, using an average neighbourhood operation on 11 × 11 size pixel size window to extract the interpolation errors. Exact elevation of denudation levels was calculated from this smoothed DEM. Histograms were drawn to analyse height values of landforms.

Antiquated and local geomorphic terms were revised according to the most recent international geomorphic literature (Goudie 2004). Local (Hungarian) names for stratigraphic units were reinterpreted with regard to the terminology currently used in stratigraphy (ICC 2013) and a stratigraphic chart was drawn with the TS-Creator 4.2. to specify their relations.

DENUDATION LEVELS IN THE WESTERN MECSEK MOUNTAINS AND RELATED TERRACES OF THE PÉCS BASIN

Several smaller levels were found on the southern slope of the Western Mecsek Mountains. They were identified as denudation surfaces, according to their uniform geomorphic and geologic properties. Denudation surfaces were categorized into three main denudation levels based on their elevation, as I. P. Kovács et al. (2007) previously suggested (Fig. 2). The extent of denudation surfaces

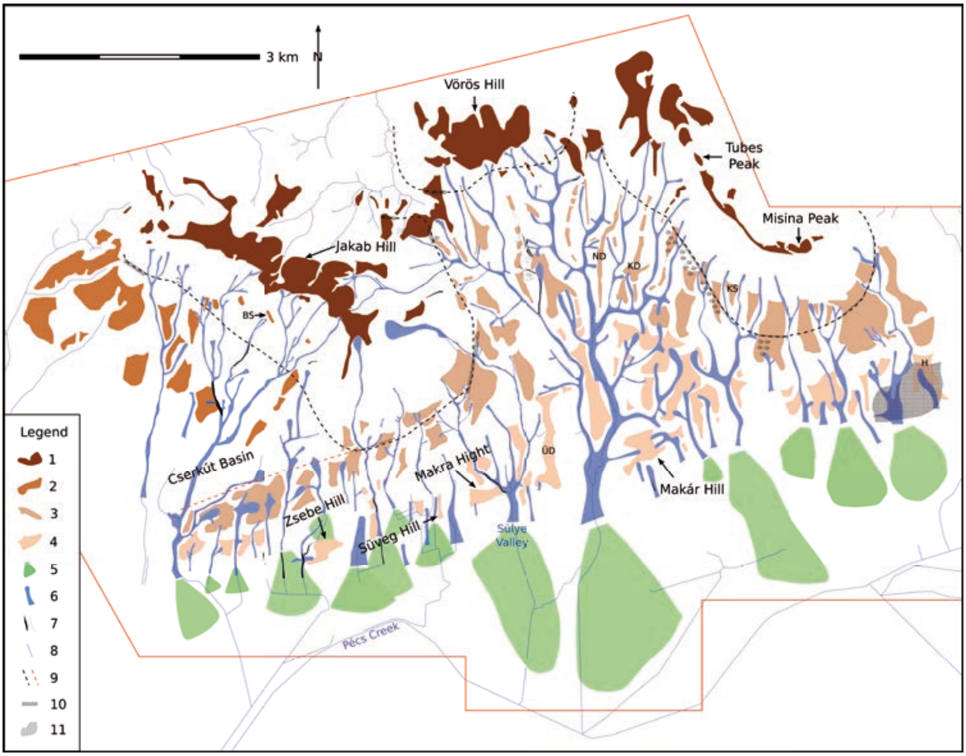


Fig. 2. Geomorphic map of the planation surfaces on the southern slopes of the Western Mecsek Mountains. 1 — S1; 2 — $_{JH}S2^{b}$; 3 — S2; 4 — S3; 5 — alluvial fan; 6 — valley; 7 — gully and incison; 8 — stream; 9 — the limit of Badenian abrasion platform (Szabó 1931), red intermittent line — corrigated line of the platform; 10 — Badenian abrasion sediment site (Szabó 1931); 11 — Sarmatian sediment site; BS — Babás szerkövek; H — Havi Hill; KD — Kisdeindol; KS — Kisszkókó; ND — Nagydeindol; ÜD — Ürög doűli

Table 1

The altitudinal position of denudation levels on the Western Mecsek Mountains

<table>
<tr><th>Name of the mountain range</th><th colspan="2">Short name of the surface type</th><th>Altitudinal position (m a.s.l.)</th></tr>
<tr><td rowspan="4">Jakab Hill (JH)</td><td colspan="2">$_{JH}S1$</td><td>540–592</td></tr>
<tr><td rowspan="2">$_{JH}S2$</td><td>$_{JH}S2^{a}$</td><td>160–360</td></tr>
<tr><td>$_{JH}S2^{b}$</td><td>220–460</td></tr>
<tr><td colspan="2">$_{JH}S3$</td><td>170–270</td></tr>
<tr><td rowspan="3">Misina and Tubes Range (MTR)</td><td colspan="2">$_{MTR}S1$</td><td>535–611</td></tr>
<tr><td colspan="2">$_{MTR}S2$</td><td>280–410</td></tr>
<tr><td colspan="2">$_{MTR}S3$</td><td>200–280</td></tr>
</table>

was modified according to the field experience and refined with the derivatives of DEM. Denudation levels were categorized according to their location on the southern slope of the Jakab Hill (JH) or Misina and Tubes Range (MTR), due to their different geomorphic features in comparison with the main mountain blocks (Tab. 1 and Photo1).

Photo 1. The view of denudation surfaces on the southern slope of Misina and Tubes Range (from the Jakab Hill to the East)

DETAILED GEOMORPHIC DESCRIPTION OF DENUDATION LEVELS

The *highest denudation level* (S1) forms the summit part of the mountains. It is separated from the lower levels by 25–70% steep slopes. The level was categorized as *emerged summit surface* (S1). The direction of $_{JH}$S1 is equal with the NW–SE strike of the axis of the Western Mecsek anticline. Its N–S width is between 200 and 400 m and the length is 2750–2800 m whereas in the W–E direction it has a 1200 m in length and ca. 800 m in width at the Vörös Hill. The level appears as a narrow (50–150 m wide) ridge at the Misina and Tubes Range and lowers with gentle slopes to the top of Misina.

The *middle denudation level* (S2) encompasses the lower surfaces and is oriented toward the mountain blocks. S2 starts to rise from the southern limit of the Cserkút Basin. Based on the geomorphic position, $_{JH}$S2 can be divided in two parts. Thus, the lowest part of $_{JH}$S2^{a} is situated at 160–170 m a.s.l. and it has a 500–600 m in width on the SW side. The middle part of $_{JH}$S2^{a} is smaller in extent. The NE part of $_{JH}$S2^{a} reaches 350–360 m a.s.l. with wider surfaces similar to the south-western part.

To date, the origin (or age) of the $_{JH}$S2^{b}, located in the western part of the research area, has not been determined. $_{JH}$S2^{b} appears as a gentle, dissected surface remnant or narrow and steep ridge. $_{JH}$S2^{b} can be found at different altitude: from 220–360 m to 430–460 m a.s.l.

On the southern slopes of the Vörös Hill and the western part of $_{MTR}$S2, S2 appears as a group of narrow (70–100 m wide) constantly lowering ridges. They are divided into several small steps.

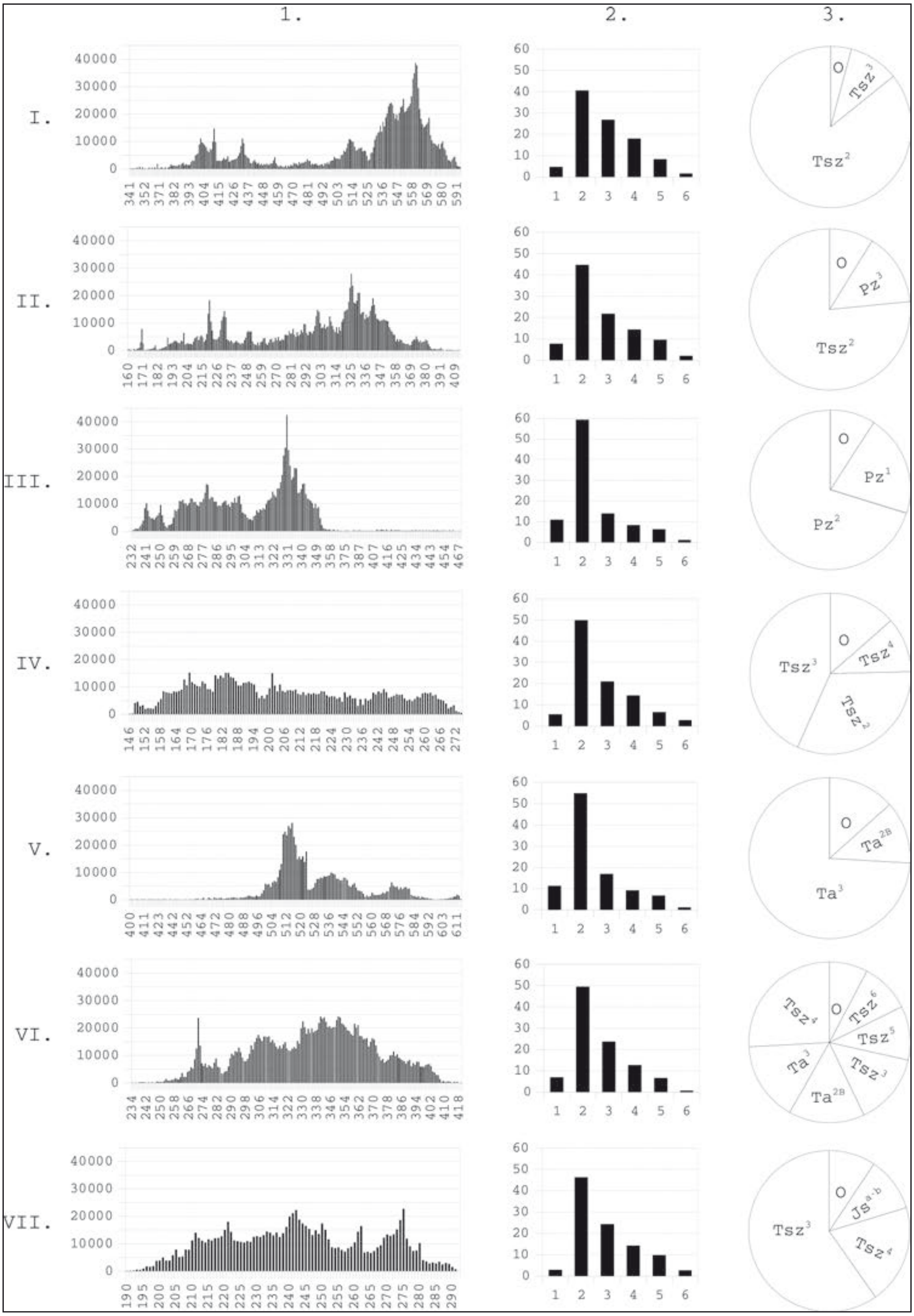
The largest surface remnant of $_{MTR}S2$ is 1400 m long (Nagydeindol). Between Kisdeindol and an unnamed hill situated to the east of Kisszkókó, $_{MTR}S2$ has a uniform appearance. Its highest part is 125–250 m wide, but the lower part is considerably more narrow. In the eastern part of S2, the surfaces become wider (250–700 m) and longer (650–850 m). The surfaces uniformly rise from 280–310 m a.s.l. to reach 400–410 m a.s.l. in their highest parts. They are also steeper than normal denudation level fragments within S2.

The *lowest denudation level* (S3) appears as hills (the Zsebe Hill 170 m a.s.l., the Süveg Hill 168.9 m a.s.l. and the Makra Hight 182 m a.s.l.), separated from its surroundings ($_{JH}S3$), and consistently rises up to 250–270 m a.s.l. at the Makár Hill (Koch 1988; Kovács et al. 2007). The fragments of the denudation level are only 150–320 m wide and 200–300 m long. The Zsebe Hill is the widest (370 m) and the Ürög dűlő is the longest of these surfaces (1.3 km). The isolated parts of the $_{MTR}S3$ have the same altitude (260–280, 200–210 m a.s.l.) and their lengths range from 400 to 800 m. The three main denudation levels are separated from each other and from their neighbourhood with steep 15–25% slopes.

GEOMORHOMETRIC PROPERTIES OF DENUDATION LEVELS

The histograms of height values (see column 1 on Fig. 3) of the denudation levels differ from each other and show the local nature of their initial segments. Taking into consideration the local maximums of height values (expected interpolation errors of DEM), the denudation levels contain at least three specific height groups (e.g. within $_{JH}S2^b$ and $_{MTR}S1$). The charts of the slope of denudation levels (see column 2 on Fig. 3) show uniform values, where the 5.1–12% (relatively gentle) slopes are dominant and the rate of steeper slope are low. According to the calculations based on the geological background of denudation levels, the denudation surfaces eroded into Palaeozoic and Triassic bedrock. The Palaeozoic sandstone, conglomerate and aleurite are dominant on the levels of

Fig. 3. The height, slope and geological settings of denudation levels. I — $_{JH}S1$; II — $_{JH}S2^a$; III — $_{JH}S2^b$; IV — $_{JH}S3$; V — $_{MTR}S1$; VI — $_{MTR}S2$; VII — $_{MTR}S3$; 1 — area of height values in square meters; 2 — slope of denudation levels (1 — 0–5%; 2 — 5.1–12%; 3 — 12.1–17%; 4 — 17.1–25%; 5 — 25.1–40%; 6 — steeper than 40%); 3 — bedrock formations: Pz^1 — Kővágószőlős Sandstone Formation, Bakonya Member, red, green and grey sandstone, conglomerate; Pz^2 — Kővágószőlős Sandstone Formation, Kővágótöttös Member, grey and green sandstone; Pz^3 — Kővágószőlős Sandstone Formation, Cserkút Member, red sandstone; Tsz^2 — Jakabhegy Sandstone Formation, red sandstone an aleurite; Tsz^3 — Patacs Aleurite Fomation, red and green sandstone, aleurite, claystone; Tsz^4 — Hetvehely Formation, Magyarürög Anhydrite Member, marl, dolomite mal, claystone, anhyrite and gyps; Tsz^5 — Hetvehely Formation, Hetvehely Dolomite Member marl, dolomite mal, claystone; Tsz^6 — Viganvár Limestone Formation, limestone, limestone with limestone marl stripes; Ta^{2B} — Lapis Limestone Formation, laminated limestone with dolomite lentils; Ta^3 — Lapis Limestone Formation, lenticular limestone; Js^{a-b} — Vasas Marl Formation, sandstone, Gryphaea marl with sandstone layers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the Jakab Hill; Triassic marl, dolomite and limestone built up the denudation levels of the Misina and Tubes Range. One or two predominant rock formations cover two-thirds of the denudation level segments and three or four secondary formations cover significantly less than 10% of the same area. We found no correlation between the shape of the landforms (for histogram values see Fig. 3) and the bedrock. Comparison of the spatial distribution of the levels and bedrock indicated that on the same bedrock different denudation levels can be observed and the same denudation level occurs on different bedrock.

FLUVIAL TERRACES OF THE PÉCS BASIN

Five different terrace levels of the Pécs Stream were mapped and identified (Fig. 4) in the southern part of the Pécs Basin (Fábián et al. 2005). The difference in elevation between the terrace levels is almost a few meters, however, they are separated from each other with more than 10% steep slopes. The surfaces are well visible in the southern part of the basin, but they do not occur at the junction of the basin and the mountains. Therefore there is no connection (or direct correlation) to the older denudation levels here; the forms represent a younger stage of development of the basin (Fig. 5).

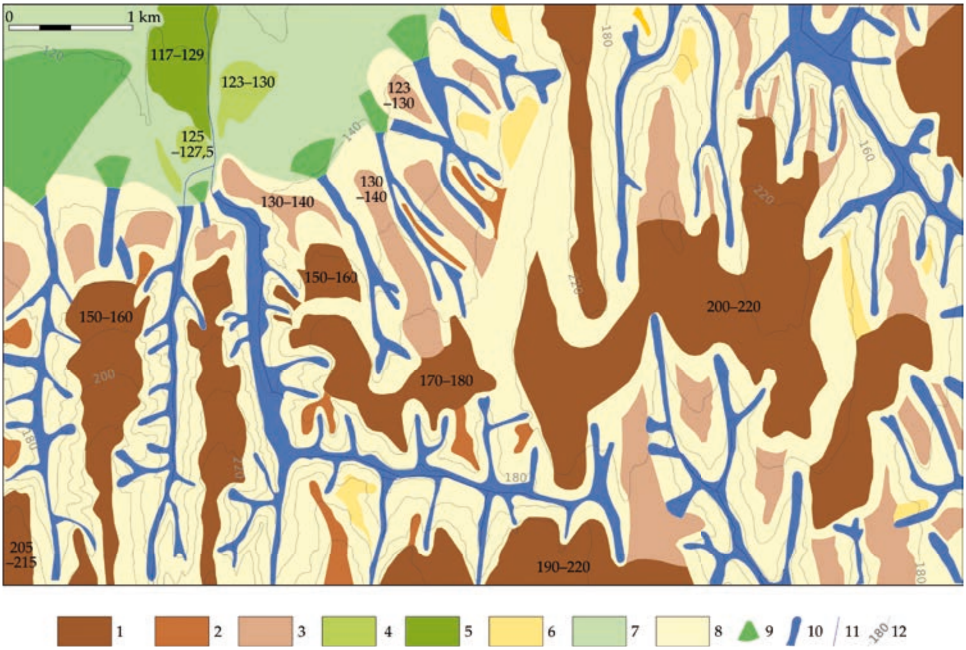

Fig. 4. Geomorphic map of Málom (redrawn after (Fábián et al. 2005). 1 — low plateau on 150–250 m a.s.l.; 2 — low ridge, higher than 150 m a.s.l., wider than 100 m; 3 — low interfluve, wider than 100 m; 4 — terraces; 5 — waterlogged area; 6 — noses; 7 — alluvium; 8 — slope; 9 — alluval fan; 10 — thalweg; 11 — creek; 12 — contour line

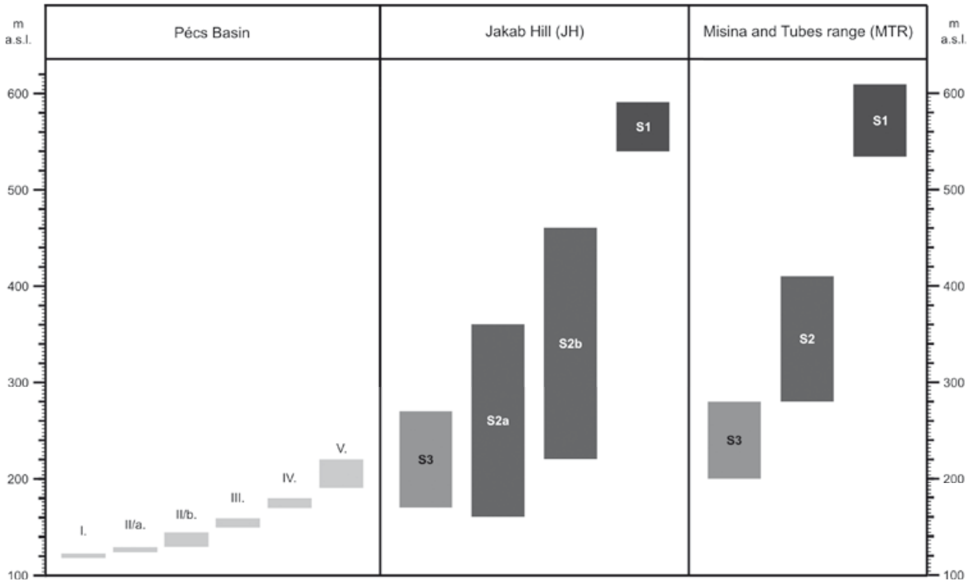

Fig. 5. The altitudinal position of denudation levels and terrace surfaces

CORRELATIVE SEDIMENTS OF DENUDATION LEVELS AND TERRACE SURFACES

In the past, several authors found correlative sediments of denudation levels. On the S1, Gy. Lovász (1970) described clay layers that was theorized to Oligocene. P. Z. Szabó (1931) observed granitic gravels on the northern slopes of S1. These granitic gravels and sandy sediments were described later as clastic deposit of the Early Miocene Szászvár Formation (Chikán 1991; Jámbor, Szabó 1961; Wéber 1982).

On the S2 denudation level abrasion gravels of the Middle Miocene (i.e. Badenian) sea (Prinz 1936; Szabó 1931; Vadász 1935) and the Sarmatian sea (Vadász 1935) were found. Sarmatian marine limestone deposits, though limited in extent, are present on the eastern part of $_{MTR}$S3 (Havi Hill) at 180–250 m a.s.l. These sediments are missing on $_{JH}$S3, but on the southern slopes of the Eastern Mecsek Mountains they can be found at similar altitude.

Late Miocene sediments of the remnant of the Paratethys (Lake Pannon) also exist on S2 (Chikánné et al. 1983; Kleb 1973). However, the Late Miocene (Lower Pannonian) abrasion terrace sediments were found only on $_{JH}$S3, on the Zsebe Hill (Kleb 1973; Prinz 1936; Vadász 1935).

Correlative sediments of the Pécs Stream terraces are almost missing. Only one, a 60 m-deep borehole was drilled and analysed in the Posta Valley (Pécsi et al. 1988a). The borehole was located at 215 m a.s.l, south of the 5th terrace of the Pécs Stream on a former glacis surface of the Western Mecsek Mountains. In the borehole, at 195 m a.s.l, a paleomagnetic event was recorded that overlaps with the change of the direction of sediment transport from south to north. Red and reddish clay layers, with cyclic sandy intercalations, found in the lower part of the borehole at 42–56.2 m (cf.: Fig. 2. in: P é c s i et al. 1988a) are considered correlative sediments of the glacis.

DISCUSSION

RELATIVE AGE OF THE DENUDATION LEVELS AND FLUVIAL TERRACES

The mapped denudation levels on the southern slopes of the Jakab Hill and the Misina and Tubes Range were described in the past but their age and development were disputed (Fig. 6). The S1 was first interpreted as pediplain remnant (S z a b ó 1931), according to the Davisian 'cycle of erosion'. Later it was described as a relict of an Eocene-Oligocene etchplain (L o v á s z 1970) using the Büdelian style of 'climatic geomorphology'. The granitic gravels and clastic deposits (S z a b ó 1931; C h i k á n 1991; J á m b o r, S z a b ó 1961; W é b e r 1982) on the northern slopes of S1 were interpreted as fluvial deposits transported from the Görcsöny Hills in the south, between the Mesozoic era and the Early Miocene. The development of S1 surface started after the accumulation of the granitic gravels in the Early Miocene and before the Middle Miocene (Badenian) transgression. Nevertheless, there is no further data about its age.

Former studies described S2 as the result of different erosional processes in the Neogene. The S2 was formed first by the Badenian sea (P r i n z 1936; S z a b ó 1931; V a d á s z 1935) in the Middle Miocene and later by Lake Pannon (C h i k á n n é et al. 1983) in the Late Miocene. However, it may have also developed due to the Late Miocene (Bérbaltavárium) pedimentation processes (P é c s i 1963), as its correlative sediments (red clay) were found in the Posta Valley borehole. There is no sedimentological evidence of its Late Miocene development, due to the lack of the correlative sediments of pedimentation processes on the S2. Although, the red clay and its altitudinal relation to the S3 confirms that it was transformed during the Bérbaltavárium by pedimentation processes.

According to the Late Miocene (i.e. Sarmatian) limestone deposits, after the Middle Miocene (Badenian) transgression – a new abrasion terrace developed in the Sarmatian at lower elevation and was subsequently transformed by the abrasion processes of Lake Pannon in the Late Miocene, (Lower Pannonian). Younger lacustrine sediments buried this terrace in the Late Miocene (Upper Pannonian) and abrasion processes reshaped the Middle Miocene (Badenian) abrasion surface. After the retreat of Lake Pannon (M a g y a r et al. 1999) this

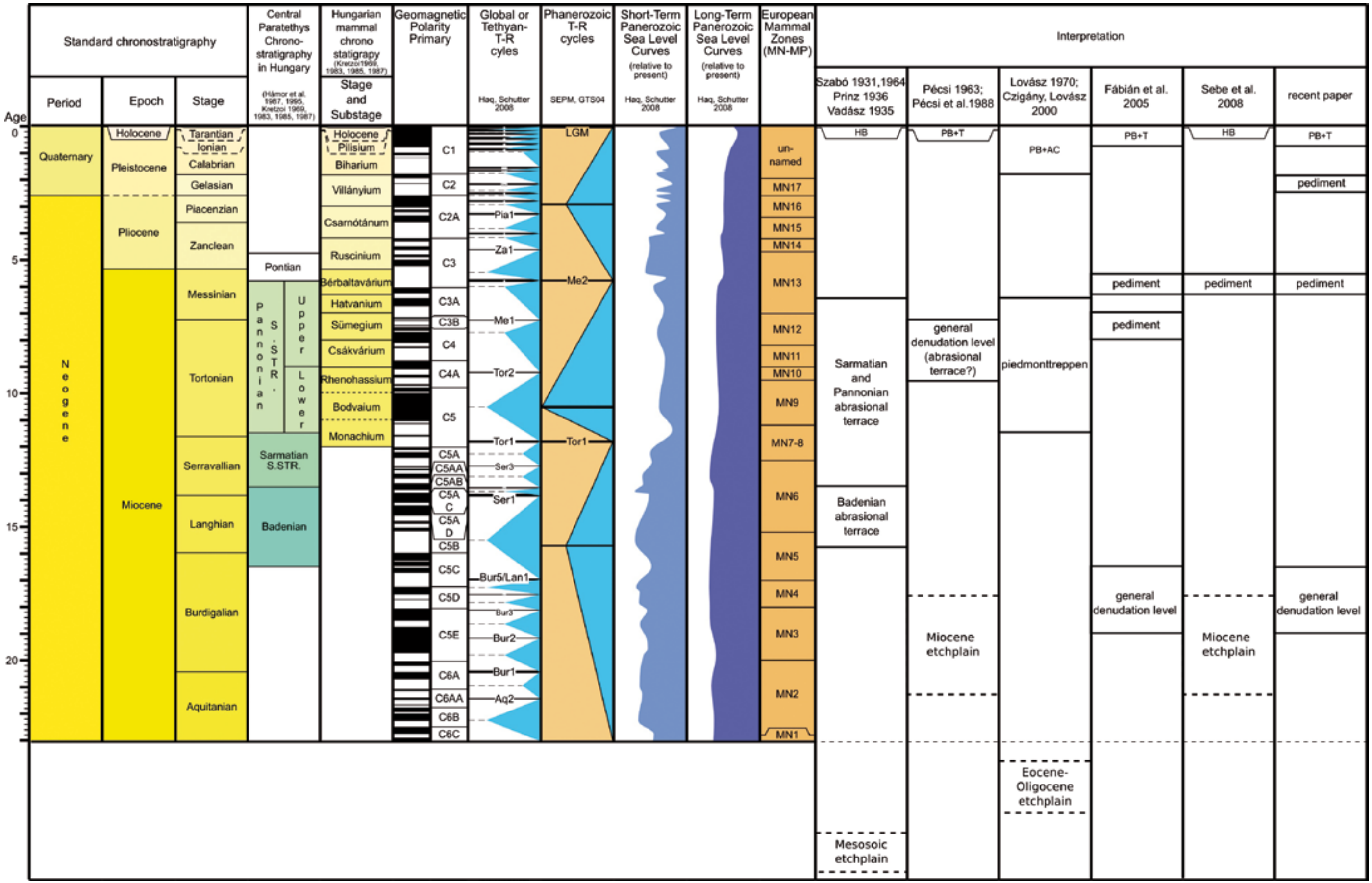

Fig. 6. Interpretation of the age and the number of planation surfaces of the Westen Mecsek Mountains and the age of the Pécs Basin. HB – Pécs Basin with Holocene age; PB – Pécs Basin with Pleistocene age; AC – alluvial cones; T – terraces

terrace was reshaped into pediment surface (S2) in the Late Miocene (Bérbaltavárium). Correlative sediments of the pedimentation processes were accumulated on the Görcsöny Hills. The covered Late-Miocene abrasion terrace was exposed and developed into a lower pediment surface (S3) during the Early Pleistocene (Kislángium). Its correlative sediments were accumulated also on the glacis (Görcsöny Hills). It has to be emphasised that the Pécs Basin separated the S2 and the S3 pediment surfaces from their glacis (Fig. 7).

The age and the development of the Pécs Basin are still debated, even though Sz. A. Fábián et al. (2005) described its terraces and revised the paleomagnetic epoch (cf. Pécsi et al. 1988a) that indicates a process of its formation. The age of the paleomagnetic event, measured in the Posta Valley borehole, was debated, because of an erosional hiatus within the drilled layers. It was formely interpreted (Pécsi et al. 1988 a, b) as the Blake event (117 ka) within MIS 5e. Sz. A. Fábián et al. (2005) revised this paleomagnetic event considering the altitudinal position of 5th overlapping terrace and re-interpreted it as Brunhes-Matuyama reversal (730 ka). This interpretation allows to correlate the 5th terrace of the Pécs Stream with the palaeomagnetic boundary and with the change in the direction of sediment transport that indicate the fact that the opening of the basin reached the northern surroundings of the borehole. The sediment flux from the longitudinal valleys was southern and turned to northern due to the subsidence of the Pécs Basin. The basin subsidence caused river captures on its eastern part in the Early Holocene (Szabó 1964).

Sz. Czigány and Gy. Lovász (2000) described three Pleistocene subsidence periods of the Pécs Basin, based on the analysis of the altitudinal position of alluvial fan deposits on the southern slopes of the Jakab Hill. However, I. P. Kovács (2011) considered these alluvial fans to be Holocene forms.

Mammal fossils of the Kozármisleny fauna site also suggest a 20–600 ka subsidence of the eastern sub-basin (Varga et al. 2010 a, b). However, the Pécs Basin was described as a markedly older pull-apart basin (Sebe et al. 2008) and its structural development was linked with the Mecsekalja Dislocation Zone (Konrád, Sebe 2010).

Sz. A. Fábián et al. (2005) explained the lower part of the drilling as the accumulated sediments of the glacis. The subtropical climate in the Middle Pliocene produced red clay that is used for identifying Late-Miocene pediment surfaces. This is because the red clay is a typical Middle Pliocene sediment and its lack on the Miocene pediment surfaces indicates Early and Mid-Miocene denudation. Moreover, if found on a given surface, the red clay proves the absence of Miocene denudation (Schweitzer, Szöőr 1997; Fábián et al. 2002, 2004; Kovács et al. 2011). It has a great importance due to significant tectonic movements in the Miocene. According to F. Schweitzer (1997) the Early Pleistocene reddish clay layers can be used to correlate the younger pedimentation processes. The highest parts of the Görcsöny Hills (approx.

250 m a.s.l.) were described as the remnants of the above-mentioned glacis surface (Fábián et al. 2005).

According to the previous studies (Koch 1988; Kovács et al. 2007) $_{JH}S2$ and $_{JH}S3$ are tilted to the WSW with a dip angle of 1.5°, while $_{MTR}S2$ and $_{MTR}S3$ are horizontal. Hence, only the $_{MTR}S2$ and $_{MTR}S3$ could be used to compare and correlate with other geomorphic surfaces of study area.

The elevation of $_{MTR}S3$ matches the position of the reddish clay of the Posta Valley borehole and the top surfaces of the Görcsöny Hills, which are higher than the 5th terrace of the Pécs Stream. We interpret this connection between the $_{MTR}S3$ and the Görcsöny Hills as a gentle piedmont surface that was reshaped during the opening of the Pécs Basin. The complex development of S3 started with the abrasion phase in the Middle Miocene (Sarmatian) and the Late Miocene (Lower Pannonian) (Kleb 1973), and finished with young pedimentation processes in the Early Pleistocene.

GEOMORPHIC PROPERTIES OF DENUDATION LEVELS

A local maximum in the histogram (see column 2 in Fig. 3) indicates the initial flat surface fragment, small in extent, is one of the already described three main denudation levels. Flat surface fragments with different elevation can be found on denudation levels which resulted from Pleistocene and Holocene climate changes (Kovács et al. 2007). However these surfaces correspond to the main denudation levels, sufficient data allowing their detailed evolution is still lacking. The domination of gentle 5.1–12% slopes (see column 2 on Fig. 3) along the denudation levels indicates their uniform, evenly flat appearance. Denudation levels were dissected by deep, erosional valleys, therefore there are steeper areas within the denudation levels. The small 'extremely' steep slopes occur on histograms because of the generalization during geomorphic mapping. During the generalization we combined small-extent flat surfaces, however, the slopes between them were also analyzed with GIS methods and displayed on histograms. Their presence does not modify consistent appearance of denudation levels. The improvement of DEM, based on 1 : 10,000 scale maps is also needed to correct the interpolation errors.

The analysis of the slope and height data was based on the DEM and the geomorphic map. On one hand, the results are in agreement with geomorphic mapping and interpretation and the geomorphic data became more accurate by these findings. On the other hand, a comparison of the geomorphic map and the results of automated surface extraction (independent GIS method) could improve the recent geomorphic map. More detailed geological map is also needed to clarify the connection between bedrock and the shape of denudation surfaces.

CONCLUSION

Detailed geomorphic map demonstrates three main denudation levels on the southern slopes of the Western Mecsek Mountains. Geomorphometric analysis indicated that these levels developed independently from bedrock formations. The denudation levels were dissected by deep erosion valleys, nevertheless, they have a uniform flat appearance. It has been demonstrated, that denudation levels represent the surface development of the Western Mecsek Mountains between the Early Miocene and the Early Pleistocene. In situ correlative sediments were not found, but the foreland sediments have the same pattern. Therefore the only consequence is, that foreland area could be used to correlate them (indirectly). It proves that the youngest denudation level was developed during the Lower Pleistocene, and the S1 developed in Early Miocene and the S2 in the Late Miocene. The three denudation levels and their relative age corresponds to the paleoclimate and history of surface development in the Carpathian Basin. With this correlation and modern geomorphic interpretation of the denudation levels they become benchmarks to clarify the geomorphic evolution of the study area. Denudation levels are composed of smaller surface fragments, as the histograms and slope diagrams show. However, they were formed as a result of the lowering of some parts of the original denudation levels caused by the Pleistocene and Holocene climate changes.

In spite of the geomorphic studies of the Western Mecsek Mountains in the last 130 years, the integration of the denudation levels and subsequent giving interpretation dismissed to complexity of landscape evolution. Based on these findings the conception of denudation surfaces is still in use in geomorphic studies and in relative correlation of landscape evolution.

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