FIELD OBSERVATION OF THE BURIED WEATHERING CRUST IN THE OSHTAVA GRABEN (SOUTHWESTERN BULGARIA)

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ABSTRACT. Geological and geomorphological features of the area of Oshtava graben (southwestern Bulgaria) are presented in the paper. The area is characterized by fault tectonics and the predominant basement rocks are granites. In the current research special attention is paid to the weathering crust which is covered by Neogene sediments. This deep weathering is related to the subtropical conditions in the late Neogene. The weathering crust is preserved under the clastic sediments, formed as a result of the deep erosion. The accumulation of these clastic materials is connected to the Messinian salinity crisis in late Neogene when changes in local and regional erosion bases (Aegean Sea level) led to the deep river incision, followed by areal erosion and deposition. Buried under these sediments the rocks of the denudation surfaces weathered chemically but without washing and removal of the weathering products, which continue to accumulate under the clastic formations.
The aim of the current paper is to direct the attention of researchers and experts to the deep weathering in Southwest Bulgaria, which has not been investigated in detail until now. The topicality of the research is determined by the significance of the buried weathering crust and the impact that it could have on the environmental processes and infrastructure.

Keywords: weathering crust, granite, Oshtava graben

ПОЛЕВИ ИЗСЛЕДВАНИЯ НА ПОГРЕБАНАТА ИЗВЕТРИТЕЛНА КОРА ОТ ОЩАВСКИЯ ГРАБЕН (ЮГОЗАПАДНА БЪЛГАРИЯ)

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РЕЗЮМЕ. В статията са представени геоложки и геоморфоложки особености на района на Ощавския грабейн (Югозападна България). Районът се характеризира с разломна тектоника, а преобладаващите коренни скали са гранити. В настоящото изследване е обърнато специално внимание на изветрителната кора, покрита с неогенски седименти. Дълбокото изветряне е свързано със субтропичните условия в късния Неоген. Изветритената кора е запазена под кластичните седименти, образувани в резултат на дълбока ерозия. Натрупването на тези кластични материали е свързано с Месинската криза през късния Неоген, когато промените в местните и регионалните ерозионни бази (нивото на Егейско море) водят до дълбоко врязване на реките, последвано от площна ерозия и кластично седиментоотлагане. Погребани под тези седименти, скалите, изграждащи денудационните повърхнини, изветрят химически, но без отмиване и отнасяне на изветрителните продукти, които продължават да се натрупват под кластичните образувания. Целта на настоящата статия е да насочи вниманието на изследователи и експерти към дълбокото изветряне в Югозападна България, което до момента не е подробно изследвано. Актуалността на тематиката е обусловена от значимостта на изветрителната кора и въздействието, което тя оказва, върху инфраструктурата.

Ключови думи: изветрителна кора, гранити, Ощавски грабен

Introduction

At the beginning of the Cenozoic a circum-equatorial sea current existed that spanned the entire Earth. It flowed unimpeded through the Tethys Sea and warmed the planet. As the continents continued to separate, the Tethys Sea gradually closed, cutting off the circum-equatorial currents (Bryden and Kinder, 1991). It cooled the Earth as the cooling culminated in the ice ages. These events shifted significantly the global sea level. The isolation of the Mediterranean from the world ocean, happened in the Burdigalian (20-15 Ma) but the most pronounced climatic event happened 7-5 million years ago and is known as the Messinian Salinity Crisis (MSC), also referred to as the Messinian Event (Hsü et al., 1977). This event was first discovered in 1970 by drilling on a number of localities in the Mediterranean of several hundreds of meters of salts by Glomar Challenger. The culmination of the crises led to desiccation of the Mediterranean that took place about 5.5 Ma ago. Such a catastrophic event had a great impact on the landscape of the entire region. The lowering of the base-level of erosion led to deep incision of rivers that drained in the Mediterranean. Deep Messinian canyons are recorded throughout the region. It also led to unusually active Late Miocene groundwater movement and karstification. The climate became drier and cooler. This was a change from the generally warmer climate of the Neogen.

In this paper, the effects of the late Neogene erosion and deposition in part of Southwest Bulgaria are discussed. The aim is to direct the attention of researchers and experts to the deep weathering in the Southwest Bulgaria, which has not been investigated in detail until now. The paper has been elaborated on the basis of field observation and literature review.

Study area

The area of study of the current research is located in southwestern Bulgaria and is part of the western slopes (foothills) of Pirin mountain (Fig. 1). It is situated into a regional tectonomorphologic domain known as the Struma lineament (Загорчев, 1988). The area comprises a series of tectonic troughs named: Blagoevgrad graben, Simitli graben and Sandanski graben. The orientation of this chain of troughs is NNW – SSE. They are constrained by the Vlahinski, Verilski, Ograzhdenski and Belasishki elevated blocks to the west, and to the east they border the mountains Rila and Pirin. The time of initiation of this linear structure cannot be accurately defined but it dates back at least to the beginning of the Eocene. Although the troughs are constrained by faults, the evolution of the lineaments could be related to the global climatic events too.

During the Neogene, until the beginning of the Quaternary temperature drop, the region of the present southwestern Bulgaria was affected by subtropical climatic conditions. The global climatic changes in the late Neogene, related to the drying of Mediterranean Sea (MSC) shifted the erosional bases of the rivers, which combined with tectonic reasons, resulted in deep areal erosion and deposition of coarse clastic sediments in Messinian time. Buried under these sediments the granites and metamorphic rocks of the denudation surfaces continued to weather chemically but without washing and removal of the weathering products, which continued to accumulate under the clastic formations. During the Quaternary the main river acquired its present valley and the flows from west and east cut and partially removed the late Neogene sediment cover, although parts of it are still on place.
The sediments of the Struma lineament recorded the change of the rivers erosional bases. Very distinctive rock formations were deposited in the lineament area during the Messinian time. These formations known as Kalimantsi and Sandanski Formations (Kojumdjgieva et al., 1982) have been dated and it appears that their deposition corresponds to the time of the deepest erosional incision of the rivers flowing towards the Aegean Sea (Zagorchev, 2002). In the time span 7-5 million years ago very fast and deep erosion and deposition, and subtropical weathering, happened in the troughs of the Struma lineament. The clastic rocks are locally derived, poorly sorted and usually very coarse. They covered denudation - accumulation surface carved over variegated fundament.

Geological settings

Extends of the Oshtava graben

In the Bulgarian literature (Загорчев и Маринова, 1990, 1993) the Sandanski graben is shown as containing two dissimilar parts. The northern part is an elevated terrace at the western slopes of Pirin Mountain that has fundament of granites and metamorphic rocks. This part comprises a hilly terrain, east of the Kresna gorge, and separated from the gorge by an elevated ridge (Figures 1 and 2). The southern part of the Sandanski graben, south of Kresna, comprises a wide fluvial plane of the river Struma.

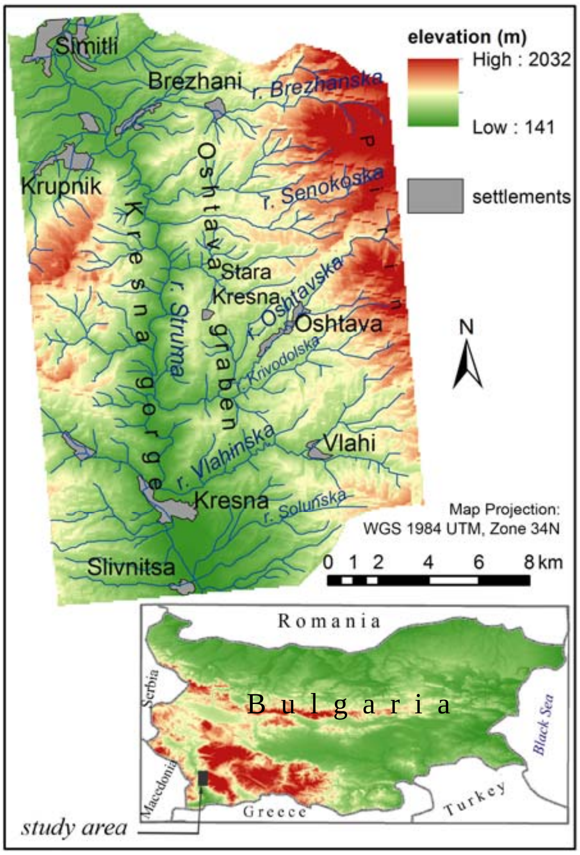

Fig. 1. Location of the area of study with colored representation of the topographic elevation.

Features of the northern part of the graben will be discussed in the paper. The difference between the northern and southern part is that the northern part is considerably elevated compared to the southern one and it seems to reflect different geologic evolution. Most of all it contains evidence of a river flow, presumably the predecessor of river Struma, that flowed easterly, and on elevated level, compared to the present position of the river in the Kresna gorge. This older river we call Paleo-Struma in accordance with other authors (f.e. Ivanov, Bozukov, 2017). The area east of the Kresna gorge is best described with the name of Oshtava graben, rather than naming it as Sandanski graben.

The generalized geomorphic situation of the Oshtava graben (or Oshtava area of the Sandanski graben) is shown on Figures 2 and 3. North of the village of Brezhani it borders the Oranovo-Simitli graben and south of Kresna it passes into the wider fluvial plane of Struma. Both the northern and the southern border domain are lower in hypsometric sense and lacking the ridge of fencing hills from west, thus the area of the Oshtava graben can be examined as an elevated older terrace compared to the northern and southern domains.

Judging from the coarse clastic sedimentary rock, that once covered it completely, the Oshtava graben was fluvial valley between the Messinian and the beginning of the Quaternary but remained as an elevated terrace after river Struma acquired it present valley in the Kresna gorge.

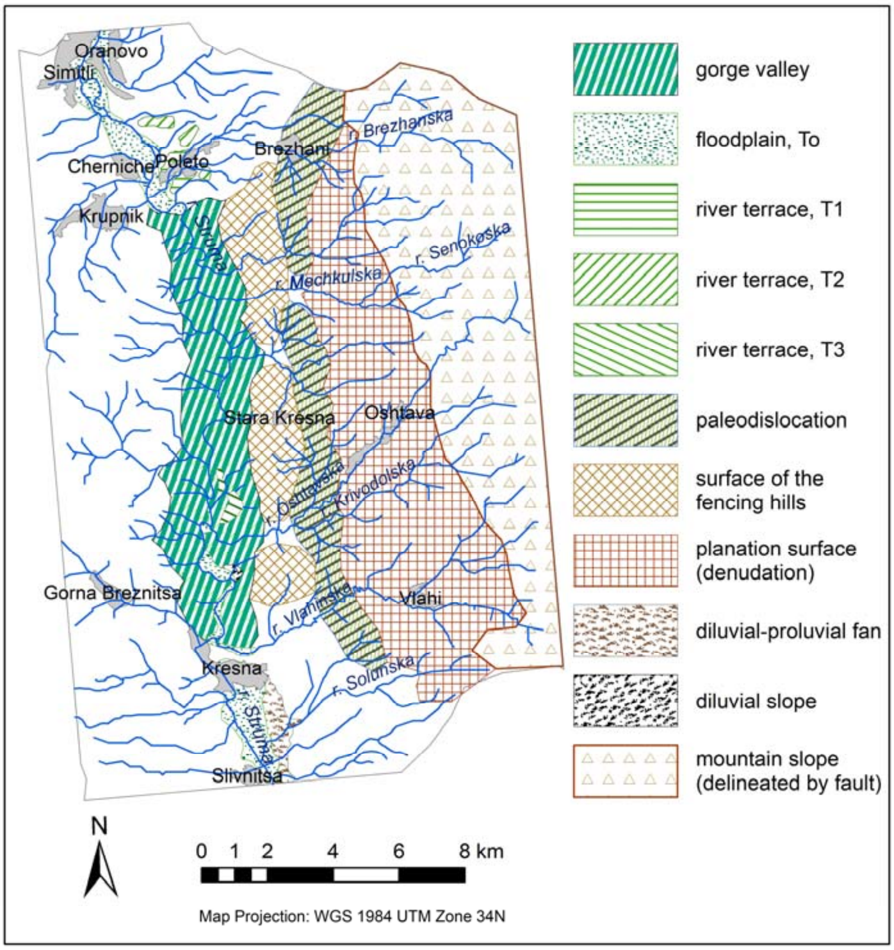

Fig. 2. Morphological features of the terrain east of the Kresna gorge, between the settlements of Brezhani and Kresna.
From west to east, zones elongated in north-south direction are recognized and named as: Kresna gorge, fencing hills, paleodislocation; denudation plane, and mountain slope. The paleodislocation is a deep, and relatively straight valley of fault predisposition that is interpreted as the valley of the predecessor or the river Struma. The fencing hills, paleodislocation and the denudation plane are transected by the present tributaries of the river Struma. The depression between the fencing hills and the mountain slope can be discerned also on the slope map shown on Figure 3.

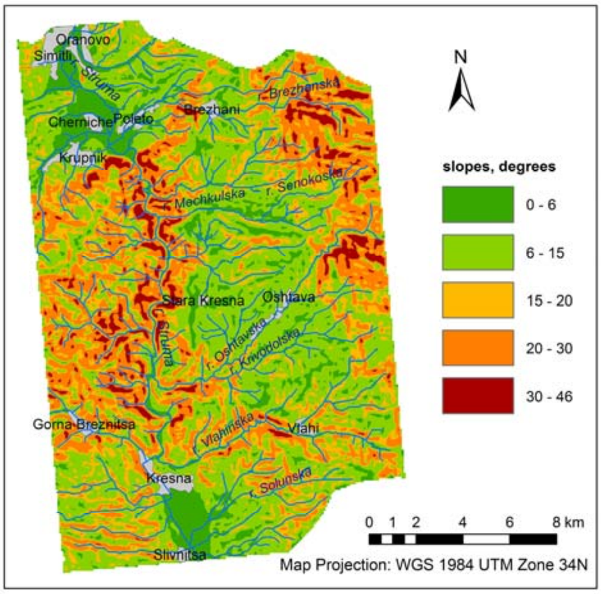

Fig. 3. Slope map of the terraineast of the Kresna gorge, between the settlements of Brezhani and Kresna

Rock formations in the Oshtava graben

The following rock formations outcrop in the Oshtava graben:

1. Predela metamorphic complex of inferred neoproterozoic age (Милованов и др., 2008, 2009). It comprises tectonically inserted sleeve of various iron-rich metamorphics in amphibolite facies;
2. Maleshevska metamorphic complex, comprising mostly sialic rocks - gneisses and schists, injected with anatectic melts;
3. Granites of the North Pirin pluton. The dating of these granites by Бояджиев и Лилов (1971, 1976) yielded 30-41 Ma. Age of 92 +/- 22 Ma was accepted for the national geological map of Bulgaria (Загорчев и Маринова, 1993). Age of 32.99 +/- 0.39 Ma was accepted for the national geological map in scale 1:50 000 (Милованов и др. 2008, 2009).
4. Sandanski Formaton (Kojumdgieva et al., 1982) that contains sandstones, alevrolites, sandy clays, grits and conglomerates of the Late Miocene - Meotian to Pontian regiostages. These regiostages from the Central Paratethys domain correspond to the Messinian and Zanclean of the ISC stage division (Gozhyc, et al., 2015), spanning between 7.2 and 3.6 Ma.
5. Kalimantsi Formation (Kojumdgieva et al., 1982), comprising very coarse conglomerates with various proportions of pebble, cobble and boulder fragments in sandy matrix and

Meotian, Pontian and Dacian fauna. It has rich assemblage of giraffes' remains of late Miocene age (Geraads et al., 2005).
6. Alluvial deposits of Quaternary age are found only in the valley of river Struma and in narrow river terraces in the area.

The granites covered with discontinuous cover of the Kalimantsi Formation are the most widespread in Oshtava graben. Small exposures of boulder conglomerates and sandstones reveal that the entire area of the Oshtava graben was covered by Late Neogene clastic rocks.

Fault network

Three fault orientations dominate in the region. These are N-S, NW-SE and NE-SW. The N-S faults seem to be older than the rest. They control the boundaries of the sedimentary basins and the flow of the larger rivers prior to the Quaternary. At present, they are intersected and locally displaced by the active NE-SW faults. The entire length of the Oshtava graben is controlled by the splays of one such fault. It controlled the river flow of the predecessor of Struma and was sealed by coarse clastic sediments of the Kalimantsi Formation. Wedges of conglomerate still exist on several places in its valley.

The Quaternary rivers following the NE-SW faults, such as Mechkulska, Oshtavska, Krivodlska, Vlahinska and Solunska transected the older N-S valleys, partially removing their clastic infilling (Fig. 4).

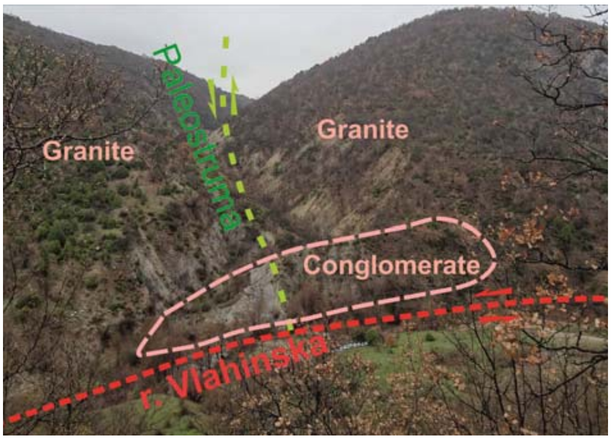

Fig. 4. Junction of the Paleo-Struma valley of Neogene age, striking N-S and Vlahinska river valley, of Quaternary age, striking E-W.
The Vlahinska valley displaces Paleo-Struma at least 250 m to east (eft on the picture). At the junction, in front on the picture, a sleeve of Kalimantsi Formation is exposed in the old valley that is partially eroded by the river Vlahinska

Geomorphological settings

In the unpublished geological reports (Костадинов и др., 1968) for the region are recognised 7 erosion-denudation levels, 2 levels of floodplains and 6 upper river terraces. The average height of the planation surface on Figure 2 varies between 600 and 800 meters a.s.l. and the heights of the fencing hills, that separate it from the Kresna gorge, are also between 600 and 800 meters a.s.l., however, because the planation surface is inclined to the west, the fencing hills stand higher compared to it. The planation surface and the fencing hills have some flat tops at different levels, which imply that they represent different erosional levels related to the different position of the local erosional base but the Quaternary erosion and likely tectonic denivelation complicate their differentiation.

Paleotopography and water flow

Since the Neogene topographic features are partially buried by clastic rocks, the water follows a complicated path in the Oshtava graben. Surface waters are drained by the N-S valleys and are driven under the Neogen sediments, where they run as subsurface flows until they discharge into the E-W valleys of the Quaternary streams. Thus, the fault network, combined with the barrages of still uneroded Late Neogene sediments deposits in the N-S trending fault valleys, creates two distinct water pathways: hidden subsurface pathway from north to south and visible surface pathway from east to west.

Quantification of the weathering crust

There is stark contrast between the degree of weathering of the granites in the Quaternary Kresna gorge, where the granites are virtually fresh, and those in the region to the east of the fencing hills, where granites are deeply weathered. This can be explained with the fact that the weathering products that formed in dry subtropical conditions, were trapped under the Neogene sediments without the opportunity for washing and removal. Under the sedimentary cover there was abundant supply of water, so the weathering has continued until present day. In contrast, in the Kresna gorge all weathering products are immediately washed out.

Given that the Oshtava graben was formed predominantly on granitic basement, the ISRM (International Society for Rock Mechanics) chart (Fig. 5) is used for quantitative description of the weathering.

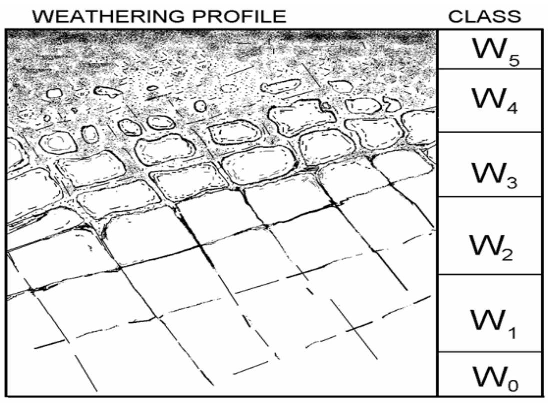

Fig. 5. Chart of weathering staged after ISRM (1978).

All six weathering stages can be found in the area of study and the only thing that varies is the thickness of the layers. The variation is due to: 1. geomorphological position of the outcrop, which is: valley bottom, slope, wide or narrow hilltop; 2. time of removal of the clastic cover, and 2. the tectonic predisposition of rocks, as the faulted rocks weather much deeper.

In general, wide and flat surfaces have thicker crust of class W5 and W4 and the weathering of classes W3 and W4 reaches much deeper. In the vicinity of fault zones weathering of class W4 was found in boreholes at depths of 90m and beyond. In the slopes of the N-S trending valleys, where the

Neogene cover was recently stripped the weathering crust is much thicker than in the slopes of the Quaternary streams flowing from east to west.

The Kalimantsi Formation in the area was locally derived and it contains boulders of granite, included in sandy matrix, which was also derived from granite, so sometimes it is difficult to distinguish it from the spherically weathered granite. For this purpose a field test can be used using steal tipped hand tool like hammer or mattock. It was found that the steel tool cannot penetrate in spherically weathered granite (Fig. 6) for more than 1-2 cm, while is can penetrate in the matrix of Kalimantsi conglomerates (Fig. 7) considerably deeper.

Fig. 6. Outcrop showing spherical weathering of granite as the spherical cores are also weathered. The exposure is located immediately under the Kalimantsi Formation which follows upsection.

The weathering of the metamorphic rocks produces clay rich diluvium that is thicker than in unweathered domains.

Fig. 7. Exposure of Kalimantsi Formation located close to the granite basement.

Engineering geological effects of the weathering

Weathering strongly influences the strength properties of the rocks. It alone, without any other negative influence, can shift the position of the rock in the widely used rock mass classification systems such as RMR or GSI (Bieniawski, 1989, Hoek and Brown (1997) towards the classes of poor and very poor rocks, with regards to the road and tunnel construction. Since the uppermost, strongly weathered part of the section, is thick at least several meters most of the excavations and many foundations are done inside it. These make the foundations vulnerable to soil creep (Fig. 8 and Fig. 9) and water erosion (Fig. 10). The geodynamic processes that accompany the weak layers of weathered rock are easily recognizable on the slopes of Oshtava graben. Inclined trees and ravines are common in contrast to the modern Kresna gorge, where the rock falls are a danger.

Fig.8. Slope of N-S trending fault valley with intensely weathered granitic slopes. Multiple channels are seen on the slope as well as root excavation and tumbling of trees.

The weathering crust modifies not only the mechanical properties of the terrain but also its hydrological ones. In general the fracture reservoirs are of small capacity but the weathered crust of the granite has porous properties, which impose hysteresis on its water discharge potential.

Fig. 9. Tree inclined to 45^{o} in a fault valley outh of Stara Kresna.

Fig. 10. Ravine in flat hilltop with thick weathering crust to south west of Oshtava village.

The hysteresis is expressed in that rain water is accumulated in the porous weathering crust and does not immediately impact the surface runoff.

Conclusions

Subtropical weathering crust was sealed under the late Neogene clastic formations of the Struma lineament. Under the cover of clastic sediments the chemical weathering continued until recent days. There is a sharp contrast in the weathering profile of the Quaternary rivers and those of the Neogene fault valleys that were buried under clastic sediments. At present, in the region east of the Kresna gorge, the erosion of the Neogene sediments is at its final stage revealing beneath them buried weathering products. The expansion of the road construction projects east of the Kresna gorge shall take into account challenging engineering conditions, which are not well known to this moment.

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