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PHYSICAL GEOGRAPHIC CHARACTERISTICS AND GEO-HERITAGE OF FRUŠKA GORA MOUNTAIN (VOJVODINA, SERBIA)

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Abstract

Geo-heritage represents a group of all geological, geomorphological, pedological and particular archeological features that are of great scientific and cultural importance (MIJOVIĆ et al., 1999)

The massif of Fruška Gora is the peculiar orographical form and the area of the biggest diversity of geological and pedological formations in Vojvodina. The big numbers of geological, geomorphological and pedological values satisfy to join this mountain in the list of geo-heritage. Greater parts of objects are *in situ*. The most important object of geo heritage, which are separated from their natural habitat, are located in Čerević Country museum and in the Institute for Protection of Nature of Serbia, Department of Novi Sad. Big concentration, diversity and scientific importance of it refer to us to make one step beyond and to proclaim this area for geo-park.

Introduction

Geo-heritage represents a group of all geological, geomorphological, pedological and particular archeological features that are of great scientific and cultural importance (MIJOVIĆ et al., 1999). During the last decades many national and international institutions and communities, whose main aims are making a list, study and management of geo-heritage sites, were formed in Europe. The National Committee for geo-heritage of Yugoslavia, whose projects draw more and more attention of experts as well as of wider public, was also formed. One of such projects, initiated five years ago, is the research of the geo-heritage of Fruška Gora as well. Within the planned activities by now preliminary list of geo-heritage sites has been made, a few suggestions about the protection of the most important geo-heritage sites have been made, and making plans for the promotion of geodiversity and its representatives of the unique mountain in Srem region is in preparation as well.

Fruška Gora is a low, isolated, island-mountain rising above the Vojvodinian plains in northern Serbia, with the highest peak at 539 m (Crveni Čot). Its lens shaped massif extends some 80 km in the direction W-E from the line Šarengrad-Šid from the west to the line Belegiš-Surduk-Stari Slankamen to the east (45° 0'N - 45° 15' N and 16° 37'E - 18° 01' E) (**Fig. 1.**).

With its position beside the river Danube, mineral reserves, unique flora and fauna it has a great economic, transportation and touristic significance. The mountain was declared a National park in 1960. including areas of various level of protection. The goal of protective measures is to ensure sustainable development in this micro region, giving the exploration of natural objects and phenomena a great importance for spatial planning.

Beside it's morphological excellence this mountain massif represents the area of the greatest diversity of geological and pedological formations in the Pannonian part of Serbia.

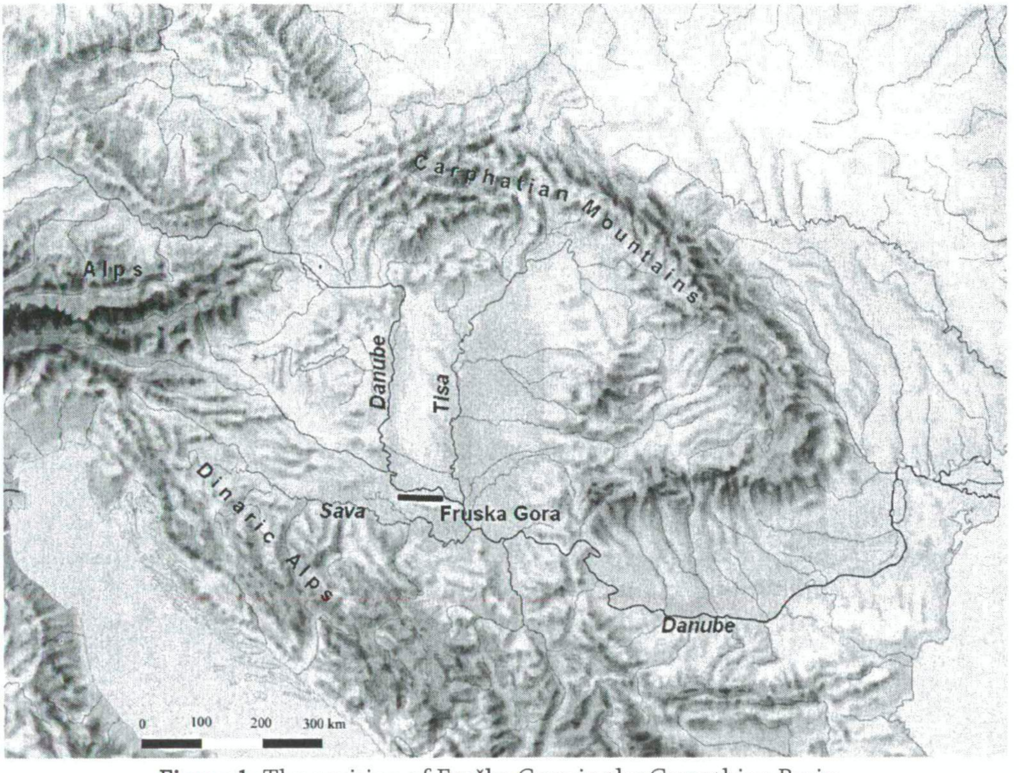

Figure 1. The position of Fruška Gora in the Carpathian Basin
(based on map by László Zentai)

The geological and geomorphological characteristics of Fruška Gora have been intensely studied from the second half of 19th century. Researchers had already noticed a great variety of geological formations of Fruška Gora (WOLF, 1861; KOCH 1871, 1876, 1896; LENZ, 1872; ROCHLITZER, 1877, after PETKOVIĆ et al., 1976.).The most prominent researchers of Fruska gora from this period were A. Koch, who published numerous works about the geologic composition of the mountain and was a devoted explorer of Fruska gora, establishing the foundation for modern studies with his book "A Fruska Gora geológiája" (Budapest, 1895), H. WOLF and O. LENZ whose findings contributed greatly to A. KOCH's works, M. KISPATIC with many valuable petrologic analyses.

The most important studies about geology, relief, hidrology, climate and pedology of Fruška Gora made by MILIĆ (1973), PETROVIĆ et al. (1973), MILOSAVLJEVIĆ et al. (1973), PETKOVIĆ et al. (1976), KNEŽEVIĆ (1995/97), MILJKOVIĆ (1973, 2001) and MARKOVIĆ et al. (2001).

All these works provided a detailed, but fragmented and unsystematic knowledge about the natural characteristics of Fruska gora. A comprehensive monograph about the physical geography of Fruska gora was published by Matica srpska from 1973. The monograph consists of 5 books dealing with geologic and tectonic structure, geomorphology, climate, waters and soils of Fruska gora, containing the summary of results of previous studies corrected or extended with the newest findings.

Geologic and tectonic characteristics

The geologic composition of Fruska gora is very complex. The soil and vegetation that cover almost the entire mountain greatly reduce the possibilities of direct observation. Some geologic features can be recognized in open profiles of quarries, uncovered loess profiles, clay mines, and valleys of water streams, especially if they contain fossils. Tectonic movements and metamorphism have changed the original position and constitution of rocks in many places, especially in central parts of the mountain, which makes reconstruction nearly impossible.

The base of the mountain consists of highly metamorphosed probably Paleozoic-aged rocks represented with green schists and phyllite, which reach the surface along the ridge. In the absence of paleontological find from the Paleozoic period, it is difficult to date these rocks in the core and ridge of the mountain.

Mesozoic sediments occupy smaller area, and are generally thinner. Mesozoic is represented with Triassic red and gray sandstones and mica schist, reddish lime stones, conglomerates and breccias, and cretaceous sandstones, conglomerates, lime stones, dolomites and flisch rich in some of the oldest fossils on the mountain.

Tertiary sediments cover large surfaces on the peripheral area of the mountain and are represented with marl, sandstones, and conglomerates.

Quaternary sediments are represented with thick loess cover, which can be found in the lower parts of the mountain and alluvial sediments, gravel and sand.

Magmatic rocks can be found around the tectonic faults, in forms of intrusions in Mesozoic and Cenozoic sediments, and both effusive forms - submarine/sublacustric and continental, and finally in form of tuff. These rocks date from Paleozoic, Triassic, Cretaceous and Tertiary period, and are represented with gabbros, diabase, trachytes which are being intensively mined in quarries for building material. One of the disputed environmental questions is related to a quarry near the Ledinacko Lake, which was formed during the process of exploitation. Further mining could damage the unique ecosystem around the lake and pollute its waters, and destroy its touristic potential.

Fruska gora is the easternmost representative from a range of low, isolated, hilly island-mountains (e.g. Papuk, Psunj) in Slavonia, Croatia, continuing southwards to the mountains of Sumadija in central Serbia (PETKOVIC, 1952).

Common to these various mountains are their E-W orientation, Paleozoic crystalline core with serpentine, magmatic intrusions along tectonic faults, their similar geologic composition consisting of Paleozoic, Triassic, Jurassic and upper Cretaceous layers covered with quaternary sediments. Questions were raised about the place and role of these mountains in the Alpine orogene.

According to one view, the Fruska gora and other mountains in this range belong to the Alpine system. More recent explorations of the Pannonian-basin support the view that the Fruska gora can be grouped in the Dinaric-Alpine system.

The formation of Fruska gora began in the upper cretaceous period, when a horst started to emerge from the surrounding terrain, which was subjected to tectonic sinking. The anticline core of the horst started to form between the Austrian and Savic phases in the Alpine orogene. From the early Miocene, a series of transgressions and regressions combined with epeirogenic movement and tectonic faulting exposed the mountain to erosion. Finally in the period of late Pleistocene and the beginning of Holocene loess and alluvial sediments were deposited and during this time an epeirogenic arch was formed, with its axis orthogonal to the sides of the anticline in the basis of the mountain.

Climate conditions

The climate of Fruska gora, as an isolated mountain significantly differs from its surroundings, and modifies the local meteorological conditions. Although the mountain is low, the wooded slopes and the E-W direction of the ridge influence the passing air masses greatly.

Table 1. Mean monthly and annual temperature for meteorological stations Petrovaradin and Iriski venac for the period 1968-1980
(source: Climatological Yearbooks for period 1968-1980)

Month / T(°C)	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yr.
Petrovaradin	1.1	3.5	7.7	11.3	16	19.9	21.3	20.9	16.9	11.5	6.4	2.5	11.7
Iriski venac	-0.7	0.3	4	10.2	14.7	18.3	20.3	20.5	17	11.4	4.9	1.5	10.2

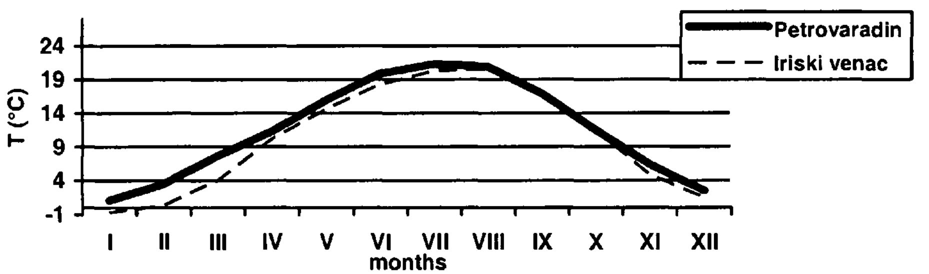

Figure 1. Mean monthly temperature for meteorological stations Petrovaradin and Iriski venac for the period 1968-1980 (source: Climatological Yearbooks for period 1968-1980)

Humid air masses coming from NW supply the northern part of the mountain with much higher annual precipitation compared to the surrounding lowlands. The strong SE winds called Kosava diverge on the eastern edge of the mountain, losing their intensity.

The temperatures fall according to increasing height. The following figures illustrate the climatic conditions by comparing lower parts of the mountain (Petrovaradin at 80 m) with higher parts (Iriski venac at 444 m)

Some of the typical problems arising from the climate influence on Fruska gora are soil erosion, landslides, and air pollution from the cement Factory in Beocin. The problem of air pollution from the cement factory is caused by the misplacement of heavy pollution emitting objects in the vicinity of nearby settlements. The planners did not consider the prevailing wind directions, which carries and deposits the fine dust from the factory on the settlements. This represents a great health hazard for the local population, and degrades the environment.

Table 2. Mean monthly and annual precipitation for meteorological stations Petrovaradin and Iriski venac for the period 1968-1980

(source: Climatological Yearbooks for period 1968-1980)

Month / mm	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Yr.
Petrovaradin	32	34	33	47	59	79	53	69	44	52	47	36	598
Iriski venac	64	69	52	64	89	91	65	48	45	48	74	79	788

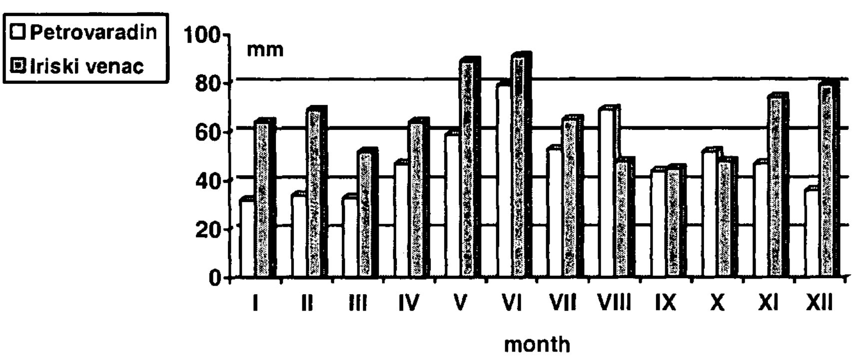

Figure 2. Mean monthly precipitation for meteorological stations Petrovaradin and Iriski venac for the period 1968-1980

(source: Climatological Yearbooks for period 1968-1980)

Hydrology

Fruska gora is a water rich mountain. Numerous drainage valleys dissect the surface from the vicinity of the ridge to the base of the mountain and a multitude of springs indicates an abundant groundwater. 28 streams can be found on the northern and 14 on the southern side of the mountain. On the steeper northern slopes the valleys are deeper, shorter and some streams reach the Danube, and other re-appear as concentrated or dispersed springs in places where the river uncovered the contact zone of collector and impermeable rocks.

On the southern slopes these valleys are longer and the water often disappears in the thick loess cover at the base of the mountain. Many of them end in a marshy terrain, which is submerged throughout the whole year. These small lakes and marshes are being fed from the uncovered shallow groundwater collectors.Some of these brooks were transformed to lakes by building dams (Lake Borkovac, Mutalj).

The springs in Fruska gora have three types of flow rate: constant springs flow all year, regardless of precipitation, and their flow rate depends from groundwater levels. The periodical springs flow only after long and heavy rainfalls or more often in the spring fed by the melting snow. The occasional springs flow from limestones after very heavy rain combined with melting snow, and depends from the internal water circulation in the collector environment.

Four levels of spring zones can be distinguished: the highest occurs near the ridge at the altitude of 420 m, and the lowest at 280 m. The general characteristic of these springs is their stable flow rate between 1-5 l/min. Also the temperatures are unchanging and are between 8-10 °C (5, 54)

There are 3 only springs in Fruska gora, which can be defined as thermal water (with water temperature higher than the mean annual air temperature). One thermo-mineral spring was accidentally opened near the Vrdnik coal mine, when a karst cavern was uncovered during prospective exploration. The karst groundwater forms in Mesozoic lime stones covered and enclosed in a barrier of tertiary sediments and infiltrates under great pressure in the surrounding terrain feeding the deeper horizons of groundwater. The Vrdnik thermo mineral spring has a temperature of 24 °C and a stable flow rate of 3-5 l/s (5, 24). The other two thermal springs are located near Stari slankamen (18,5 °C) and the monastery Staro Hopovo (18,5°C). The later flows from a contact zone of Paleozoic schist and magmatites, and has a high sulfur and iron content. (5, 25)

Geomorphology

Today's surface of Fruska gora is a result of a very complex interaction of endogenic and exogenous forces. The first striking feature of the mountain shape is the asymmetric N-S profile: the northern slope is much steeper and much more eroded. The Fruska gora massif forces the flow of Danube to turn from N-S direction to the east. The flow slowly undermines, erodes the northern parts of the mountain, causing landslides. The southern slope is more moderate, and disappears seamlessly in the Srem loess plateau.

The remains of the initial relief can be observed above 400 m. This terrain is surrounded nearly concentric surfaces. The first is situated between 420-440 m and represents a fluvial surface, because no littoral sediments were determined. The surface between 360-380 m is carved in crystalline schist, and its origin cannot be determined with certainty. The absence of littoral material suggests a fluvial genesis. The surfaces between 310-340 m, 240-270 m and 200-220 m have fluvial origin. The lower surfaces have been covered with loess during the Pleistocene. (2, 35-36) Numerous valleys dissect the surface of the mountain. The fact that none of the valleys reach the ridge and cross to the opposite slope suggests that these erosive forms are relatively young. B. BUKUROV (1952) determined three types of valleys. The valleys of brooks emerging near the ridge constitute the first type. They are deeply carved in the initial surface. The valleys of second type start from the middle surfaces ranging from 310 m, and are carved in younger sediments. Valleys formed in the loess cover at the base of the mountain belong to the third type.

The valleys on the steeper northern slope end often in alluvial deposits, in contrary to the southern side, where such forms are less prominent, but would be expected due to greater temperature amplitudes on the southern exposition and the process of stone crumbling. This shows that the climate has only limited influence on the forming of accumulative forms, and that the steepness of relief played a primary role in forming the recent accumulative forms.

Large areas are covered with aeolic sediment – loess, accumulated periodically during the glacial phases in the Pleistocene. The warmer interglacials have left a mark in form of fossil soils in loess. However, the increased erosion, re-accumulation and tectonic movements complicate the reconstruction of this process.

Landslides represent the greatest problems in construction, transport that arise from recent geomorphologic processes, and require close monitoring.

The Important Localities of the Geo-heritage of Fruška Gora

The geo-heritage sites of Fruška Gora are selected on the following criteria:

Scientific importance, educational significance, degree of preservation, aesthetic attraction, and approachability for visitors (MIJOVIĆ-MILJANOVIĆ, 1999) The following facts are given for every selected locality: the ordinal number, name/toponym, a short description and the value level. Their position is shown in **Fig. 3.** with the appropriate numbers from the table.

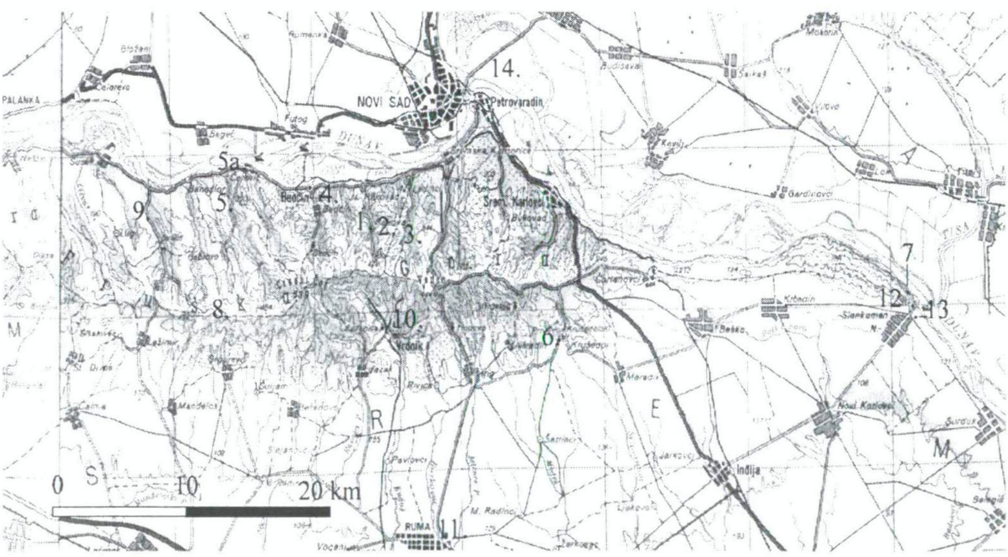

Figure 3. Geo-heritage sites on Fruška Gora

All the listed geo-heritage sites of Fruška Gora are *in situ*, and under a different degree and regime of protection (some sites are not protected at all), level of management and facilities of aesthetic qualities and distance from the existing traffic lines.

All these things indicate that it is necessary to put the selected geo-heritage sites under the appropriate degree of protection, management and to label them with informative boards, and to connect them separately with the unique geo-path for tourist visits.

The appropriate propagandistic material should be made, therefore the public would be informed about their importance.

The special part of the geo-heritage of Fruška Gora includes two important collections of material evidence, fossils, rare rocks and minerals collected on the sites of the geo-heritages of Fruška Gora.

Collected from the natural ambient, one part of these scientific proofs is in the geosite section in the custody of the Institute for Protection of Nature of Serbia, Department of Novi Sad, and the other part is in the collection of Cretaceous fossils in the Country Museum of Čerević. These collections serve for scientific researches and indeed they contribute to promotion of the selected geo-heritage sites.

Precious documentation-profiles, maps, drawings of the geological labyrinth Vrdnik, as well as numerous objects that keep the memory of long miner tradition are in rooms of RMU "Vrdnik" in Vrdnik.

The most important features of the geo-heritage sites of Fruška Gora are their scientific and educational importance. These sites, formed during different geological periods, ranging from the Paleozoic to Quaternary (PETKOVIĆ et al., 1976) represent the history of the creation of Pannonian (Carpathian) basin.

It should be pointed out also that their significance, in the system of all the geo-sites of Pannonian geotectonic unit, moves from local Grgurevačka cave, speleologic site of average dimensions (PETROVIĆ, 1968) to European – locality Čot near Stari Slankamen which represents one of the most important Middle

Pleistocene loess-paleosol site on our continent (BRONGER, 1976, 2003; MARKOVIĆ-KUKLA, 1999; MARKOVIĆ et al., 1998, 1999).

The given preliminary list of the geo-heritage sites of Fruška Gora is not concluded and future geo-scientist researches will mark new localities such as the IGM "Ruma" eastern open clay-pit, where 8 skeletons of Middle Pleistocene bears of *Ursus deningeri* were discovered in 2000 (MARKOVIĆ et al., 2001, in press).

Great scientific and educational importance, solid aesthetic quality and a good position from the existing net of traffic lines suggest the important tourist potential of the geo-heritage of Fruška Gora.

When the positions of the shown geo-heritage sites are analyzed, it can be noticed that they are near other natural and anthropogenic tourist sites of Fruška Gora, i.e. on the tourist paths that had already been established.

Table 3. The preliminary list of the geo-heritage sites of Fruška Gora mountain

E: European; **B**: Balcanic; **N**: National; **L**: Local

N°	The geo-heritage site	The description of locality	The value level
1.	The locality of volcanic tufa, Galerija near Rakovac	8 m thick layer of tufa interstratificated into Miocene-Tortonic sediments. The monument of Nature from 1982.	N
2.	The stone-pit of trachyte Kišnjeva Glava	Trachyte dyke injected into Cretaceous sandstone and flysch. The height of steep slopes up to 80 m.	L
3.	The stone-pit of trachyte, Srebro near Ledinci	Deserted stone-pit where the lake of great aesthetic qualities was formed. Steep slopes high up to 110 m.	L
4.	The paleontological site of Miocene marine fossils, Filijala near Beočin	Upper-Miocene-Pannonian sediments that consist of rich marine fauna. Classified in the sites for establishing the age of sediments in the Tethys area.	B
5.	The paleontological site of Cretaceous marine fossils in Čerević	The most complete succession of Upper-Cretaceous sediments. Fossil remains of orbitalinids, corals, worms, brachiopods and gastropods.	N
5a.	The collection of Cretaceous marine fossils in Čerević	The collection represents the richest Maastrichtian fauna in former Yugoslavia (127 species).	N
6.	The paleontological site miopliocenic fossils, Grgeteg	The sediments of Sarmat, Pannon and Upper Pont with rich marine fauna of mollusks. More than 40 species have been fortified, and twelve of then are in our country for the first time.	B
7.	The structural paleontological site of Neogene fossil marine snails near Stari Slankamen	The Pannonian sediments are placed discordantly and transgresively across the Badenian lime stones. The numerous shells of fossils marine snails.	N
8.	Grgurevačka cave	A unique gomorphological object in Vojvodina province.	L
9.	A gorge-like part of Almaš brook valley	Composite valley formed in the lower course of brook (of around 100 m) sediments.	N
10.	Vrdnik basin	The geologic treasury that consist of 26 vertical miners pit deep up to 280 m and with cores from drilled wells.	N
11.	Loess exposure of brick factory in Ruma	Around 20 m thick loess exposure with detailed evidence of paleogeographic events during the last 350.000 years. Huge Pleistocene mammals – *Mammuthus primigenius* and *Ursus deningeri*, are found in quarry of local brick factory.	B
12.	The exposure in loess valley situated between Stari Slankamen and Novi Slankamen	The only protected loess exposure in Serbia	N
13.	Loess exposure Čot in Stari Slankamen	40 m thick exposure with 10 paleosols layers where precious paleoclimatic and paleoecological evidence of Middle and Upper Pleistocene are preserved.	E
14.	The geological collection of the Institute for Protection of Nature of Serbia, Department of Novi Sad	The richest natural collections in Vojvodina province are: the collection of cores from deep drilled wells for petroleum investigations, the collection of paleofauna from the area of Fruska Gora (localities: Grgeteg, Čerevićki potok, Bukovac...), the collection of paleoflora from the localities Vrdnik and Janda, the collection of fossil remains of Pleistocene vertebrate, mineralogical and petrological collection from numerous localities in Fruška Gora and Vršačke mountains	N

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