

KARST RESEARCH INSTITUTE ZRC SAZU



INQUA Section on European Quaternary Stratigraphy

Quaternary Stratigraphy in Karst and Cave Sediments



PROGRAM & ABSTRACTS & GUIDE BOOK

Postojna, 2018

INQUA Section on European Quaternary Stratigraphy

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Postojna
2018

Editors:

Nadja Zupan Hajna, Andrej Mihevc, Magdalena Năpăruș-Aljančič

Issued by:

Karst Research Institute, Scientific Research Centre of the Slovenian Academy of Sciences and Arts, Titov trg 2,
6230 Postojna, Slovenia

Published by:

ZRC Publishing

Represented by:

Oto Luthar

Printrun:

100

Organizing committee:

Andrej Mihevc, Markus Fiebig, Nadja Zupan Hajna, Petra Jamšek Rupnik

Supported by:

Scientific Research Centre of the Slovenian Academy of Sciences and Arts
INQUA Commission on Stratigraphy & Chronology (SACCOM)
INQUA Section on European Quaternary Stratigraphy (SEQS)
SINQUA Slovenian National INQUA Committee

Cover photo:

Sediment section in Markov spodmol (A. Mihevc)

Printed by:

Cicero Begunje, d. o. o.

First edition, first printrun.

Postojna 2018

CIP - Kataložni zapis o publikaciji
Narodna in univerzitetna knjižnica, Ljubljana

551.44(082)
551.7"628.6"(082)

Quaternary Stratigraphy and Karst and Cave Sediments: program, abstracts
& guide book/ [editors Nadja Zupan Hajna, Andrej Mihevc, Magda Aljančič]. -
Ljubljana: ZRC Publishing, 2018

ISBN 978-961-05-0111-4
1. Zupan Hajna, Nadja
296246272

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PROGRAM

SEQS _ Quaternary Stratigraphy in Karst and Cave Sediments

Karst Research Institute ZRC SAZU, Titov trg 2, Postojna, 12 – 17 September 2018

TUESDAY, September 11

12.00-18.00 Registration of participants

WEDNESDAY, September 12

08.00-12.00 Registration of participants

OPENING SESSION

08.30-08.45 Opening

08.45-09.00 **Mihevc A.:** Karst – formation, morphology and sediments on examples from Slovenia

SESSION 1a: Karst and Cave sequences

09.00-09.15 **Zupan Hajna N., Mihevc A., Bosák P. & Pruner P.:** Cave sediments and their research in Slovenia

09.15-09.30 **Häuselmann P.:** Nothing IS possible - An introduction to stratigraphical studies in caves

09.30-09.45 **Bosák P. & Pruner P.:** Paleomagnetism and magnetostratigraphy: useful tool in analysis of karstogenesis

09.45-10.00 **Vrabec M., Pruner P., Zupan Hajna N., Mihevc A. & Bosák P.:** Neotectonic vertical-axis rotations in the Adria-Eurasia collision zone revealed from Paleomagnetic data of Pliocene-Quaternary cave sediments (Slovenia)

10.00-10.15 **Westaway R.:** Late Cenozoic uplift history of the Peak District, Central England, inferred from dated cave deposits and integrated with regional drainage development

10.15-10.45 Coffee break

10.45-11.00 **Bočić N.:** Some examples of cave sediments from Croatian karst

11.00-11.15 **Danukalova G., Yakovlev A., Kosintsev P., Kurmanov R., Osipova E., Yakovleva T., Sokolov Y., van Kolfschoten Th.:** Quaternary cave deposits of the Southern Uralian region (Russia)

11.15-11.30 **Sobczyk A., Szczygieł J., Kasprzak M., Stefaniak K., Marciszak A., Bosák P.:** Polyphase evolution of the karst system of the Jaskinia Niedźwiedzia Cave (Sudetes, SW Poland) – a review

11.30-11.45 **Gerasimenko N., Ridush B. & Avdieienko Yu.:** Late Pleistocene and Holocene environmental evolution on the Crimean karst plateau: palynology, palaeontology and lithology from the Emine-Bair-Khosar cave sequence

11.45-12.00 **Pawlak J., Błaszczuk M. & Hercman H.:** Last interglacial climate variability observed in stalagmites from Central and South Eastern Europe

12.00-12.15 **Hercman H., Błaszczuk M., Sierpień P., Gąsiorowski M., Pawlak J., Bosák P., Matoušková Š., Pruner P., Zupan-Hajna N. & Mihevc A.:** Climate change at Brunhes-

Matuyama boundary: multi-proxy record from flowstones from the cave Račiška pečina (SW Slovenia)

12.15-12.30 Błaszczyk **M.** & Hercman **H.**: Paleoclimate conditions from MIS 9 to MIS 7 in The Tatras recorded in stalagmite from Szczelina Chochołowska Cave

12.30-14.30 *Lunch break*

14.30-17.00 Visit of the cave Postojnska jama (walk from the Institute – **start at 14.30**; train at 15.00 exact! tourist cave, walking shoes)

SESSION 1b: Karst and Cave sequences

18.00-18.15 Horáček **I.**, Fejfar **O.**, Ložek **V.**, Čermák **S.**, Wagner **J.**, Knitlová **M.** & Hošek **J.**: Early-Middle Pleistocene transition in Central Europe in a high-resolution record of karst deposits

18.15-18.30 Ridush **B.**, Stefaniak **K.**, Nadachowsky **A.**, Ratajczak **U.**, Socha **P.**, Popiuk **Y.**, Ridush **O.** & Nykolyn **O.**: Pleistocene fauna of the Emine-Bair-Khosar Cave (Crimea, Ukraine): new data

18.30-18.45 Avdieienko **Yu.**, Gerasimenko **N.** & Ridush **B.**: Paleontological and lithological study of the Kryshtaleva cave (Ukraine)

18.45-19.00 Khenzykhenova **F.**, Erbajeva **M.**, Alexeeva **N.**, Shushpanova **G.** & Tumurov **E.**: The Late Pleistocene-Holocene Cave Small Mammal Fauna of the Fore-Baikal Area (Baikal region)

19.00-19.15 Fadeeva **T.** & Kosintsev **P.**: Mammal remains from Makhnevskaya ledyanaya cave (Perm Pre-Ural, Russia): biostratigraphic reconstruction

19.15-19.30 Gimranov **D.** & Kosintsev **P.**: Quaternary large mammals from the Imanay Cave

19.30-19.45 Križnar **M.**: Cave bears (*Ursus spelaeus* s.l.) in Slovenia: sites, species and datings

THURSDAY, September 13

SESSION 2: Quaternary stratigraphy, geomorphology and tectonics

09.00- 09.15 Schokker **J.** & Busschers **F. S.**: Stratigraphy of Eemian deposits near the classic type locality at Amersfoort (NL)

09.15-09.30 Susini **D.** & Pieruccini **P.**: The skin of Quaternary: Meghalayan stratigraphy and land use in small karst basin (Southern Tuscany, Italy)

09.30-09.45 Mencin **Gale E.**, Jamšek **Rupnik P.**, Trajanova **M.**, Bavec **M.**, Anselmetti **F.S.** & Šmuc **A.**: The Plio-Quaternary fluvial archives in the Slovenj Gradec and the Nazarje Basin, Northern Slovenia

09.45-10.00 Ferrarese **F.**, Palumbo **L.** & Fontana **A.**: Morphometric study of the epikarstic landforms of the western Karst (Italy) through the analysis of LiDAR derived data

10.00-10.15 Toker **M.** & Tur **H.**: 3D near-surface basin modelling and faulting styles of the Lake Erçek Basin, Eastern Anatolia (Turkey), from high-resolution seismic reflection images

10.15-10.30 Trifonov **V.G.**, Simakova **A.N.**, Çelik **H.**, Shalaeva **E.A.**, Aleksandrova **G.N.**, Trikhunkov **Ya.I.**, Frolov **P.D.**, Zelenin **E.A.**, Tesakov **A.S.**, Bachmanov **D.M.**, Latyshev **A.V.**, Sokolov **S.A.**: Brackish-water Caspian-type Upper Pliocene deposits in the

western Shirak Basin (NE Turkey), applied to estimation of the Quaternary uplift of the Lesser Caucasus

10.30-11.00 Coffee break

SESSION 3: Assessing chronology of Quaternary deposits by Radiometric dating and Pedostratigraphy, Magnetostratigraphy and Lithostratigraphy

- 11.00-11.15 **Lefort J-P., Dergacheva M.I., Danukalova G., Monnier J-L., Osipova E. & Bazhina N.:** Evidence for five short “warming” episodes during MIS 6 at the westernmost tip of continental Europe: Contribution of pedogenesis
- 11.15-11.30 **Stolpnikova E. & Kovaleva N.:** Biomarkers and paleolandscape indicators in early Pleistocene mountain soils and pedolithic sediments in the Caucasus
- 11.30-11.45 **Sanko A.F., Koloshich S.M. & Dubman A.V.:** Key-sites of the Belarus Upper Pleistocene
- 11.45-12.00 **Krokhmal A.:** Reference sections of the paleofaunal subdivisions of the Early Pleistocene (Eopleistocene) in the South of Eastern Europe (on the basis of small mammals)
- 12.00-12.15 **Kotowski A., Sobczyk A., Borówka R. K., Badura J., Stachowicz-Rybka R., Moskal-del Hoyo M., Hrynowiecka A., Alexandrowicz W. P., v. d. Made J., Shpansky A. V. & Stefaniak K.:** *Stephanorhinus kirchbergensis* from Gorzów Wielkopolski (Poland) – its significance in research on Polish Eemian Interglacial
- 12.15-12.30 **Tsydenova N.:** Late Pleistocene – Holocene transitional complexes in the Trans-Baikal region: stone industries and oldest ceramics

12.30-14.30 Lunch break

SESSION 4: Major regional subdivisions of the Quaternary in European and Asian regions: toward a common data-base (DATESTRA)

- 14.30-14.45 **Gerasimenko N.:** The candidate sections for DATESTRA from the North-Eastern Ukraine
- 14.45-15.00 **Lasberg K.:** Pleistocene stratigraphy key-sites of Estonia in DATESTRA
- 15.00-15.15 **Šeirienė V.:** Pleistocene stratigraphy and key sites in Lithuania
- 15.15-15.30 **Ponomarev D.:** Quaternary key sections in the north of European Russia – a contribution to DATESTRA
- 15.30-15.45 **Titov V.V., Tesakov A.S., Simakova A.N., Frolov P.D., Borisova O.K., Panin P.G., Timireva S.N., Konov Yu.M. & Syromyatnikova E.V.:** Key sections of Pleistocene continental deposits from North-Eastern Sea of Azov region
- 15.45-16.00 **Khenzykhenova F., Kradin N., Prokopets S., Simukhin A., Imenokhoev N., Namzalova O. & Namsaraeva S.:** The Art of the Hunnu Ivolsky Settlement (Baikal Siberia)
- 16.00-16.15 **Marks L.:** An input of key sites in Poland to the European stratigraphy
- 16.15-16.30 **Sobczyk A., Pitura M., Badura J. & Stefaniak K.:** Poland during the Eemian (MIS 5e) stage: a project of the Web GIS interactive database

16.30- 16.45 Coffee break

POSTER SESSION

16.45-17.30 **Poster presentations** (3 minutes/poster)

1. **Borodin A., Tiunov M., Strukova T., Zykov S.:** New finds of *Mimomys* in the Late Pleistocene cave deposits in Russia
2. **Izvarin E. P & Ulitko A. I.:** Stratigraphical and paleotheriological description of Holocene sediments from Nizhneirginsky grotto (middle Urals)
3. **Kirillova I., Borisova O., Chernova O., van Kolfshoten T., van der Lubbe J., Panin A., Pečnerová P., van der Plicht J., Shidlovskiy F., Titov V. & Zanina O.:** Small mammoth from the Eastern Siberian Sea coast (Russia)
4. **Korsakova O. & Lavrova N.:** Neopleistocene (Middle and Upper Pleistocene) stratigraphy and applicable key points in the Karelia, N-W Russia
5. **Kosintsev P. A. & Bachura O. P.:** Chronostratigraphy of sediments in the Ural caves
6. **Maciejewski M., Sobczyk A. & Szczygiał J.:** 3-D structural model of the Niedźwiedzia Cave (Sudetes, SW Poland) karst system
7. **Makoś M. & Sobczyk A.:** Using a 3D model for visualisation of the Quaternary deposits within glacial cirque – a case study from the Łomniczka Valley, Eastern Karkonosze Mts.
8. **Pitura M. & Sobczyk A.:** Paleoglaciological record of the Scandinavian Ice Sheet advance during Mid-Pleistocene glaciation in Central Europe (Sudetes, SW Poland): an interplay of local topography and Quaternary stratigraphy reassessed
9. **Polak S.:** First evidence of Barbary macaque (*Macaca sylvanus* Linnaeus, 1758) (Primates, Cercopithecidae) from Pleistocene sediments in Slovenia
10. **Ratajczak U., Stefaniak K., Kotowski A. & Shpansky A. V.:** *Bison priscus* skull from the Eastern Europe and Siberia
11. **Rychel J., Woronko B. & Honczaruk M.:** Relict of Pleistocene permafrost in North-Eastern Poland – one of the proposal for datestra
12. **Sierpień P., Hercman H., Bosák P., Pruner P., Zupan-Hajna N. & Mihevc A.:** The paleoclimate reconstruction of Pliocene–Pleistocene transition: oxygen and carbon stable isotopes from flowstones in the cave Račiška pečina (SW Slovenia)
13. **Stefaniak K., Ratajczak U. & Kotowski A.:** Stratigraphic significance of Polish Pliocene and Quaternary deer
14. **Zambaldi M., Angelucci D. E. & Arzarello M.:** Rethinking stratigraphy and site formation processes of the Ciota Ciara Cave (Monte Fenera, Italy)
15. **Zaretskaya N.E., Panin A.V., Molod'kov A.N., Trofimova S.S. & Baranov D.V.:** Pleistocene chronostratigraphy and key-sections of the Vychegda River Basin (European North-East)
16. **Zykov S.V. & Izvarin E.P.:** Variations in yellow-necked mouse (*Apodemus flavicollis* Melch., 1834) dental morphologies of the Nizhneirginsky Grotto sediments (Middle Urals) in a phylogeographical context

Posters

Poster size: max. format is 70 cm x 100 cm (width x height, **portret layout**).

Each author(s) should prepare a **2-3 minute presentation** where the essence of their poster is presented. These short presentations will be presented at Poster session.

Stand by your poster during the poster display.

FRIDAY, September 14

8.30-19.00 **Field trip:** Classical karst: caves Škocjanske jame, Črnotiče Quarry and Socerb

Start: bus station in Postojna.

Bus & walk: tourist cave, karst surface; walking shoes, umbrella or rainproof coat.

Lunch is provided.

Dinner & Overnight: in village of Divača; shared rooms in 2 guesthouses & breakfast.

SATURDAY, September 15

8.30-20.00 **Field trip:** Contact karst of Matarsko podolje: Odolina blind valey, caves Račiška pečina and Ulica pečina

Start: in Divača.

Bus & walk: easy short caves, karst surface; lamp/light, walking shoes, umbrella or rainproof coat.

Packed lunch is provided.

Dinner & Overnight: in Topolščica Spa; shared rooms in hotel & breakfast.

SUNDAY, September 16

8.30-18.00 **Field trip:** Alpine cave Snežna jama

Start: in Topolščica Spa.

Bus & walk: visit of managed ice cave through steep entrance across the ice and inner, warm part of the cave; lamp/light, walking shoes, umbrella or rainproof coat

Packed lunch is provided.

Dinner & Overnight: in Topolščica Spa; shared rooms in hotel & breakfast.

Farewell dinner and free swimming.

MONDAY, September 17

8.00-18.00 **Field trip:** Sedimentary environments of Ljubljana Basin

Start: in Topolščica Spa.

Bus & walk: cave Arneževa luknja, Sava fault and river terraces of Tržiška Bistrica young glacial till and fluvioglacial fill in Sava valley, glacial valley Vrata and North wall of Triglav (2864 m); walking shoes, umbrella or rainproof coat.

Packed lunch is provided.

Return to Postojna.

Participation at the excursions is at your own risk!

The organisers do not accept any liability for any loss, damage, injury or death arising from or connected with the excursions. Participants are advised to arrange an appropriate insurance policy. The participants are obliged to comply with the instructions of the organizer.

Lamp/Light is necessary if written. Organizer will provide few lamps, but if you have your own, please bring it with you.

Use of **insect repellents** is highly recommended because of ticks (possible infection with Lyme boreliosis and tick-borne encephalitis).

ABSTRACTS*

* In alphabetical order

Paleontological and lithological study of the Kryshtaleva cave (Ukraine)

Avdieienko Yu.¹, Gerasimenko N.¹ & Ridush B.²

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Session 1: Oral

The Kryshtaleva Cave is located near the Nyzhnye Kryvche village (the Ternopil region) on a narrow plateau between the valleys of the left tributaries of the Dniester River. The cave is worked out in the Miocene gypsum strata overlain by limestones. The cave labyrinths near the entrance are filled out almost completely with allochthonous loamy deposits. Remains of the Late Pleistocene (*Lepus timidus*, *Ochotona pusilla*, *Vulpes lagopus*, *Rangifer tarandus*) and Holocene fauna were found in the cave (Bachynskyi & Tatarinov 1996), but their stratigraphical position was not known.

The new section is studied in the vertical gallery (1 m in width) which forms the entrance to the Serednya-2 tunnel of the cave. The chronostratigraphic subdivision of the section (3 m in thickness) is based on ¹⁴C date 12,240±70 yrs (POZ-59413) obtained on the *Ursus arctos* bones (Ridush 2014), and ¹⁴C-dates 11,710±60 (Poz-51431), 11,890±60 (Poz-51430) yielded from charcoal (Nadachowski *et al.* 2015). The obtained pollen data indicate that the cave infilling was formed during the end of the Middle Pleniglacial, the Late Pleniglacial, the Late Glacial and the Early Holocene. Grain-size study of the deposits has been also fulfilled in the section.

The sediments at the base of the section (depth interval 3.00-2.85 m) are represented by dark-brown loams (the content of particles <0.01 mm is the highest in the Pleniglacial deposits). The significant percentages (50%) of arboreal pollen (AP) and the complete absence of palynomorphs of arcto-boreal and arcto-alpine elements of vegetation indicate that these sediments were formed under an interstadial climate. The area around the cave was occupied by a boreal forest-steppe: light pine forests with an admixture of arboreal birches and meadow steppes. This interstadial might be related to the end of the Middle Pleniglacial (Vytachiv unit).

Higher up in the profile (depth interval 2.9-2.50 m), the AP drops significantly (8-17%) which indicates the existence of open landscapes. The very low percentages of pine pollen show that this tree did not grow in the area. It might be explained by the very cold climate, as the low pollen percentages of xeric herbs indicate that the aridity could not be the reason of deforestation. There existed a periglacial tundra-steppe with shrub forms of birches (*Betula fruticosa*, *B. nana*), mesophytic herbs, grasses and spore plants: Bryales, arcto-boreal and arcto-alpine species of club-mosses (*Lycopodium dubium*, *Diphazium alpinum*, *Lycopodiella inundata*). Such vegetation is typical for the onset of the cryohygrophytic phase of the Late Pleniglacial. The content of clay fraction decreases in these sediments to a half of its values in the underlying unit, though the content of coarse silt ("loess") fraction (0.01-0.05 mm) is not large (39.5-47.6%). It may indicate that an intensity of dust storms, which are usually typical for the periglacial zone, was not strong under the relatively wet climate.

In the depth interval 2.50-2.30 m, the phase with a milder climate was revealed by an increase in AP (30%) and the presence of spores from the plants growing in boreal and temperate climate (Polypodiaceae and *Lycopodium annotinum*). Meadow steppes dominated near the cave, light sparse woodland from *Pinus sylvestris* and *P. sibirica* occurred, and the role of cryophytes decreased significantly. The content of coarse silt further decreased balanced by an increase in fine silt (35.2-40.8%). The correlation of this phase with the formation of the Early Bug incipient soil is suggested.

The next phase of vegetational development (from the depth interval 2.33-1.42 m) represents the maximum spread of steppe. The steppe associations consist mainly of forbs and grasses, though a role of xerophytes (particularly *Ephedra*) increased noticeably. The arcto-boreal and arcto-alpine species (*Diphazium alpinum*, *Lycopodium dubium*, *Lycopodiella inundata* and, especially, *Botrychium boreale*) were an important part of the ground cover, and, thus, that indicates a tundra-steppe vegetation. A few arboreal hygrophytes (*Alnus glutinosa*, *Betula pubescens*, *Salix* sp.) grew alongside with dwarf birches (*Betula nana*) only in the wet relief depressions. Such hygrophytes as Cyperaceae, as well as ferns grew abundantly at the cave entrance. The findings of such faunal species as *Arvicola amphibius* (dominated), *Vanellus vanellus*, *Larus* sp., *Philomachus pugnax*, *Scolopax rusticola*, Anatidae, *Anser anser*, *Asio flammeus*, and Bufonidae (Ridush 2014) indicates the close location of the cave to water basins and bogs. An increase in input of sand fraction into the cave (30.0-36.8%) may indicate the occurrence of flashfloods. The miserable role of arboreal associations in the vegetation, the significant spread of cryophytes, as well as a significant proportion of large silt ("loess fraction") in the cave deposits reflects a periglacial climate. The increase in xerophytic plants enables to relate this time interval to the beginning of the cryoxerophytic phase of Last Pleniglacial, characterized by a decrease in moisture.

The beginning of the Late Glacial (^{14}C 12,240±70 yrs, the Bölling interstadial) is marked by an increase in AP (19%) and its diversity (*Picea*, *Pinus sibirica*, *P. sylvestris*, *Juniperus* sp., *Alnus glutinosa*, *Betula pubescens*), and the disappearance of cryophytes (only *Botrychium boreale* occurred rarely). The spread of forests occurred gradually, the grass-forb steppe dominated. Cyperaceae occupied relief depressions, and xeric herbs (*Ephedra*, *Artemisia* subg. *Seriphidium*) grew on disturbed soil substrata. The cave deposits became darker (as a result of the increase in humus), a role of coarse silt decreased (22.9-27.5%) balanced by the increase in small silt fraction (40.3-43.5%). It may indicate a decrease in intensity and frequency of strong dust storms, responsible for loess accumulation on the surface. A complete skeleton of a brown bear (*Ursus arctos*) and remains of a reindeer (*Rangifer tarandus*) were found in this unit.

The next unit (depth interval 0.95-0.75 m) is represented by a dark-grey material of colluviated humic soils with a significant admixture of charcoal and burnt gypsum (a cultural layer without artifacts?). The ^{14}C dates (11,710±60, 11,890±60 yrs BP) enables its correlation with the Allerød interstadial. The deposits have the high content of clay fraction (30.2-30.5%) and low content of coarse silt (13.3-27.5%). This unit has the highest AP percentages in the section (up to 60%), which includes predominantly *Pinus sylvestris*. Pollen of *Betula pendula*, *B. pubescens*, *Alnus glutinosa*, *Salix*, *Juniperus* and Ericaceae are present. There existed a boreal forest-steppe: meadow-steppe coenoses from diverse mesophytic herbs and pine forests with club-mosses and ferns in the ground cover. As opposite to the deep Dniester and Prut valleys (Bolikhovskaya 1995; Gerasimenko et al. 2014), broad-leaved trees did not grow on plateau of the eastern bank of the Dniester River.

The overlying unit (depth interval 0.55-0.65 m) is lighter in colour and less sandy than the Allerød unit. At the same time, the sediments are clearly laminated, that indicates the intense development of colluvial processes. The unit is marked by a sharp decrease in AP (10%), represented by *Betula pubescens*, *B. pendula*, and *B. sect. Nanae et Fruticosae*. The NAP sharply increases, especially due to Lactuceae pollen, which belong to meadow species and plants of disturbed substrata. Steppe of subperiglacial climate was a zonal type of vegetation. This enables the suggestion that this unit was formed during the Young Dryas stadial.

The last unit of dark humic heavy loams, strongly enriched in charcoal, is marked by the lowest content of coarse silt particles in the section (6.1%), and by the appearance of pollen of broad-leaved trees (<2%). Forests spread significantly (47% of AP). They consisted mainly of

Betula pubescens and *B. pendula* (which is typical of the Early Holocene) and diverse shrubs (*Corylus avellana*, Ericaceae, Caprifoliaceae and Malaceae) in the undergrowth. There existed a south-boreal forest-steppe. The steppe coenoses were mesophytic and included very diverse forbs. Pollen of xeric herbs was not found. This unit evidently is related to the Early Holocene.

Thus, a complex analysis of the allochthonous deposits of the Kryshtaleva Cave enables a characterization of different stages of environmental evolution in the cave environs.

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Paleoclimate conditions from MIS 9 to MIS 7 in The Tatras recorded in stalagmite from Szczelina Chocholowska Cave

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Session 1: Oral

Speleothems are the most interesting cave sediments in the context of paleoenvironmental reconstructions. Their formation is determined by the average rainfall, the mean annual temperature and vegetation changes near the cave and those conditions are being recorded. Moreover, speleothems are one of the few paleoclimate data sources from terrestrial environment that cover such long-lasting, usually continuous, periods of time. Their next advantage is the possibility of using them for precise dating by U-series methods.

In the presented research, speleothem from the Western Tatra Mountains region was sampled and studied in detail. In the karst rocks of Tatra Mts. (mainly wierchowa limestone series) the longest and the deepest caves in Poland were formed. To date, over 857 caves have been discovered in that region with a total length of over 133 km. The collected speleothem came from the Chocholowska Cave, which is the largest cave in the Chocholowska Valley (over 2300 m long).

The stalagmite found in the New Corridor is about 21 cm high and has about 10 cm diameter. The entire stalagmite had been described in detail and then various comprehensive

study methods were performed. Preparing a detailed macroscopic description of stalagmite, three growth discontinuities were found, as well as different types of calcite building the stalagmite were identified. The U-series dating and age-depth modeling allowed to determine the time of growth of the stalagmite between 323 and 232 ka, during the MIS 9 - MIS 7 (Marine Isotope Stage) and also allowed to distinguish two breaks in the deposition of the stalagmite successively around 289 and 243 ka. This older part of the stalagmite is separated from the much younger Holocene layers by a distinct discontinuity.

The complementary use of several different methods: oxygen and carbon stable isotopes analysis, microfacial analysis and analysis of trace elements content allowed to reconstruct the evolution of past climate conditions. Those multiproxy results are valuable source of information about temperature, precipitation, changes in vegetation intensity and soil activity prevailing in the analyzed time span, and it should be emphasized that these are the first comprehensive data of this type in area of Central and Eastern Europe. At the same time, the presented results are only the first stage of realization of the scientific project aimed at analyzing the paleoclimatic conditions prevailing in the periods from MIS 9 to MIS 6 in the Tatra and the Low Tatra Mts.

Acknowledgments The study was supported by M. Błaszczuk project funded by the National Science Centre, Poland (2016/23/N/ST10/00067) and by the bilateral mobility cooperation PAN-17-22 between Czech Academy of Sciences and Polish Academy of Sciences.

Some examples of cave sediments from Croatian karst

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Session 1: Oral

Karst in Croatia occupies about 50 % of the area (~ 28000 km²) and mostly belongs to the Dinaric karst. In addition to the well-known surface forms (karren, dolines, uvalas, poljes, etc), numerous caves have been found here. Their genesis and development have left many different cave sediments. Although the research of cave sediments in Croatia has not been conducted systematically, there is a large number of investigated sites, in particular from paleontological and archeological aspects. The emergence of these sediments and deposition environment were less explored. Nevertheless, cave sediments of various kinds have been recorded so far, and they belong to different deposition environments. Two recently recorded examples will be presented in this presentation. The first example is a few caves from the Velebit Mountain, where glacial and fluvio-glacial cave sediments have been recorded. Another example is from the northeastern edge of the Dinaric karst (Kordunski krš). Here, the erosion residues of fluvial sediments have been recorded in Dunjak Cave. Layers of the quaternary fluvial sediment vertically exchange with the flowstone layers. Both examples are valuable sources of data on paleoclimatic changes, but also about the conditions of speleogenesis.

New finds of *Mimomys* in the Late Pleistocene cave deposits in Russia

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Session 1: Poster

In the material obtained as a result of paleontological excavations in the Tetyukhinskaya Cave (Middle Sikhote-Alin, 44°35'N, 135°36'E) of Primorsky Krai (Russian Far East), three isolated teeth belonging to the representative of the genus *Mimomys* were found. All the discoveries of *Mimomys* were made in pits laid in the entrance grotto. All the pits were dug to the rocky bottom. On an isolated tooth of an Asian black bear (depth 40–50 cm), similar in preservation and colour to the *Mimomys* teeth, a radiocarbon date of 39874 ± 133 BP (NSK–850, UGAMS–21786) was obtained by accelerated mass spectrometry (AMS) (Kosintsev et al., 2016). Of all the radiocarbon dates obtained, this is the oldest. This is the second find of a representative of this genus in cave deposits in the Russian Far East. For the first time this genus was recorded in the region from the Late Pleistocene strata of the Medvezhyi Klyk Cave deposits (Tiunov et al., 2016).

From other small mammals in the sediments of these caves, bone remnants of the Siberian flying squirrel (*Pteromys volans*), Eurasian red squirrel (*Sciurus vulgaris*), Siberian chipmunk (*Eutamias sibiricus*), Korean field mouse (*Apodemus peninsulae*), brown rat (*Rattus norvegicus*), greater long-tailed hamster (*Tscherskia triton*), zokor (*Myospalax psilurus*), grey red-backed vole (*Craseomys rufocanus*), northern red-backed vole (*Clethrionomys rutilus*), wood lemming (*Myopus schisticolor*), reed vole (*Alexandromys fortis*), Maximowicz's vole (*A. maximowiczii*), tundra vole (*A. oeconomus*), and Mongolian vole (*A. mongolicus*) were found.

The presence of fauna at that time that were forest species and species that hunt mainly in open spaces shows the distribution of savannah-like landscapes typical of the outskirts of the mammoth steppe. A similar finding was made recently and in the Urals in the Bosonogaya Cave. In the early Holocene sediments, only one ml of *Mimomys* was found along with thousands of early Holocene small mammals. Near the cave for hundreds of kilometers there are no deposits of this age. . If the Early Pleistocene forms in the Altai (Serdyuk, Tesakov, 2006) are confined to the layers directly at the rock bottom of the cave and may be the remnants of the oldest deposits, the Late Pleistocene age of the deposits of the caves of the Far East Russia and the Holocene of the Urals, in which the remnants of *Mimomys* were discovered, is beyond doubt. The presence in the Late Pleistocene strata of representatives of the genus *Mimomys*, whose last finds were known only from the Middle Pleistocene, significantly increases the period of existence of this genus in individual refugiums. At the same time, we do not completely exclude the possibility of any redeposits or accidental drifts of bird tours to these caves. Perhaps subsequent studies of fossil fauna will solve this problem.

Acknowledgments This study was supported the Russian Foundation for Basic Research (projects 16-04-01625 and 18-04-00327).

Paleomagnetism and magnetostratigraphy: useful tool in analysis of karstogenesis

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Session 1: Oral

Cave sediments (flowstones and clastic sediments) represent very significant source of information on palaeomagnetic polarities and on rock-magnetic data as well (cf. White 1988; Ford & Williams 1989, 2007). The aim of application of paleomagnetic method was to determine the principal magnetic polarity directions in cave deposits, similarly to surficial ones, and to compare them with the Global Paleomagnetic Time Scale (GPTS; Cande & Kent 1995). Those dates serve for preparation of stratigraphic correlations of studied sections. Dating of cave sediments by the palaeomagnetic method is a difficult and sometimes risky task, as the method is comparative in its principles and does not provide numerical ages. Results from other numerical and correlated dating methods are therefore welcome.

Cave sediments are principally classified as allochthonous (transported to cave from surface) and autochthonous (generated inside caves – like: collapses, speleothems, organic deposits). In any case, cave clastic sediments cannot be classified as soils; they are special kinds of clastic sediments, but not product of soil-forming processes (interaction of rock substrate, climate, relief, organisms and time). Subsurface weathering connected with prolonged hiatuses were recorded only in few sites studied by us.

Cave deposits are developed in two facies – entrance and internal (Ložek & Kukla 1958). Due to its character, entrance cave facies was studied by paleomagnetic method not so often. The method has been broadly applied in the internal cave facies with often alternating clastic and chemogenic deposits and occurrence of suitable clastic petrologies (clays to silts). The character of cave fill deposition is highly dynamic with hiatuses, reworking, re-deposition and sandwiching. Some diagenetical changes (like bioturbations, migration of solution, precipitations on geochemical barrier) can influence and modify original paleomagnetic signal in sediments. Number of hiatuses is often reflected in lower and upper limits of individual magnetozone. Magnetozone geometries are therefore often deformed and some excursions and magnetozone can be even missing or hidden inside the record. Those characteristics result in fact, that (1) the precise calculation of the temporal duration of individual interpreted magnetozone can be problematic in places, and (2) the exact calibration of the geometric characteristics of the magnetostratigraphic logs with the GPTS cannot be attained at all or only with problems, especially if it is not adjusted by results of other dating and geomorphic methods and/or stable isotopic and astrochronological studies. Depositional velocities can be calculated only exceptionally.

The first attempts to apply palaeomagnetic analysis and magnetostratigraphy to cave deposits were carried out by J.S. Kopper and K.M. Creer in 1975 and 1976 on Mallorca (Balears, Spain) and in Spanish inland (Esporles). Victor A. Schmidt (1982) conducted the pioneering successful large-scale magnetostratigraphic dating in relic and active passages of the Mammoth Cave – Flint Ridge system (Kentucky, USA). He dated the oldest fine-grained sediments back to about 2.1 Ma. Great number of later paleomagnetic research of cave sediments is summarized in Zupan Hajna *et al.* (2008).

The application of complete paleomagnetic analysis, both by the TD and AF demagnetization, only to pilot samples and the shortened selected field/step approach to other samples does not offer sufficient data set for reliable interpretations. Reliable data can be

obtained only by the application of high-resolution paleomagnetic sampling of both clastic and chemogenic deposits (for details see Zupan Hajna *et al.* 2008) and complete demagnetization procedures on all samples. Measured data should be subjected to multi-component analysis of the remanence (Kirschvink 1980). The individual components must be precisely established to determine the CRM directions. Mean CRM directions must be analyzed using the statistics for spheres (Fisher 1953) but small number of samples could not be used for a reliable interpretation. It was proved, that the TD and AF demagnetization of speleothem samples from the Račiška pečina (Slovenia) have given identical results from specimens belonging to the same sample of the same layer.

Paleomagnetic method and magnetostratigraphy interpretation of number of profiles of cave deposits in the Czech Republic, Slovakia, Hungary, Poland, Slovenia, Italy, Macedonia, Republic of Korea during last 20 years have contributed to the better understanding of cave depositional processes and their position in geologic time scale. We have obtained important data concerning tectonic processes and geomorphology evolution of broader surroundings of studied caves when the paleomagnetic method was combined with other dating methods (especially U-series, cosmogenic isotope dating, classical zoo- and phytapaleontology, apatite fission track method, zircon LA-ICP-MS dating) and modern stable isotopic studies (incl. statistical processing).

Acknowledgment Publication was prepared in the frame of MOBILITY SAZU-16-03 project.

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Quaternary cave deposits of the Southern Uralian region (Russia)

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Session 1: Oral

The area of the Southern Urals is characterized by a wide distribution of the Palaeozoic carbonate rocks. Because of the humid moderate climate geological processes of weathering are leading to the development of the karst processes and as a result – numerous big and small cavities are attributed to the river valleys and interfluvies on this area.

Sulfur and carbonic karst with its varieties – sulfate, carbonate and of mixed origin are developed in the region. Sulfur karst occurs in the areas of pyrite deposit development in the Southern Trans-Urals. Carbonic karst is widespread in the eastern part of the Eastern European platform, in the Fore-Urals and Southern Urals, and is characterized by wide development of the Pre-Cambrian and Phanerozoic carbonate and sulfate deposits.

Process of weathering in the cavities originate series of the loose deposits which represent the underground (subterranean) series with two groups of cave deposits (subterranean group) and deposits of the springs (fontanel group).

Among the cave deposits in the region, it is possible to identify the deposits of the collapses, residual deposits, water-mechanical, water-chemogenic and organic sediments. The authors studied the deposits originated after carbonate karst processes. These deposits are practically of the same type throughout the entire section and they can be divided into stratigraphical horizons only with help of the radiocarbon method.

An insoluble loamy, clayey and silty residue formed during the leaching of rocks represents residual deposits. This residue or terra-rossa consists of insoluble aluminium and iron oxides that give the rock a reddish- or yellowish-brown colour, as well as silicon oxides represented by sand and gravel, sometimes there are silicified organic remains (for example, crinoids or brachiopod shells). These sediments, so-called “krasnozem” (or “red-earth”), lining the bottoms of surface and underground karst forms of relief. These deposits are no layered or with poorly expressed stratification, and contain (in caves in particular) a large number of unrounded fragments of carbonate rock with different size which were crumbled down. The thickness of the residual deposits varies and depends on the size of the karst cavities, of the relief and of the bottom slope. The thickness of the deposits in the inclined at the entrance part of the cave is up to 5 m (Bajslan-Tash cave). The thickness of the deposits in the entire part of the Uralian caves is from 0.3 m to 1 m. These deposits were formed mainly during the Holocene (especially in small caves), but their lower horizons accumulated during the Middle and Late Neopleistocene (Verkhnyaya, Bajslan-Tash, Kapova, Zapovednaya caves, etc.).

Biostratigraphical investigation of the unconsolidated (residual) deposits found in caves allowed determining ages which are ranging between the end of the Middle Neopleistocene and the Late Holocene. Holocene deposits were studied in 36 cavities; Upper Neopleistocene

deposits were investigated in 18 caves. The results of mammalian investigations and radiocarbon dating provide the basis for the stratigraphical subdivision. Palynology, molluscs, fishes, amphibian and reptiles are used for the reconstruction of the palaeoenvironments.

The cave sequence are characterised by mammals of the late Mammoth and Holocene complexes. Southern Uralian small mammal faunas indicate the synchronous existence of steppe and forest species during Middle and Late Holocene, and steppe, forest and tundra species during Late Neopleistocene and Early Holocene. In these ecological groups, the contribution of the forest species increased up to nowadays. Modern fauna of mammals, amphibians and reptiles developed at the end of the Late Holocene.

During the Late Neopleistocene - Holocene, the forest-steppes were widespread. Part of the forest vegetation was higher during the warm periods (Tabulda, Middle-Late Holocene) and areas covered by the trees were reduced during the cold intervals (Kudashevo, Early Holocene), when they were growing in the river valleys. The modern mountain mixed (coniferous-broadleaved) forests appeared only in the latest Holocene.

Few caves contain archaeological artefacts of the Palaeolithic, Bronze and Iron Ages and other periods (Kapova, Ignatievskaya, Bajslan-Tash caves and other).

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Mammal remains from Makhnevskaya ledyanaya cave (Perm Pre-Ural, Russia): biostratigraphic reconstruction

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Session 1: Oral

Paleontological studies of Makhnevskaya ledyanaya cave (the Perm Pre-Ural) began after publications about the detection of bones of Asiatic black bear and Malayan porcupine (Baryshnikov 2001, 2003) from excavations of "black" paleontologists. The internal grotto of this cave (where many bones of animals were revealed) locates at the end of the long corridor. This corridor comes to the end with abrupt precipice (depth up to 2 meters). The cave received this name because the ice stopper before descent in the grotto existed at the XX century (Maximovich 1947). Animals could get to this grotto only during the periods of the lack of the ice in the corridor, it is probable in warm climatic intervals of the time. Numerous fossil bones of animals were found in deposits of this grotto and were studied from deposits of its several parts (Fadeeva et al. 2011).

The differentiation of bones according to the preservation degree showed previously, that the majority of bones of small mammals have light color, without mineral educations on a surface (I type of the preservation). Bones and teeth of large mammals and part of bones of small mammals have other preservation (II type – more ancient) - dark color and existence of spots and dendrites of manganese oxides. The analysis of the preservation of bones proved, that all studied deposits of a cave are mixed (as a result of “black” excavations).

In past year new excavations of deposits under the rock in this grotto were carried out. As the result, we received fossil material from deposits “in situ”. This material allows us to draw preliminary conclusions on the structure of faunae of mammals for at least two temporary periods of the past. Numerous fragments of bones of large mammals were found on all thickness of the studied deposits (~ 0, 5 meter). The vast majority of these bones belong to bears. Fossil remains of small mammals (generally isolated teeth, the lower mandibles without teeth) of the I type of the preservation were very numerous on the surface of deposits and were found in a layer 1 (up to the depth of 20 cm). In deeper deposits (layers 2, 3, 4) the number of fossil bones of small mammals rather is small and all of them have II type of the preservation.

Three genres of rodents prevail on all studied depth of deposits - gray voles (*Microtus agrestis*, *M. oeconomus*), red-backed voles (*Clethrionomys rufocanus*, *Cl. glareolus*, *Cl. rutilus*) and wood lemmings (*Myopus schisticolor*). However, their ratio of bones number changes at different depths - red-backed voles and wood lemmings prevail on the surface, gray voles - in 1 and 2 layers and red-backed voles - in 3 and 4 layers. The difference of the

ratio of species within group of forest voles is also noted in at different depths – gray large-toothed red-backed vole (*Clethrionomys rufocanus*) dominates on the surface, bank (*Cl. glareolus*) and ruddy (*Cl. rutilus*) voles prevail in all other layers. Single teeth of water vole (*Arvicola terrestris*) of I type of the preservation are found on the surface, more numerous teeth (II type) of this specie are defined in other layers. Teeth of northern birch mouse (*Sicista betulina*) are found only in top layers. Teeth of wood mouse (*Sylvaemus* ex gr. *sylvaticus-uralensis*), yellow-necked mouse (*Sylvaemus flavicollis*) and porcupine (*Hystrix* sp.) belong to the II group of the preservation and were found in deposits of 1, 3 and 4 layers.

Fossil remains of common mole (*Talpa europaea*) and three species of shrews (Eurasian common shrew *Sorex araneus*, even-toothed shrew *S. isodon*, Laxmann's shrew *S. caecutiens*) were revealed practically in all layers. The most part of lower mandibles of shrews (*S. isodon* and *S. caecutiens* prevail) was found on a surface. Bones of other species of insectivorous mammals (hedgehog *Erinaceus* sp., white-toothed shrew *Crocidura leucodon*, lesser shrew *Sorex minutus*, water shrew *Neomys fodiens*) are defined from 1-4 layers and have to ancient type of the preservation.

Northern bat (*Eptesicus nilssonii* - prevailing specie), long-eared bat (*Plecotus auritus*) and small species of common bats (*Myotis* sp.) were determined according to lower mandibles (both types of the preservation) and found in all studied layers.

Single bones of lagomorphs (hare *Lepus* sp., pika *Ochotona* sp.) belong to the II type of the preservation (2-3 layers).

Bones and teeth of cave bear (*Ursus spelaea*) and small cave bear (*Ursus savini*) dominate among the remains of large mammals, found in deposits "in situ" and in the mixed deposits. All skeleton elements of these are found. Bones belong to individuals of all ages – from newborns to old. It indicates that the cave was the place of winterings of cave bears. Other species (wolf *Canis lupus*, fossil lion *Panthera* ex gr. *fossilis-spelaea*, Asiatic black bear *Ursus thibetanus*, mustelids *Martes* sp., European badger *Meles meles*, glutton *Gulo gulo*, horse *Equus ferus*, elk *Alces alces*, red deer *Cervus elaphus*, Pleistocene bison *Bison priscus*) are presented by a small amount of bones. All bones of these species of big mammals belong to ancient type of the preservation.

Thus, we allocate two faunistic complexes in the studied deposits of this cave. The first complex is similar in structure and dominating species (*Microtus agrestis*, *M. oeconomus*, *Clethrionomys rufocanus*, *Cl. glareolus*, *Cl. rutilus*, *Myopus schisticolor*, *Arvicola terrestris*, *Sicista betulina*, *Eptesicus nilssonii*, *Plecotus auritus*, *Myotis* sp., *Talpa europaea*, *Sorex araneus*, *S. isodon*, *S. caecutiens*) with the complex of the middle Holocene from the next-door cave Bolschaya Makhnevskaya ($3\,628 \pm 86$ years, IEMEG-1385) and likely existed in the Middle - Late Holocene. The second complex of small mammals contains bigger quantity of species - above-mentioned list and *Erinaceus* sp., *Sorex minutus*, *Neomys fodiens*, *Ochotona* sp., *Sylvaemus* ex gr. *sylvaticus-uralensis*, *Crocidura leucodon*, *Sylvaemus flavicollis*. The last two species and also *Hystrix* sp. were not found in deposits of the second half of the Late Pleistocene and the Holocene in caves from this territory. All species of large mammals also belong to this complex. Layers 1-4 also contain many fossil remains of amphibians. Only single bones of the collared lemmings *Dicrostonyx* sp. and narrow-skulled vole *Microtus gregalis* (they dominated among of small mammals of this territory in the period of the second half of the Late Pleistocene) were found in the mixed deposits of this cave. Possibly the entrance to the grotto in this period was closed with ice. We assume the time of the existence of second complex of mammals (forest species prevail) - Mikulino or one of the warm periods of the first half of the Late Pleistocene.

Acknowledgment The reported study was funded by RFBR according to the research projects № 18-04-00982a, № 16-55-14002 ANF-a.

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Morphometric study of the epikarstic landforms of the western Karst (Italy) through the analysis of LiDAR derived data

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Session 2: Oral

In this work we present a morphometric study of epigeous landforms (dolines) of the Isontino Karst, which corresponds to the western part of the Trieste-Slovenian Karst. The study area has an extent of 32 km² and rises for about 120 m over the Soča River and the Friuli Plain, that bound the Karst on its western side. On the East, the area is limited by the so-called Vallone Carsico and the Italian/Slovenian boundary

The bedrock consists of three different limestone formations formed between the Lower Cretaceous and the Lower Eocene and they correspond to a carbonate platform, which experienced several tectonic events related to the Dinaric and Alpine orogenesis. These deformative phases caused the uplifting and faulting of the carbonate succession until the emersion of the Karst. Since a very long period the surface portion has been prone to weathering processes and erosion.

The investigated area is particularly suitable for geomorphometric analysis because of the following characteristics: i) natural morphologies are very well preserved and visible thanks to the lack of important human settlements and the limited land use; ii) stratigraphic surfaces are almost horizontal and with little deformation; iii) orographic and climatic characteristics are homogenous and allow to consider the Isontino Karst as a single morpho unit; iv) the Regione Autonoma Friuli Venezia Giulia has recently allowed the public access to the altimetric data (DTM and DSM with a cell size of 1 m and a vertical accuracy of ± 0.15 m) derived from LiDAR survey carried out in 2006-08 with high-resolution orthophotos taken contemporary to the LiDAR shooting. These data allow to overstep many difficulties due to identification of landforms directly in the field because of the dense and thorny vegetation, anthropic fences and other territorial constraints. Moreover, an enormous amount of time and energy would be required to carry out a detailed field survey.

The accuracy of DTM is strongly enlarging the scale at which it is possible to carry out geomorphological studies, improving the details of the landforms and of the calculations of morphometric values and parameters. The morphometric analysis of dolines through LiDAR data allow us to calculate and analyze accurate values, extracting more than 30 parameters for each doline. In the Isontino Karst the doline is the most diffused landform of the karstic

landscape and we recognized more than 1600 of these features. They cover an area corresponding to 21% of the total investigated surface and an average value of 51.4 doline per km² (doline density) was calculated. Dolines generally have a sub-circular shape but the elongated ones show a prevalent dinaric direction, like the local faults and structural data. The average value of area and volume seem to indicate a well-developed karst system, but still in evolution. The volume of dolines has caused a whole surface lowering of about 0.5 m. It is very interesting to note that the Isontino Karst has a different doline distribution for the three different limestone formations forming the bedrock, testifying a strong constraining action of the lithologies.

Late Pleistocene and Holocene environmental evolution on the Crimean karst plateau: palynology, palaeontology and lithology from the Emine-Bair-Khosar cave sequence

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Session 1: Oral

The Emine-Bair-Khosar Cave is located at a lower level of the karst plateau of the Crimean Mountains (44°48'N, 37°17'E, 990 m a.s.l.). The site has yielded bones of more than 50 vertebrate species (Vremir & Ridush 2005; Ridush & Vremir 2008; Ridush *et al.* 2013; Doan *et al.* 2018). The Museum Hall section (5 m in thickness) is cut through a sediment and fossil trap located below the vertical pit of the cave. A previous study reported on the pollen and lithology of the clastic deposits of this section (including grain-size analysis) (Gerasimenko *et al.* 2010, 2014), as well as on their palaeomagnetic and rock magnetic characteristics (Bondar *et al.* 2008), and on stable-isotope analysis of bones (Gasirowski *et al.* 2014). The palaeoenvironmental implications of these and the newly obtained data are presented in this paper. The latest palaeofaunal findings are described in this volume (Stefanyak & Ridush *et al.*). The chemical removal of carbonates from the clastic deposits enables analysis only of their allochthonous terrigenous component. The latter are very rich in well-preserved pollen. The fossil palynospectra were compared with those of modern surface samples. The cave is located between plateau meadows (the Yayla) and the forest of the mountain slopes. The palaeovegetation of this ecotone was very sensitive to climatic change.

The deposits at the base of the section were formed during the last interglacial, as evidenced by the pollen succession and the percentages of broadleaf taxa (up to 60%), that exceed those of the present. Telocratic and mesocratic phases of an interglacial (Quercetum mixtum and Carpinetum) are well expressed. Bones of *Bos primigenius* (a typical representative of the interglacial) were revealed, and remains of *Cervus elaphus* predominate in these brown-coloured deposits with very high clay content. The last indicates intense clay weathering in the soils around the cave, whose material was colluviated into the pit. Thus, the temperate climate was much wetter than at present.

The overlying bed (¹⁴C >47,000, >46,000 BP) is characterized by a sharp drop in arboreal pollen (AP), with an almost complete disappearance of broadleaf taxa pollen and an increase in xerophytes (particularly *Ephedra distachya*). This indicates the cool and arid climate of a stadial. The overlying sedimentary sequence, ¹⁴C-dated between 48,500±2,000 (cal.

53,020±3262 BP) and >42,000±1,200 BP (Ridush *et al.* 2013), represents the first half of the Middle Pleniglacial and differs by a sharp increase in fern spores and in large silt particles (0.01-0.05 mm) balanced by a decrease in the clay fraction. The alternation of three interstadials and stadials is clearly seen in the appearance and disappearance of broadleaf tree pollen, though a significant increase of such pollen (mainly *Tilia cordata*) occurs only during one interstadial. The AP drops in interstadials to a half of its interglacial percentages (it is also lower than at present). During interstadials, the climate was rather wet, but cooler than at present. During stadials, herbal coenoses, which included xerophytes (particularly *Ephedra distachya*), prevailed. Large silt particles are especially abundant in these deposits, which is regarded as an indication of frequent dust storms. The climate was boreal and drier than during the interstadials. The deposits of the second half of the Middle Pleniglacial (between ^{14}C >42,000±1,200 and 27,700±250 yrs) are marked by a drastic increase in NAP (mainly forbs) at the expense of a drop in spores. This indicates a general aridification. A well-expressed interstadial preceded the ^{14}C -date 33,100±400 yrs, and after this date, during the most arid stadial, boreal steppe completely occupied the Yayla. The regular presence of a few pollen grains of broadleaf taxa indicates the existence of their refugia on the mountain slopes.

Middle Pleniglacial deposits contain the most abundant and diverse faunal assemblage in the site. Open-country forms dominate among the small mammals. They include species which inhabit dry steppe or semidesert (*Marmota bobac*, *Eolagurus luteus*, *Lagurus lagurus*, *Microtus gregalis*, *Ochotona pusilla*), and which, at present, do not occur in Crimea, as well as the northern vole (*Microtus oeconomus*). Bones of larger steppe species (*Bison priscus*, *Saiga tatarica*, *Vulpes corsac*) and Pleistocene megafauna (*Mammuthus primigenius*, *Equus ferus*, *E. hydruntinus*, *Coelodonta antiquitatis*, *Megaloceros giganteus*) occur together with remains of *Cervus elaphus*, *Martes* sp., *Sicista* cf. *betulina* and *Apodemus sylvaticus*. This indicates the predominance of steppe or meadow-steppe on the plateau and the presence of woods in the cave environs. As there are no faunal remains dated to the LGM and pollen of arcto-boreal plants is absent, the entrance to the cave was probably closed with a snow 'cork' at that time.

The Late Glacial (^{14}C 10,490±170, 12,050±60 yrs) is represented by deposits of a stadial and the Bölling-Alleröd interstadial. During the latter, the diversity of trees and the role of broadleaf taxa and ferns increased. The deposits of the stadial are marked by an increase in *Artemisia* pollen, the lowest content of clay and very low magnetic susceptibility. Remains of Pleistocene megafauna species are absent. Bones of woodland animals include *Cervus elaphus*, *Ursus arctos*, *Felis* sp. and *Apodemus* cf. *flavicollis*. During the stadial, steppe species dominated: *Saiga tatarica*, *Bison priscus*, *Vulpes corsac*, *Mustella eversmanii*, *Cricetus cricetus*, *Microtus arvalis*, *Eolagurus luteus* and *Lagurus lagurus*. Late Glacial mammal faunas and pollen assemblages indicate a cooler and drier climate than at present.

The beginning of the Holocene sedimentary sequence is marked by a significant decrease in large-sized debris, an increase in the fractions <0,001mm and 0,01mm, in magnetic susceptibility, in AP, broadleaf taxa pollen and spore percentages. The disappearance of *Betula* and the reduction in xerophytic herbs are also indicative. Higher up in the profile, in the bright-brown deposits, the maximum pollen percentages of broadleaf trees (*Carpinus*, *Quercus*, *Fagus* and *Ulmus*), the maximum clay content and the minimum of large silt particles obviously indicates the Atlantic climatic optimum. The lithomorphological characteristics of these deposits show that the cave pit was surrounded by forest soils. The climate was warmer and wetter than at present. The overlying sediments (up to the level of the palaeomagnetic marker 2800 yrs BP) become darker (more enriched in humus) and include more large silt particles (with a corresponding decrease of the clay and sand fractions). The AP and pollen percentages of broadleaf trees decrease in these deposits, and pollen of

Ephedra and *Artemisia* re-appear. The mammal assemblage indicates the existence of open steppe - the occurrence of *Cricetus cricetus*, *Microtus arvalis*, and, particularly, of *Lagurus lagurus* and *Eolagurus luteus* - species indicative of continental climate which are now absent in Crimea. This aridification evidently occurred during the Subboreal.

Above a level, dated to 2800 yrs BP, dark-grey loose sandy loams represent the Subatlantic deposits: they are the product of colluviation of humic soils into the cave. In the Ukrainian steppe plains, the most intense humus accumulation also occurred during the Subatlantic (Ivanov 1992; Gerasimenko 2010). The strong enrichment in humus is reflected in the maximum values of magnetic susceptibility. From the bottom to the top of the Subatlantic sequence, AP drastically reduced with a concomitant increase in fern spores. In parallel, the proportion of sand particles strongly increases in these sediments. The absence of pollen of xerophytes indicates that these changes were not controlled by aridification, but resulted from forest clearances on the Yayla. The decrease in pollen of broadleaf trees in the upper part of the Subatlantic deposits (as compared to the modern surface samples) may reflect the cooling of the "Little Ice Age".

Due to the rich palaeoenvironmental archive of the Emine-Bair-Khosar site, it is proposed to the DATESTRA project.

The candidate sections for DATESTRA from the North-Eastern Ukraine

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Session 4: Oral

In terms of Quaternary stratigraphy, the territory of Ukraine is subdivided into two main parts: the area formerly covered by the Middle Pleistocene glaciation and the non-glaciated area. Within the first one, the northern region with the Upper Pleistocene cover of aeolian sands and interbedded palaeosol or organic deposits (Polissya), and the region of the Dnieper glacial lobe with the Upper Pleistocene loess-palaeosol cover are distinguished. Within the non-glaciated area, the north-west, north-east, central and southern regions differ significantly by the ratios in thicknesses of loess and palaeosol units, zonal types of palaeosols and paleontological indices of palaeoenvironments. The key sites studied with a complex of methods are described in each of the forenamed regions (Veklitch *et al.* 1967-1990; Velichko *et al.* 1975-1989; Adamenko *et al.* 1987-2017; Boguckiy *et al.* 1976-2016; Gozhik *et al.* 1976-2017; Matviishina *et al.* 1982-2015; Gerasimenko 1988-2017; Vozgrin 1984-2008; Sirenko 1994-2017; *etc.*). The most representative sites will be suggested as candidates for DATESTRA.

In this paper, two stratigraphically complete sites of the northern part of Ukraine are represented. Sedimentary sequences of both sites start (from the top) with deposits of the Bug unit (the terrestrial equivalent on MIS 2) and end below the M/B boundary. The Muzychi site (50°21'N, 30°7'E) is located on the loess 'island' surrounded by cover sands, in the quarry on the plateau, 30 km SW from Kyiv. The pedostratigraphy (including grain size, bulk chemical, organic matter and carbonates distribution) and pollen of the whole Quaternary sequence have been studied (Gerasimenko 1988, 2004), as well as micromorphology of the Upper Pleistocene palaeosols (Karmazinenko 2010) and palaeomagnetic properties of the deposits (Vigilyanskaya 2001). For the upper part of the sequence, TL-dates have been obtained by Shlyukov *et al.* (1999); Shelkoplyas & Khristoforova (2008); and Prilipko (2010). In places,

the Bug loess (up to 5 m thick) is cut by the incisions filled in with the Late Glacial deposits, and, in places, it includes the incipient Dofinivka soil (TL 15 ± 3 ka). The loess was formed under a periglacial tundra-steppe. The underlying Vytachiv pedocomplex, consisting from the upper weak humic soil and the lower Cambisol, have been dated (32 ± 5 , 50 ± 8 ka) to MIS 3. The Cambisol was formed under a south-boreal forest, and the upper humic soil developed under a cold steppe. Both soils have much more clayey particles than the other Upper Pleistocene units. The Uday loess (the correlative of MIS 4) is strongly gleyed in its lower part (0.5 m thick). It accumulated under periglacial forest-tundra-steppe. The underlying Pryluky pedocomplex consists of the uppermost incipient soil, the Mollisol (1 m thick), with long humus wedges (TL 78 ± 9 ka), and the Greyzem, which was also strongly cryoturbated. The Mollisol was formed under a forest-steppe (light pine groves included a few oak and hazel). The Greyzem developed under a mixed forest with birches (dominated) and broad-leaved trees. The Tyasmin unit is represented by a thin sand bed with connected sand wedges. The Kaydaky pedocomplex includes the upper Mollisol (110 ± 8 ka) and the lower Luvisol. In relief depressions, pollen from the latter demonstrates telocratic and mesocratic phases of the Last Interglacial. It got TL-dates 132 ± 13 and 137 ± 19 ka. On the higher grounds, the Luvisol is formed on the till and dated to 222 ± 90 ka. The underlying Dnieper till is 4-6 m thick. The Kaydaky unit is correlated with MIS 5e, the Tyasmyn unit with MIS 5d, the Pryluky Greyzem with MIS 5c, and the Pryluky Mollisol with MIS 5a.

The palaeosol below the till is truncated, secondary gleyed and tentatively related to MIS 7. The underlying Upper Zavadiivka pedocomplex consists of the upper thick Mollisol (with humus wedges), and Luvisol, dated to 339 ± 30 ka. The former developed under a forest-steppe of a temperate climate, the latter formed under broad-leaved forest. Below, a thick meadow soil (TL 375 ± 48 ka) with humus wedges, was formed on alluvial deposits. Such old TL-dates are doubtful, but, nevertheless, pollen succession from the meadow Lower Zavadiivka soil is similar to that of the Holsteinian, and the last appearance of *Pterocarya* was observed, as well as the palaeomagnetic event, which might be compared with the Emperor excursion. From the two alluvial suites below this soil, the upper one (Tyligul unit) was formed under a periglacial steppe (the Elsterian), and the lower one was accumulated in a climate of temperate forest (the Lubny unit, the Late Cromerian interglacial?). The lower alluvium cut through the Martonosha meadow soil whose locality was surrounded by a forest with an admixture of very diverse Neogene relic taxa. A thin loam (0.6 m), connected with a level of cryoturbations, separates the Martonosha soil from the Shyrokinе pedocomplex. The upper Brunizem of this complex, with soil wedges, was formed under a forest-steppe. It overlies the Vertisol and Luvisol. The last ones were formed, respectively, under sparse woodland and forest of a warm-temperate climate, with the Neogene relic trees. The M/B boundary is located within the non-soil clayey loam, underlying the Luvisol. Thus, four Cromerian interglacials are evidently represented by palaeosols and separated by cryogenic levels.

The Vyazivok section is a reference site for the Ukrainian Quaternary (Veklitch *et al.* 1967, 1982; Rousseau *et al.* 2001; Matviishina & Gerasimenko 2005; Haesaerts *et al.* 2016; Glavatsky *et al.* 2016) which includes all stratigraphical units of the Upper and Middle Quaternary. The M/B boundary has been revealed in the lower part of the Shyrokinе unit. The site is located in the area of the Dnieper glacial lobe with the Upper Pleistocene loess-palaeosol cover ($49^{\circ}57'N$, $32^{\circ}57'E$), 207 km SE from Kyiv on the high (the Lower Pleistocene) terrace of the Sula River. The studies applied in this site are lithology (including grain-size, bulk chemical, organic matter, carbonates and clay mineralogy analyses), palaeopedology (including micromorphology), pollen and malacology, magnetic susceptibility, palaeomagnetology and geochronology (^{14}C and amino acid dating). All soil units are represented by well developed pedocomplexes. The Vytachiv unit includes three Cambisols, the Pryluky unit consists (from the top to bottom) from the alternation of

Cambisols and Mollisols, whereas the lowermost soil is a Greysem. The Kaydaky unit includes from the top to bottom a Mollisol, Greysem and Luvisol. The pollen succession of the Last Interglacial has been revealed in the Kaydaky unit. The Dnieper till and glaciofluvial deposits reach 15 m in thickness, the Tyligul (the Elsterian) loess and water lain deposits are 9 m thick, and the Sula loess (the correlative of MIS 16) is 6 m thick. The amino acid dates indicate that the Dnieper unit can be compared with MIS 6, and the Tyligul unit can be correlated with MIS 12 (Oches *et al.* 2000). The Potyagaylivka and the Upper Zavadvka pedocomplexes (MIS 7 and 9, respectively) consist of Mollisol, partly formed on the material of the underlying Luvisol, whereas the Mollisol and Luvisol of the Lower Zavadvka unit (the correlative of MIS 11) are well separated. The levels of cryoturbations are well developed, particularly those in the Bug, Uday, Tyasmyn, Dnieper, Oril, and Tyligul units. Nevertheless, cryoturbations are also observed within the Vytachiv, Pryluky, and Zavadvka pedocomplexes. Recently, the Upper Pleistocene palaeosols catenas have been studied, starting from the plateau to the gullies bottoms in the newly discovered sites near the reference section. In the pedocomplexes of the paleorelief depressions, the high-resolution pollen analysis demonstrates short-period palaeovegetational and palaeoclimatic changes. The pre-temperate and post-temperate phases of the Last Interglacial have been found in the soils of the initial and final stages of the Kaydaky pedogenesis. The cyclic palaeoenvironmental development has been shown for Pryluky subunits, which are correlated with substages 5c and 5a.

Quaternary large mammals from the Imanay Cave

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Session 1: Oral

The Imanay cave is located in the Southern Urals (Republic of Bashkiria, Meleuzovsky Municipal District, 53°02' N, 56°26' E). First excavation unit of 18 m² was situated in the cave's interior, near the cave entrance. The excavation revealed 20 cm of sediments composed of brown clay. In all 1072 animal remains were recovered from the first unit.

The second excavation unit of 6 m² was placed in the grotto in the inner part of the cave, 100 m from the entrance. More than 12 000 animal remains were obtained from a 1.2 m² deposits composed of light-brown gravel sands. The faunal remains were unequally distributed within the sediments and 95% of the bones were obtained from the upper horizon 0.6 m thick.

All mammal remains from both units were classified into two groups on the basis of color and state of fossilization: non-fossilized bones of creamy-white and light-yellow color and fossilized bones of darker color, from light-brown to black. Light-colored remains from the first group are dated to the Holocene, while those from the second group is interpreted to be older and dated to the Pleistocene.

The non-fossilized remains recovered from the first excavation unit belong to hare (*Lepus timidus*, NISP=131) and badgers (*Meles meles* and *M. leucurus*, NISP=431). Majority of the bones have carnivore teeth marks. The fossilized animal remains belong to steppe marmot (*Marmota bobak*, NISP=119), porcupine (*Hystrix brachyura*, NISP=5), red fox

(*Vulpes vulpes*, NISP=2), badger (*Meles* sp., NISP=6), wolverine (*Gulo gulo*, NISP=1), brown bear (*Ursus arctos*, NISP=44), mammoth (*Mammuthus primigenius*, NISP=2), horse (*Equus ferus*, NISP=13), woolly rhinoceros (*Coelodonta antiquitatis*, NISP=18), wild boar (*Sus scrofa*, NISP=1), elk (*Alces alces*, NISP=1), reindeer (*Rangifer tarandus*, NISP=4), red deer (*Cervus elaphus*, NISP=4), and steppe bison (*Bison priscus*, NISP=5). The radiocarbon dating of sample taken from fossilized bone gave an age of 32350 ± 110 (IGAN-5650). The wild boar remains are scarce and include only three porcupine-gnawed bones. This is the first record of wild boar from the Late Pleistocene of Northern Eurasia.

The second excavation unit provided Holocene faunal assemblage dominated by steppe marmot (NISP=516) and hare (*Lepus* sp., NISP=241) with rare occurrence of badger and small mustelids (*Martes* sp., *Mustela* sp.). Most of the marmot and hare bones show signs of digestive corrosion. The remains of small cave bear (*U. savini*) prevails in the Pleistocene faunal assemblage from the same unit. More than 10 000 bones from 108 individuals were identified. All bones are highly fragmented. About 40% of the remains belong to young animals, including embryos and newborns. This indicates that bears used the inner part of the cave as a den. The second most abundant species in the fossil record is cave lion (*Panthera (Leo) ex gr. fossilis-spelaea*). A total of 715 bones representing a minimum of 11 individuals were collected. Only adult individuals are present. The remains of other species such as hare, beaver (*Castor fiber*), steppe marmot, wolf (*Canis lupus*), dhole (*Cuon alpinus*), red fox, arctic fox (*V. lagopus*), corsac fox (*V. corsac*), badger, wolverine, small mustelids (*Martes* sp., *Mustela* sp.), cave bear (*U. kanivetz*), brown bear, Asian black bear (*U. thibetanus*), woolly mammoth, horse, woolly rhinoceros, steppe bison, saiga antelope (*Saiga tatarica*) and mufﬂon (*Ovis ammon*) are very rare (each species is represented by only 1-5 bones). The carnivore gnawing marks on bones are absent. Two radiocarbon dates on cave bear remains were obtained: 26320 ± 1790 (GIN-14244) and 34940 ± 140 (IGAN-5652).

Bifacial points similar to those from the third cultural layer of the Mousterian open-air site Il'skaya in the Northern Caucasus were found in the upper horizons of the second excavation unit alongside with faunal remains. The artifacts from the Il'skaya site were dated to the beginning – first half of the Late Pleistocene (Schelinskiy & Kulakov 2005). Though, it should be noted that there are no traces of human activity on bones from both excavation units.

Two factors contributed to the accumulation of animal remains in the Imanay cave: death of the animals during hibernation (cave and brown bears, badger) and predatory activities of carnivores (other species). The primary source for the accumulation of cave lion remains is still unclear. No bones with human modification were found, so humans can be ruled out as a bone accumulation agent, though ancient people obviously visited the cave.

Most of the identified species were inhabited the Southern Urals throughout the Late Pleistocene and Holocene (Kosintsev & Bachura 2013). The Asian black bear and porcupine occurred in the area during Eemian interglacial (OIS 5e) (Kuzmin *et al.* 2017). The dhole, cave and small cave bears, mufﬂon lived in the early – middle Late Pleistocene (OIS 5–OIS 3) (Kosintsev & Bachura 2013). The arctic fox, woolly mammoth, woolly rhinoceros, steppe bison and saiga antelope were common species during the Late Pleistocene (OIS 5–2) (Kosintsev & Bachura 2013).

The analysis of faunal remains from the Imanay cave, archaeological evidence and radiocarbon dates suggests that mammal bones were accumulated during the Late Pleistocene and the Holocene (OIS 5–1). The Pleistocene deposits were formed in the early – middle Late Pleistocene (OIS 5–3).

Fossil collection was conducted under the State Contract of the Institute of plant and animal ecology, analysis and interpretation of the data were supported by the Program of UB RAS (project № 18-4-4-3). All collected materials are stored in the Zoological museum of the Institute of plant and animal ecology, Yekaterinburg (collection number 2284).

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Nothing IS possible - An introduction to stratigraphical studies in caves

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Session 1: Oral

Caves are an erosional form and are primarily characterized by absence of bedrock. However, both the erosion itself (creating a "nothing") as well as the infilling of the created void by sediments provide stratigraphical and thus climatical and geographical information. This information is often readable despite the fact that caves are open systems, and recent processes can partially obliterate older sediments and forms.

The talk gives an introduction to cave-forming processes, informs about the sediment deposition modes, and presents the concept of relative chronology which enables a correlation of cave morphology and sediment deposits. Examples of the Swiss (Siebenhengste) and Slovenian Alps (Snezna jama) are presented. In many areas which had been glaciated, the underground information is the only one remaining, since the last glaciation most often effectively obliterated older traces at the surface.

As a conclusion, a stratigraphic information out of a "nothing" is very possible.

Climate change at Brunhes-Matuyama boundary: multi-proxy record from flowstones from the cave Račiška pečina (SW Slovenia)

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Session 1: Oral

Speleothems are valuable source of information on environment condition in the past. Among the numerous physico-chemical parameters dependent on environment factors, the variability of oxygen and carbon isotopic composition is particularly often used for the reconstruction of paleoclimatic conditions (e.g. rainfall or temperature) in the vicinity of the cave. Calcite microfacies as well as trace elements contents can provide additional information on depositional conditions of speleothems, like water drip intensity in the cave, water flow character or the amount of allogenic material supplied to the cave.

The relict cave Račiška pečina is located in the Matarsko Podolje (SW Slovenia), a part of the Classical Karst. The cave was used as a military magazine in the past. Large technical adaptations of cave interior provided large cut through flowstones and sediments. Charcoal layers (residues of fireplaces) in the upper part of flowstone profile proved repeated human inhabitation of the cave.

Unique series of sediments composed of interbedded flowstones and red fine-clastic sediments deposited in the main cave passage. The studied sediment section is about 13 m long with the cumulative thickness nearly 6.5 m. Detailed paleomagnetic and magnetostratigraphy studies, combined with mammalian zoopaleontology and some numerical dating stated the start of flowstone deposition to over 3.4 Ma and the termination at ca 6 ka, i.e. from early Pliocene to Holocene with some hiatuses.

Reddish light brown flowstone was collected from the upper part of the section (yellow clastic interbeds with cave bear bones) in the thickness of ca 23.5 cm. The boundary of Brunhes and Matuyama Chrons (B/M) was found there at the depth of ca 17.5 cm.

The flowstone is built by three macroscopical types of calcite with different porosities and colors. Based on microscopic observations, it can be stated that most of the flowstone is built of calcite facies similar to dendritic fabric with characteristic high porosity, significant content of detrital material and V-shaped appearance of branching polycrystals. The most significant changes were related to the B/M boundary zone, where dendritic open fabric changed to columnar microcrystalline one (with the highest calcite crystals purity throughout the analyzed flowstone) on a relatively short distance. Other transitions are less noticeable.

Oxygen isotopic composition ($\delta^{18}\text{O}$) of analyzed flowstone changes within the range of 3‰ (from -4.5 to -7.5‰). Characteristic rapid decrease in the $\delta^{18}\text{O}$ value was observed at the B/M transition. Carbon isotopic composition ($\delta^{13}\text{C}$) changes within similar range from -8.3‰ to -11‰. The $\delta^{13}\text{C}$ values drop of ~1‰ at the B/M transition, i.e. there is the similarity with the oxygen isotopic record. Isotopic record was correlated with other proxies from studied flowstone section, i.e. trace elements relative content or magnetic susceptibility. All proxies have indicated clear change of paleoenvironmental conditions at the B/M boundary.

Early-Middle Pleistocene transition in Central Europe in a high-resolution record of karst deposits

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Session 1: Oral

With a switch of the glacial cycle period from 41 to 100 ka and onset of deep and long glacial stages the Early-Middle Pleistocene Transition (EMPT) became one of the most momentous turning point of the Late Cenozoic history. Here we survey aspects of EMPT based on the high-resolution faunal and sedimentary record from karst deposits of the Bohemian Massif.

In faunal record, the Middle and Early Pleistocene communities (Toringian and Biharian or Q3 and Q2 in biostratigraphic terms) differ essentially in response to alternation of glacial and interglacial stages. The Middle and Late Pleistocene mid-European fossil record clearly

reveals regular alternation of glacial and interglacial communities differing essentially in their species composition and energetic structure. In contrast, the Early Pleistocene record (including continuous sequences covering terminal cycles of that stage in high resolution - Stránská skála, Koněprusy C718 and JK) shows greatly diversified but structurally homogeneous communities responding to glacial oscillations with minute changes only. The transition between the two ways of community dynamics is documented in details at sedimentary complex Chlum 4 where three glacial cycles appear in direct superposition. The upper two cycles at section Chlum 4 demonstrate by a reliable vertebrate and mollusc record this biostratigraphic boundary as a sharp switch associated with LAD *Mimomys savini* and *Lagurus pannonicus*, FAD *Arvicola* and FAD of the glacial type community (with *Dicrostonyx simplicior* and *Microtus gregalis*) at the glacial stage between the two cycles.

Biostratigraphic correlation operating with faunal records from continuous loess series in Červený kopec (Red hill) in Brno dates that transition to MIS 16. The transition was accompanied by rearrangement of phylogenetic morphoclines in more clades and appearance of exotic taxa specific for the transitional period during the cycles preceding to the respective biostratigraphic boundary (Q2/Q3): *Macroneomys*, *Petauria*, *Ursus thibetanus*, *Campylaea capeki* etc.

The sedimentary complex in Chlum 4 with a series of cave deposits (covering a period from MIS 20 to MIS 15) overlays the gravels of 80 m high terrace of Berounka river, the uppermost terrace prior to stage of intensive deep river erosion, what dates it to the cycle MIS 22-21. The structure of the complex suggests that the underground cavities were opened for subsequent sedimentary capture by removing their former infill by river activity. Synchronously, a similar situation preformed also the conditions for sedimentation of Stránská skála talus deposit. Also the evacuation of vertical communications of Koněpruské caves prerequisite for sedimentation of sequences in the sites C718 and JK appeared probably due to local tectonic instability activated by rapid uplift of Bohemian Massif starting at that time.

The increased intensity of alpine tectonic, globally patterning the EMPT period, driving the continuous Middle Pleistocene uplift of Bohemian Massif and neighboring regions, resulted in increased declivity and increased deep erosion. In karst regions it reduced a probability of preservation of deposits of that age what explains a curious anomaly in fossil record of this region: almost complete absence of the Middle Pleistocene deposits contrasting to a high number of the earlier records.

In these regards, the case of the EMPT reminds us that a detailed study of faunal records from cave deposits can not only provide important biostratigraphic and paleoecologic issues but also relevant information on local karst history and regional tectonic development (and vice versa!).

Stratigraphical and paleotheriological description of Holocene sediments from Nizhneirginsky grotto (middle Urals)

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Session 1: Poster

Results of stratigraphical and paleotheriological study of Nizhneirginsky grotto Holocene sediments are presented. The grotto was detected and described by authors in 2009 year. It is

located on the left bank of the Irgina river (left tributary of the Sylva river, Kama river basin), on the outskirts of the village Nizhneirginskoe, Sverdlovsk region. The river valley lies in the southwest of Middle Urals, on a border between Krasnoufimsky insular forest-steppe and mixed coniferous-broad-leaved forest. The grotto is located in a limestone rock 70 m above the river. The site has southeast exposition. Entrance is 3.2 m in width and 3-3.5 m in height. The length of the grotto is 4 m. The total area of the excavation square is 1.75 m² and the depth of the pit to rock bottom is about 0.47 m. Sedimentary sequence contains 3 layers (Ulitko 2014).

Layer 1 is humus sandy loam with inclusion of numerous small and middle-sized rubbles. Thickness is 0.05-0.07 m. The layer contains not numerous remains of birds and mammals and recent anthropogenic trash. Discovered mammal fauna of the layer included fossils of: European mole *Talpa europaea*, bats Chiroptera indet., mountain hare *Lepus timidus*, Siberian flying squirrel *Pteromys volans*, northern birch mouse *Sicista betulina*, common hamster *Cricetus cricetus*, grey red-backed vole *Myodes rufocanus*, bank vole *M. glareolus*, northern red-backed vole *M. rutilus*, water vole *Arvicola amphibius*, common vole *Microtus arvalis*.

Layer 2 is brown sandy loam containing small- and middle-sized rubbles. Thickness is 0.12-0.15 m. The layer contains the largest number of vertebrate remains especially rodent bones and teeth. Among mammals, there were found: European mole *Talpa europaea*, Eurasian water shrew *Neomys fodiens*, common shrew *Sorex araneus*, Laxmann's shrew *S. caecutiens*, even-toothed shrew *S. isodon*, Eurasian pygmy shrew *S. minutus*, bats, mountain hare *Lepus timidus*, steppe pika *Ochotona pusilla*, Siberian flying squirrel *Pteromys volans*, Eurasian red squirrel *Sciurus vulgaris*, northern birch mouse *Sicista betulina*, striped field mouse *Apodemus agrarius*, herb field mouse *A. uralensis*, common hamster *Cricetus cricetus*, grey red-backed vole *Myodes rufocanus*, bank vole *M. glareolus*, northern red-backed vole *M. rutilus*, water vole *Arvicola amphibius*, tundra vole *Microtus oeconomus*, field vole *M. agrestis*, common vole *M. arvalis*, red fox *Vulpes vulpes*, brown bear *Ursus arctos*, least weasel *Mustela nivalis*, stoat *M. erminea*. Radiocarbon dates obtained from small mammal bones from the layer corresponded to Subatlantic: 795±30 yrs B.P. (SPb-971) in upper part and 2579±70 yrs B.P. (SPb-913) and 2650±70 yrs B.P. (SPb-915) in down part.

Layer 3 is light gray with a brownish tinge sandy loam with inclusion of small- and middle-sized rubbles and large lumps. It contains a large amount of vertebrate remains. Total thickness is up to 0.25 m. The layer becomes light brown in the western part of the pit (sublayer 3a). European mole *Talpa europaea*, common shrew *Sorex araneus*, Eurasian pygmy shrew *S. minutus*, bats, mountain hare *Lepus timidus*, steppe pika *Ochotona pusilla*, Siberian flying squirrel *Pteromys volans*, Eurasian red squirrel *Sciurus vulgaris*, Eurasian beaver *Castor fiber*, northern birch mouse *Sicista betulina*, striped field mouse *Apodemus agrarius*, yellow-necked mouse *A. flavicollis*, herb field mouse *A. uralensis*, Eurasian harvest mouse *Micromys minutus*, common hamster *Cricetus cricetus*, grey red-backed vole *Myodes rufocanus*, bank vole *M. glareolus*, northern red-backed vole *M. rutilus*, water vole *Arvicola amphibius*, tundra vole *Microtus oeconomus*, field vole *M. agrestis*, common vole *M. arvalis*, gray wolf *Canis lupus*, red fox *Vulpes vulpes*, martens *Martes* sp.. Layer 3 gave some radiocarbon dates indicating the second half of Subboreal: 2945±80 yrs B.P. (SPb-809) in upper part of the layer, 3120±80 yrs B.P. (SPb-808) and 3350±100 yrs B.P. (SPb-806) in middle part and 3770±100 yrs B.P. (SPb-914) in bottom part.

Taphocenoses comprise mostly fossils of mammals, especially rodents. Moreover, there are some bones of fish, amphibians, reptilians and birds. Taxonomic and preservation analysis of bone material showed that the most of small mammal remains were accumulated as a result of predation activity of birds. Most of large mammal bones are highly fragmented. Perhaps sometimes the grotto was used as a den for carnivorous mammals. Finally, considering well preservation and a large amount of bat fossils probably they were accumulated as a result of

natural death of the animals. Taxonomical composition of the taphocenoses corresponds to recent fauna of the Middle Urals (Bolshakov et al. 2006) excepting steppe pika *O. pusilla*. Now the species does not inhabit the Middle Urals, but it was common in this territory in the Late Pleistocene and Early Holocene. Evidently steppe pika lived in the Middle Urals in Krasnoufimsky insular forest-steppe as relict species of late Pleistocene mammal fauna till late-Holocene time.

Acknowledgments This study was performed within the frameworks of state contract with the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, and partly supported by the Russian Foundation for Basic Research (project no 18-34-00270 mol_a) and by the Complex Program of the Ural branch of the Russian Academy of Sciences (project no. 18-4-4-3).

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The Art of the Hunnu Ivolginsky Settlement (Baikal Siberia)

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Session 4: Oral

Ivolginsky fortified hillfort, located in the Western Transbaikalia on the Selenga River, is a famous archaeological site of the Xiongnu Empire time (Davydova 1986; Konovalov 1976, 1999, 2008; Konovalov *et al.* 2015, 2016, 2017; Kradin, Danilov & Konovalov 2004, 2012, 2014; *etc.*). This archaeological object existed from the first century BC to the second century of our era. Various crafts were developed here: pottery, metallurgy, and various types of art objects.

New excavations of the Ivolginsky ancient settlement under the supervision of Corresponding Member of the Russian Academy of Sciences N. Kradin allowed to obtain a first materials of mollusc, fish, and small mammal fauna, and collection of art objects in connection with the use of sieves for washing loose deposits with a cell diameter of 1 mm 2017-2018.

Species composition of the fauna of molluscs, amphibians and small mammals testifies to the existence of both taiga patches and dry steppe and forest-steppe near the river or temporary pond.

Unique findings are represented by a bone needle 1-2 mm thick, a tiger head made of bone, fragments of bracelets from bone, imitations of kaori shells made of perlovitsa and bronze, numerous beads of amber, wood, various minerals, and pendants.

Acknowledgements This study was supported by the Ministry of Education and Science of the Russian Federation (Grant № 14.W03.31.0016).

The Late Pleistocene-Holocene Cave Small Mammal Fauna of the Fore-Baikal Area (Baikal region)

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Session 1: Oral

In the Baikal region there are two different natural zones: periglacial Siberian (Fore-Baikal area) and non-glacial arid Central Asian (Transbaikalian area). Our investigations of the cave mammal fauna were restricted to the territory of the Fore-Baikal area.

The faunistic material was obtained by Russian geologist A. Filippov (Filippov *et al.* 1995), and in part by F. Khenzykhenova. Small mammal fauna from the caves: Staryi Zamok, Rasdolinskaya-7, Brekchievaya, Unylskaya, and Filippova. The Late Pleistocene small mammal fauna from these caves consists tundra-forest-steppe inhabitants: *Lepus timidus*, *Ochotona hyperborea*, *Pteromys volans*, *Sciurus vulgaris*, *Tamias sibiricus*, *Spermophilus undulatus*, *Dicrostonyx* sp., *Lagurua lagurus*, *Clethrionomys rufocanus*, *C. rutilus*, *Alticola argentatus*, *Lemmus* sp., *Myopus schisticolor*, *Micromys minuthus*, *Microtus arvalis*, *M. gregalis*, *M. maximoviczii*, and *M. oeconomus*. It was non-analog in recent, ecologically mixed, periglacial or disharmonious one, its two species: tundra *Dicrostonyx* and steppe *Lagurus*, which inhabit quite different natural zones at present time.

Holocene small mammal fauna was represented by modern species only, which inhabited the forest-meadow-steppe landscapes: *Lepus timidus*, *Ochotona hyperborea*, *Pteromys volans*, *Sciurus vulgaris*, *Tamias sibiricus*, *Spermophilus undulatus*, *Clethrionomys rufocanus*, *C. rutilus*, *Alticola argentatus*, *Lemmus* sp., *Myopus schisticolor*, *Micromys minuthus*, *Microtus arvalis*, *M. gregalis*, *M. maximoviczii*, *M. oeconomus*.

Acknowledgements The researches were supported by Russian Foundation for Basic Research, grant N 16-05-01096.

Small mammoth from the Eastern Siberian Sea coast (Russia)

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Session 3: Poster

In 2012, two small M3 teeth of a single individual of woolly mammoth were found on the Eastern Siberian Sea coast between the mouths of the Alazeya and Kuropatoch'ya Rivers (coll. National Alliance of Shidlovskiy "Ice Age" F-3326, 3327). The region is located in the Alazeya-Kolyma lacustrine-thermokarst province, characterized by Edoma Formation's landscape with present-day tundra vegetation.

Teeth with a length of 180 mm show a lamellar frequency of 9.4, similar in size to *Mammuthus lamarmorai*, but larger than *M. creticus*, *Palaeoloxodon cypriotes*, and *P. falconeri*. The crowns of the teeth are shorter in comparison with *M. primigenius vrangeliensis*, but similar in width. Based on the lamellar frequency, the Alazeya mammoth (AM) takes up an intermediate position between the neotype of *M. primigenius* (Taimyr Peninsula) and small mammoths from Wrangel Island and Kastyhtakh. The enamel thickness (1.4 mm) of AM teeth is similar to that of Siberian mammoths of the second half of the Late Pleistocene. It is smaller in comparison with this parameter in teeth of Late Pleistocene mammoths from Berelekh (1.5-2 mm), but slightly exceeds the enamel thickness of the Wrangel mammoth (1.0-(1.11)-1.3 mm). Teeth characteristics of AM coincide with the same ones of mammoth of the Karginian interval (Denekamp Interstadial, Late Weichselian (MIS 3)). ¹⁴C dating of sample F-3326 is older than 45000 BP (GrA-60512).

The mammoth was 42-46 years old. On the enamel wear surface thin scratches predominate, with few small pits. Probably, the last few weeks before its death the mammoth fed mainly on herbs. This is in agreement with the stable carbon isotope composition ($\delta^{13}\text{C}$) of the well-preserved enamel, which reflects a dominant C₃ diet. DNA of the mammoth was successfully extracted. However, the endogenous DNA content was rather low, with only 0.11% of the sequenced reads representing mammoth DNA.

Sediments found between the teeth roots consist of brownish-gray aleurites with vivianite, which indicates the protoxide conditions of deposits accumulation. Palynological studies show that the mammoth tooth was probably buried at the lakeshore, as indicated by the presence of pollen of typical water plants (e.g. *Myriophyllum*, *Nuphar*, and *Nymphaea*), as well as remains of green algae (*Pediastrum*, *Botryococcus*). Near the lake there were meadows with a rich variety of local species. The zonal vegetation was represented by northern taiga forest with larch, arboreal birch, shrub and dwarf shrub birches, shrub alder, and willows, with patches of tundra vegetation on the open watersheds. The composition of fossil pollen spectra and flora indicate that the mammoth lived during warm conditions, fitting to interglacial conditions. Other microfossils from the silt such as sponge spicules, testate

amoebae shells, phytoliths of grass and herbs, and others confirm waterlogged conditions of sedimentation.

Grain size analysis of sediment from teeth cavities shows a predominance of silt, typical for the Edoma Formation. The presence of sand (4-9%) points at existence of relatively close sources of coarse grains such as river channel bars. Taking into account the pollen data, we assume a lacustrine origin of source deposits (lake in a vast alluvial plain) during the Kazantsevo (Eemian, MIS 5e), Interglacial. We suppose that the degradation of permafrost led to landscapes changes and isolation of some mammoth's populations, provoking their size reduction.

Acknowledgments The study was supported by Russian Academy of Sciences Fundamental Research Program, paragraph 127 (State Task 0148-2018-0002, Registration Number 01201352492) and grant of the Russian Science Foundation, project No. 16-17-10170.

Neopleistocene (Middle and Upper Pleistocene) stratigraphy and applicable key points in the Karelia, N-W Russia

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Session 4: Poster

The review of available data includes the key site/sections with Neopleistocene stratigraphic units identified according to lithological, paleontological (pollen, diatoms, foraminifera, etc.) features in the Karelia; sporadic sediment successions are ¹⁴C aged here.

Lower Neopleistocene (pre-Holsteinian Middle Pleistocene in the Europe) glacial and interglacial deposits were drilled in southern Karelia. Their relative ages were approximately derived from the position in the sediment succession. Interglacial lacustrine and fluvial clayey sediments (c. MIS 15–17) and two glacial boulder-loam horizons (c. MIS 18 and 14) are likely presented in the boreholes at the *Pay* Village in central part of the Onega-Ladoga Isthmus (c. 61.202 N, 34.450 E). Glacial diamicton (MIS 12) occur in southern Karelia between interglacial units (MIS 13 and 11) in the sediment succession known from borehole near *Orzega* Village, western coast of the Onega Lake (c. 61.650 N; 34.486 E). Glacial gravel-bolder diamicton with 18 m thickness are also identified here under Likhvinian (Holsteinian) interglacial deposits in the borehole situated near *Matrosy* Village (c. 61.763 N; 33.797 E).

Middle Neopleistocene correlates to the Holstein and Saale in the Europe. Key sites *Matrosy* and *Orzega*, Onega-Ladoga Isthmus, proved the sediment succession included interglacial marine and lacustrine clay and paleosol with pollen spectra of Likhvin (Holstein in the Europe; MIS 9–11) type. Indicated Pinus-Picea-Betula forest with broad-leaved trees admixture, birch and coniferous pollen dominate in spore-pollen spectra, scarce pollen of *Carpinus*, *Quercus*, *Ulmus*, *Tillia* and tertiary pollen of *Juglans* sp., *Liquidambar*, *Tsuga* are also present. Glacial sediments correlated to MIS 10 have not yet been established in the Karelia. Key site *Kolodozero* (61.78430 N; 37.73372 E), SE Karelia, provide the spore-pollen evidence of the glacial (MIS 8) and marine/lacustrine (MIS 7) beds. Glacial deposits (MIS 6) are known in the *Petrozavodsk 2* and *3* outcrops (61.812 N, 34.329 E; 61.810 N, 34.334 E) on the Onega Lake terraces.

Upper Neopleistocene three key site/sections (*Petrozavodsk 2* and *3* and *Kluchevoi* (c. 61.750 N, 34.425 E)) proved the sediment succession included interglacial marine and

lacustrine sand, silty clay, silt, and clay with Mikulino (MIS 5) spore-pollen spectra. Glacial diamicton and melt-water sand (MIS 4) were identified in the key sections *Petrozavodsk 1* (61.7983 N; E 34.3694) and *Kukovka* (61.769 N, 34.380 E) in southern Karelia. These deposits are overlaid here by the interstadial (MIS 3) lacustrine sand or peat. Interstadial sediment from both mentioned sections and from the key section *Drevlyanka* (c. 61.75 N; 34.33 E) have been yielded ages 43900 ± 900 , 41800 ± 950 , 38700 ± 850 , 31750 ± 500 ^{14}C yr. BP. Last Glacial (MIS 2) till and melt-water sediments are common in the Karelia. Key sites/sections with Last Glacial sequences substantiated by paleontological data and ^{14}C aged are *Sortavala* (Kheljulia) (c. 61.750 N, 30.717 E) on the northern Ladoga coast, *Pudozh* (c. 61.806 N; 36.467 E) and *Tambichozero* (61.935 N, 37.902 E) in the SE Karelia.

Acknowledgments This is a contribution to the DATESTRA project. The studies have been carried out within the framework of the research project GI KSC RAS № 0231-2015-0010.

Chronostratigraphy of sediments in the Ural caves

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Session 3: Poster

Research area: the Northern, the Middle and the Southern Urals (from 62 N to 52 N). Objects of research were deposits in the inner parts of caves and in grottoes.

Methods. The deposits are dated by radiocarbon and biostratigraphic methods. The data of the species composition of vertebrate fauna and the evolutionary level of some mammalian genera (*Dicrostonyx*, *Arvicola*, *Microtus*) were used.

Material. The data for the sediments of the inner parts of 20 caves and 12 grottoes were used. More than 120 radiocarbon dates have been obtained from the bones of these deposits. More than 150 local vertebrate fauna (consisting of more than 200 000 bone remains) were studied.

Results. The oldest deposits in the Ural caves date back to MIS 6. It was found that in the inner parts of the caves deposits were formed at the end of MIS 6, MIS 5 and MIS 3. In the grottoes the deposits were formed in MIS 3, MIS 2 and MIS 1. In the inner parts of the caves the widest layers of sediments are formed in MIS 5e and MIS 3. In the grottoes the widest layers have the precipitations aged 14,000-10, 000 radiocarbon years ago and 2, 500-100 radiocarbon years ago. The highest rate of precipitation accumulation in the grottoes was 14 000 – 12 500 radiocarbon years ago.

Acknowledgments The reported study was funded by RFBR according to the research project № 18-04-00982a.

***Stephanorhinus kirchbergensis* from Gorzów Wielkopolski (Poland) – its significance in research on Polish Eemian Interglacial**

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Session 3: Oral

During the road works on highway S3 near Gorzów Wielkopolski (Poland) a rarely well preserved and almost complete skeleton of the forest rhinoceros *Stephanorhinus kirchbergensis* was found. This incidental find led to a detailed study of the geological context, dating of the sediments and malacological and palaeobotanical studies

The rhinoceros' skeleton and an isolated fallow deer bone (*Dama dama*) were buried in gyttja located between sediments OSL-dated as 140.8±5.4 and 109.8±5.4 ka. Also layer of peat laying above these sediments was dated with radiocarbon method to 36.0±0.3 ka. The malacofauna from the sediment was described. The ratio of *Bithynia tentaculata* opercula to its shells and the massive presence of *Valvata piscinalis*, indicate that the sediments containing the rhinoceros' skeleton accumulated in a shallow part of a lake with a silty-sandy bottom and limited presence of submerged plants. The unearthed plant material from the sediment surrounding the skeleton and from the teeth fossae was suitable for the taxonomic analysis. The pollen associated with the skeleton indicates a middle Eemian age, warm climate and landscape in which hornbeam, hazel and alder (*Carpinus*, *Corylus*, *Alnus*) prevailed. The plant remains recovered from the fossae of the teeth suggest that the rhino's last food consisted of hornbeam, hazel, birch (*Betula*) and mistletoe (*Viscum album*). Such food remains have been described from two other sites. The species was a flexible browser, selecting species and plant parts from the local vegetation according to the season. The state of preservation and completeness of the skeleton enabled measurements suitable for the size estimation. With a height of 1.82 m at the withers, 1.60 m at the rump, and a body length reaching above 3 m, the skeleton belonged to a large individual of the large species *S. kirchbergensis*. A peculiar asymmetry of thoracic vertebrae shows that the specimen had a crooked vertebral column. The wear of the teeth, fused epiphyses and senile changes point out, that though suffering from a spine deformation, the animal died at a relatively old age. Like the similar-sized African white rhinoceros, it may have had no natural predators. The lack of cut marks and near lack of tooth marks suggests that it was not hunted, butchered or scavenged.

Cave bears (*Ursus spelaeus* s.l.) in Slovenia: sites, species and datings

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Session 1: Oral

Cave bear remains are the most abundant Pleistocene fossil mammals in Slovenia. First discoveries of cave bears (as *Ursus spelaeus*) were made in Postojnska jama (finds by Henrik Freyer), Mokriška jama (first finds by Johann Pezhar and Henrik Freyer, year 1837) and Križna jama (first finds by Aleksander Skofiz and Dominik Bilinek, year 1846), all in first half of the 19th century. Mostly bones were collected for museum exhibitions in Ljubljana and Wien. After First World War more systematic and ambitious excavation was carried out in Potočka zijalka by Srečko Brodar, still most known cave bear site in Slovenia. In second part of 20th century some new sites, as part of archeological excavation, were investigated in Črni Kal (front part of quarry), Betalov spodmol, Mokriška jama and others. Interesting is that all of sites are located in caves, even those from Črni Kal quarry or Njivice site are from filled cave (cave sediments). Only one exception as plain site at Kostanjevica at Krka, where some milk teeth of cave bears were excavated (Brodar & Osole 1979).

First systematic list of cave bear sites in Slovenia was made by Ivan Rakovec (1975), with 43 cave bear sites. Most of the cave bear remains were dated to Würm age (mostly stadials Würm 2 – Würm 3). Till the end of the 20th century all the cave bear remains in Slovenia were attributed as *Ursus spelaeus* or *Ursus deningeri*. But even in the past, some researchers noticed some differences, like those from Herkove peči (Herkova jama) cave (observed by Vida Pohar). With modern dating techniques more accurate and precise datings were made. Potočka zijalka remains are dated from , from Križna jama bones of cave bears are from 46.5 to 32.55 ka (^{14}C) (Pacher *et al.* 2014) but with some other dating up to 93 ka years (Bosák *et al.* 2010). Remains from Ajdovska jama site, are dated (^{14}C) 48.3 – 51.9 ka (Pacher *et al.* 2011). Most complete dating of fossils and sediments were done in Divje Babe I. site. The remains of cave bears (*Ursus spelaeus* s.l.) are dated (^{14}C and ESR) from 40 to 115 ka year (Turk 2007).

New excavations (Potočka zijalka, Križna jama, Divje Babe I., ...) are contributed to new cave bear material which was studied with new approaches and methods (as morphological and genetic research). As results of this the new species of cave bears were determined in Slovenia (Rabeder & Hofreiter 2004; Rabeder *et al.* 2004). From Potočka zijalka 36 to 26 ka years, Križna jama and some other cave sites *Ursus ingressus* is documented (Pacher *et al.* 2014). From Ajdovska jama the smaller form *Ursus ladanicus* is confirmed (Pacher *et al.* 2011) and oldest remains of *Ursus deningeroides*? (*Ursus deningeri* group) are documented from Herkove peči (Herkova jama) site. As noticeable only few cave bear sites have taxonomic determined species, probably as some researchers oppose new taxonomy of European cave bears. The extinction or dramatic decline of cave bears, probably last species *Ursus ingressus* is known from Potočka zijalka (about 24-25 ka) and only few remains from Ovčja jama, dated as Würm 3 (Pohar 1994).

As part primary aim of Slovenian Museum of Natural History is documenting and monitoring old and new sites. As results of this project in Slovenia today more than 90 sites with cave bear remains are known. Within this project the detail publication is main goal as one of the important Slovenian Paleontological Heritage.

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Figure 1 (Križnar): Cave bear remains in newly discovered parts of cave Čolniči-Obrh. Photo: Ciril Mlinar Cic.

Reference sections of the paleofaunal subdivisions of the Early Pleistocene (Eopleistocene) in the South of Eastern Europe (on the basis of small mammals)

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Session 3: Oral

A new type of reference section, the paleofaunal reference section (PRS), was proposed to denote the most representative section (exposure), complete or partial, that contains a sufficiently informative fossil record characterizing a particular mono- or polytaxonomic faunal complex or association to be used for the purposes of stratigraphy. An integrated analysis of the geological, paleontological and dating evidence on 36 micromammalian localities (47 sections) of the Odessa and Taman faunal complex, ranging the Early Pleistocene (Eopleistocene), was undertaken.

Reference sections for paleofaunal subdivisions (complex, association) are allocated. The horizons 11 to 13 of the section Kryzhanovka were designated as the PRS for the Odessa faunal complex of small mammals: *Clethrionomys* sp., *Villanyia petenyii*, *Villanyia newtoni*, *Villanyia fejervaryi*, *Lagurodon arankae*, *Prolagurus ternopolitanus*, *Mimomys* sp., *Kislangia* sp., *Allophaiomys deucalion* (orthostratigraphic species) and others.

Described were PRSs for 2 mammalian associations of this complex: the Tiligul section (horizons 2-5) for Tiligulska (*Ellobius tiliguliensis*, *Clethrionomys sokolovi*, *Villanyia petenyii*, *Villanyia fejervaryi*, *Villanyia hungaricus*, *Mimomys hintoni*, *Mimomys* cf. *reidi*, *Mimomys* ex. gr. *intermedius*, *Allophaiomys deucalion* and others) and the Zhevakhova gora section (horizons 13-15) for Verhnezhevahovska (*Villanyia petenyii*, *Villanyia fejervaryi*, *Lagurodon arankae*, *Prolagurus ternopolitanus*, *Mimomys hintoni*, *Mimomys reidi*, *Mimomys intermedius*, *Allophaiomys deucalion* and others).

The horizons 6 to 13 of the section Nogaisk were designated as the PRS for the Tamanian faunal complex of micromammals: *Ellobius palaeotalpinus*, *Pliomys kretzoi*, *Clethrionomys sokolovi*, *Villanyia hungaricus*, *Lagurodon arankae*, *Prolagurus pannonicus*, *Mimomys reidi*, *Mimomys intermedius*, *Allophaiomys pliocaenicus* (orthostratigraphic species) and others.

Described were PRSs for 3 mammalian associations of this complex: the Chishmikiy section (horizons 1-10) for Tarkhankutska (*Pliomys episkopalis*, *Clethrionomys* sp., *Villanyia fejervaryi*, *Prolagurus ternopolitanus*, *Lagurodon arankae*, *Mimomys pliocaenicus*, *Mimomys reidi*, *Mimomys intermedius*, *Allophaiomys pliocaenicus* and others), the Nogaisk section (horizons 6-9) for Nogaiska (see above) and the Cherevichnoy section (horizon 9) for Verhnecherevichanska (*Clethrionomys glareolus*, *Lagurodon arankae*, *Prolagurus pannonicus*, *Eolagurus argyropuloi*, *Mimomys reidi*, *Mimomys pusillus*, *Mimomys intermedius*, *Allophaiomys pliocaenicus*, *Microtus hintoni* (orthostratigraphic species for association) and others).

Pleistocene stratigraphy key-sites of Estonia in DATESTRA

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Session 4: Oral

The Pleistocene stratigraphy of Estonia is quite complex because of several glacial activities. Approximately up to 60 metres of Quaternary cover has been eroded by subsequent glaciations and this is probably a reason, why sedimentary record of Early Pleistocene and older Quaternary ages is not found from Estonia and also the Middle Pleistocene sequence is incomplete (Kalm *et al.* 2011). Also many sediments are redeposited, which complicates the understanding of their actual position in stratigraphy. Thickness of Quaternary cover in Estonia is rather thin, usually from 5 to 100 m, thickest in the uplands (often more than 100 m) and in buried valleys of southern Estonia (up to 200 m).

The Pleistocene stratigraphy of Estonia is developed in combination with chronological, bio- and lithostratigraphical data from numerous sites/sections and often the sedimentary record is incomplete. On the basis of DATESTRA aims, the sites with longer sedimentary records and which are most investigated and important were chosen for the database input.

DATESTRA focuses on the main Quaternary stages as assessed by IGSC (Early-, Middle-, Upper Pleistocene and Holocene) and here is an overview of key-sites (Kalm *et al.* 2011) with their importance in Estonian stratigraphy.

Middle-Pleistocene sites:

Puistee site - oldest Quaternary sediment in stratigraphical position has been found and it is interpreted as Elsterian till.

Karuküla and Kõrveküla sites - Holsteinian interglacial deposits are found and detailed palynological and carpological analyses have been carried out.

Prangli and Valguta sites – possible interstadial deposits between two Saalian tills were found.

Upper-Pleistocene sites:

Kihnu and Rõngu sites –important Eemian interglacial sites, where entire Eemian vegetation cycle is present in the sediments.

Arumetsa and Voka site- terrestrial interstadial deposits of Middle Weichselian are present with pollen analysis, OSL dates and many more were analysis carried out.

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Evidence for five short “warming” episodes during MIS 6 at the westernmost tip of continental Europe: Contribution of pedogenesis

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Session 3: Oral

Study of the distribution and of the dynamic of the population of *Pupilla muscorum* in the Nantois loess cliff (Brittany, France) allowed to discover the existence of four abrupt and short climatic improvements during MIS6 at the westernmost tip of continental Europe. These “warming” events were compared with the alternations of cold faunas and temperate flora recorded during the same period in la Cotte de Saint Brelade (Jersey island), with the global and contemporaneous variations of the sea-level, with the concentration of laminae measured in deep boreholes of the Celtic Sea, with the relative frequency of the *Neogloboquadrina pachiderma* a benthic foraminifera preserved in the same core and with the maximum amplitudes of the astronomical parameters of insolation and precession calculated for this period. All these comparisons confirm the existence of the four “warming” events discovered in Brittany.

In order to better understand the local genesis of the “warming” episodes, we decided to re-investigate the Nantois formation (=Upper Saalian) with the ultimate purpose of checking if some paleosols could have been generated during the warming episodes. In total 64 samples of loess and loam, exceeding the Upper Limit of the Upper Saalian formation, were analysed. The magnetic susceptibility (MS), the total organic carbon (TOC), the content in CaCO₃, the share of soluble humus substances in deposits (CHS) and the position in wavelength of the fluorescence maximum of the soluble humus substance were first quantified. This initial series of analysis was followed by the study of the spectral characteristics of the humic acids in the ultraviolet, visible and infrared parts of the spectra. Taken as a whole, these investigations evidenced good correlations between the MS, TOC, CHS and positions of the fluorescence maximum in three cases (figure 1A: 1, 3, 4) suggesting the existence of three primitive pedogenesis developed during three “warming” episodes. A first singular correlation is represented by level 2 (figure 1A) where all parameters, save CHS, are characterized by lower values, although it corresponded with the larger shell production (figure 1B). The second singular correlation can be observed in level 3 which is characterised at the same time by the best developed set of parameters, typical of a soil, but also by the total absence of gastropod shells. This may result from a complete decalcification of the sediment by the fulvic acids prevailing in humus of layer 4. The “limon a doublets-like” layer (figure 1A: 5) which is made of thin alternations of sandy and silty loess, iron-rich clays and strong iron-coated silt grains was generated during an active snowmelt period. Its high iron content explains the clear MS peak. This short “warming” episode (equivalent to the Seidenkrantz’s Linxert Interstadial) was probably also at the origin of the well developed TOC and CHS values. The difference between the thickness of the decalcified zones previously calculated and the present study clearly illustrates the irregular limit of the decalcification front generated by an overlying soil.

The pedogenic study confirms that the Upper Saalian sediments of Nantois cliff formed in cold environmental conditions, identical to a tundra. The four relative “warmings” which

were postulated after the malacological study are now better identified and confirmed by the pedogenic investigations, but this study was also able to demonstrate the existence of a fifth soil completely devoid of shells which was not suspected before. The H to C ratio which was used to better define the approximate amplitudes of these limited “warmings” broadly suggests, as well as the MS and TOC parameters, the existence of a global cooling trend between 190 and 130 ka. Unfortunately, the content of humic acids in the sediments is so low that we have not been able to determine this parameter for some of them.

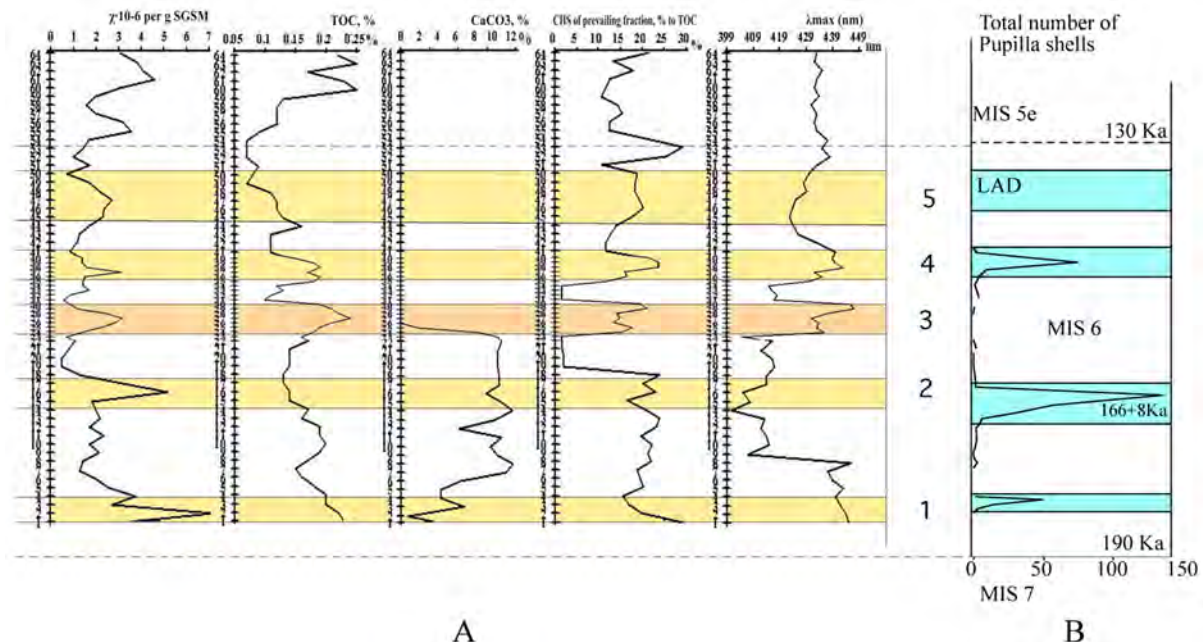


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3-D structural model of the Niedźwiedzia Cave (Sudetes, SW Poland) karst system

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Session 2: Poster

The discovery of the Niedźwiedzia (Bear) Cave in 1966 began the first research stage lasting until the mid of the 1980s. New cave exploration chapter began in 2011. In this work, we present a resultant numerical model integrating both structural data as well as cave surveying and LiDAR-based topography. The first stage of work based on the processing of the karst system measurement data followed by xTherion processing (authors S. Mudrak, M. Budaj). In the next stage, the cave model has been integrated with a LiDAR-based digital elevation model (DEM) database. Next, structural geological data have been introduced and assembled as a digital representation of planar surface within a Move (Midland Valley) package. The creation of the Niedźwiedzia cave passages model enabled accurate location of underground structural measurements sites (e.g. foliation, joints, faults). Finally, we constructed a 3D model of deep geological structure for the Niedźwiedzia Cave region based both on the structural measurements from the surface and inside the cave. The prepared model makes it possible to re-interpret the local geological setting, and among others, identification of a series of N-S folded beds and discuss the role of bedrock structure in cave origin and evolution.

Using a 3D model for visualisation of the Quaternary deposits within glacial cirque – a case study from the Łomniczka Valley, Eastern Karkonosze Mts.

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Session 2: Poster

We present the preliminary results of morphometric, structural and geophysical characteristics of the Łomniczka Glacial Cirque, also known as the Łomniczka Valley, located in the eastern part of the Karkonosze Mts. (SW Poland). Within the valley, three lithological units crop out: granite, microgranite and hornfels. Our research gives particular attention to identification and recognition of the Quaternary deposits infilling the Łomniczka Glacial Cirque composed both of glacial and slope derived deposits. The first type of strata corresponds to the Pleistocene moraine deposits. The glacial deposits occur along the Łomniczka brook, forming two hummocky-moraine ridges, 1.5 km long and 50-80 m wide. The moraine material is composed of granite debris and single blocks ranging in size from 0.2 up to 2 m. The debris material contains blocks which are angular, poorly sorted (chaotic) and structureless. Slope deposits are considered as a mixture of Pleistocene–Holocene in age sediments. They represent debris flows deposits and blocky cover on the slopes of Mt. Śnieżka. In the study area, there are two spatial clusters of debris flows tracks: on the western and southern slopes and southeastern slopes of the Łomniczka Cirque. Channel morphology is

diversified, with the maximum width in the upper part of the flows' tracks, up to a few meters and maximum length to 500 m. The highest position of source area for the erosional channels is 1520 m a.s.l. at northern slopes of Mt. Śnieżka and 1350 m a.s.l. at eastern slopes of Mt. Kopa respectively. In the upper and middle segments of the tracks, the channel floor constitutes usually a solid bedrock. In the lower parts, channels are filled with a debris material. On the eastern slopes of Mt. Kopa, debris flows formed several levees along the channels and a debris fan at the channel toe. Predominantly, the debris fans form a tongue-shaped cover deposited at different altitudes between 1200-1250 m a.s.l. to 1050 m a.s.l., reaching the Łomniczka brook floor. Both the levee and debris fan deposits consist of unstratified, poorly sorted, angular blocks and boulders. Additionally, debris flows erode Pleistocene glacial deposits, which makes their final classification challenging.

For the regional analysis we applied a digital elevation model (DEM) based on high-resolution airborne LiDAR data. Based on DEM LiDAR data we performed morphological profiles for the Łomniczka Cirque. Next, by application of DEM LiDAR data used as a proxy of recent relief combined with DEM reconstructed pre-glacial relief, we did volumetric statistics for the Quaternary strata infill. To improve the quality of the calculations, we used both a DEM-based and GPR-derived (Ground Penetrating Radar) datasets. GPR surveys have been realised with an unshielded Sub-Echo 40 antenna (Radar Team, Sweden) and a centre frequency of 52 MHz. The main aim of this survey was to recognise a boundary zone between Quaternary deposits and granitic bedrock. Then the designated lines were connected to one surface, which should represent an original relief of the Łomniczka valley. Based on our data we constructed a final 3D geological model of the Quaternary deposits supplemented with an isopach map.

An input of key sites in Poland to the European stratigraphy

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Session 4: Oral

Present stratigraphy of the Quaternary of Poland arose from several approaches presented during the last thirty years. Distinguished stratigraphical units were given names of local derivation, they comprise deposits in natural superposition and are correlated with one another based on common diagnostic features and separating boundaries. Most key stratigraphical units were defined based on lithological and palaeontological criteria, occasionally with reference to landforms, palaeoclimate and age. These units are mostly of local and regional significance but informal, although some recommendations of the International Commission of Stratigraphy were fulfilled for their establishment. Formalizing of stratigraphical units as well as creation of new and revision of existing ones demand several criteria to be fulfilled, the most important of which is not only the name, but also the unit type and order, location of stratotype section or area, sense of establishment, diagnostic features and precise criteria to determine the unit boundaries and age. The boundaries of should be concordant with extension of diagnostic features of a unit. Stratigraphic correlation is based on indication of age equivalents or lateral extension of deposits in different regions, using different criteria (e.g. fossils, lithology, radiometric data, palaeoclimate symptoms). It can result in reduction of local units in favour of regional and global ones.

A stratotype is a selected geological section (outcrop, drilling) that presents a typical sedimentary sequence for a stratigraphical unit or boundary and should be representative as much as possible for a distinguished unit. It may not contain all lithological or facies diversities but it should create foundations for a clear uniform stratigraphic definition. In the Quaternary stratigraphy complex stratotypes are usually distinguished, composed of several partial sections that is with fragments of a stratigraphical unit. A stratotype area is a region with a stratotype section or where a stratigraphic unit was distinguished for the first time. The stratotypes should be based on complex examination, firstly lithological, palaeontological and geochemical one, desirably supported by reliable dating and eventually, by reasonable correlation with marine isotope stages (MIS).

Most sites in Poland that are treated as key ones for the Quaternary stratigraphy have been univocally and fragmentarily recognized but in particular, they do not possess sufficient geochronologic backbone. Therefore, a subordination of determined stratigraphical units to a definite setting in a stratigraphical chart is commonly an arbitral decision, similarly as referring the distinguished climatostratigraphic units to individual MISes.

In the Polish stratigraphical chart the best documentation is for the Podlasiian (Cromerian I-II), Ferdynandovian (Cromerian III-IV), Mazovian (Holsteinian) and Eemian interglacials and obviously the Holocene. It determined a geological setting of the preceding and following glaciations. Setting of the Podlasiian Interglacial was recorded at the sites Kończyce (southern Poland) and Kalejty (northeastern Poland) by the Brunhes/Matuyama boundary within MIS 19 and dated at ca 780 ka BP. It permitted to set the Nidanian Glaciation to MIS 22 and the Sanian 1 (Donian) Glaciation to MIS 16 (Lindner *et al.* 2014). Correlation of palaeoclimate indices in deep-sea cores offshore Portugal determined setting of the Ferdynandovian and Mazovian interglacials (Bińka & Marks 2018), and it pointed out univocally a position of the Sanian 2 (Elsterian) Glaciation in MIS 12. A younger part of the Quaternary (MIS 6-1) is mostly within the reliability extent of OSL and radiocarbon dating, and besides setting and correlation of the Eemian Interglacial in European stratigraphical subdivision is not under discussion. Therefore, correlation of the Odranian (Saalian) Glaciation with MIS 6 and the Vistulian (Weichselian) Glaciation with MIS 5d-2 seems obvious. Age of the lower boundary of the Holocene was well determined by varve chronology in lake sediments at Gościąż in central Poland at 11,510±50 cal BP (Goslar 1998) and it is very close to the age of the global stratotype in the NGRIP ice core (Walker *et al.* 2009).

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The Plio-Quaternary fluvial archives in the Slovenj Gradec and the Nazarje Basin, Northern Slovenia

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Session 2: Oral

This study focuses on two intramontane basins in northern Slovenia, the Slovenj Gradec, and the Nazarje Basin, with preserved Plio-Quaternary fluvial sediments. It aims at defining the morphostratigraphy and provenance of the Plio-Quaternary sediments with implications on drainage evolution in the studied basins using several methods. Morphostratigraphy for each basin was constrained by using basic geomorphic analysis with high-resolution digital elevation models, which served as a stratigraphic control for the following locations: Sredme (SR), Motocross (MC) and Curava vas (CU) in the Slovenj Gradec Basin, and sections Lačja vas (LAV), Otok (OT) and Dobovec (DOB) in the Nazarje Basin. The sections were logged and sampled for clast lithological analysis, which were conducted on 60-90 clasts per sample. In total, 246 and 215 clasts were analyzed in Slovenj Gradec, and Nazarje Basin, respectively. In addition, 77 thin sections from both basins were examined focusing on indicator lithologies. The results of geomorphic analyses show a terrace stratigraphy comprising several Quaternary (T0, T1) and Plio-Quaternary terraces (T2, T3, T4). The ages of the terraces were inferred from morphostratigraphic correlations and the degree of degradation of the geomorphological characteristics (e.g. presence of the terrace surface, relief on the terraces, shape of the risers) in combination with lithological characteristics. Several indicator lithologies were identified and assigned to a certain formation/area. In the Slovenj Gradec Basin, three main lithogroups were identified: i) subvolcanic-igneous, which to some extent exhibits characteristics of formations in the Pohorje area, ii) schists to retrogressed gneisses with contact metamorphic imprint attributed to the area of Mala and Velika Kopa from the Pohorje massif, and iii) amphibolites to amphibolitic schists indicating Pohorje, Strojna and Košenjak provenance. In the Nazarje Basin, four lithogroups were identified: i) Oligocene Smrekovec volcanic rocks outcropping north and east of the basin, ii) Triassic volcanic rocks, which are preserved south of the basin, iii) Triassic carbonate rocks, which can be found in the wider area south, west and east of the basin, and iv) clastic rocks of presumably Val Gardena Formation with provenance in the area of the Savinja River spring. The provenance results imply that during the Plio-Quaternary, the drainage regime was similar to the present one.

Karst – formation, morphology and sediments on examples from Slovenia

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Session 1: Oral

Karst is a type of landscape with special surface, underground and hydrological features and phenomena. Its main characteristic is dissolution of the rock as the dominant morphological process, its removal in the form of solution, and major underground drainage that forms caves. Karst relief depends on lithology and structure of the bedrock, its topographical position, and its location within the hydrological system. Karst forms during a wide time span during which other geomorphic processes also occurred and influence karst morphology. Karst, especially caves, represent very good trap for sediments and they can be preserved in good conditions for very long time. In caves at low elevations most important are speleothems, which deposition well represent the climatic conditions on the surface.

Karst in Slovenia developed only on limestone and dolomite and covers 8,800 square kilometres (43%) of the country. According to the general morphological and hydrological conditions and its evolutionary history, it is divided into three principal karst areas.

Alpine karst is characterized by large vertical gradients and a mixture of fluvial and karst elements. Alpine karst belongs to the Southern Calcareous Alps. A thick vadose zone and deep cave systems developed there. Existing caves are mostly vadose ramp/pitch shafts. Sediments in alpine caves are usually scarce, mostly of collapse origin. However, on some plateaus and mountain ridges are some very old relict caves formed by horizontal flow of underground rivers. In some of them, in Snežna jama and caves on allogenic sediments were deposited in Pliocene before the main uplift of the Alps.

Isolated karst developed in small limestone areas surrounded by impermeable rock that controlled the evolution of the encircled patches of karst. Morphology and evolution of each of such karst is defined by the local hydrology. Usually there are many cave entrances and caves with abundant sediments quaternary or older sediments.

Dinaric karst is the main type of relief of Dinaric mountains and represents the major karst area in Slovenia. The central part of the mountains consists of row of 800–1500 m high karst plateaus. From them step-like low karst plateaus and planation surfaces descent to both sides. Lowest plateau on littoral side, above the Trieste bay is Kras.

Dinaric karst is most prominent in terms of size, geomorphology, hydrology, and caves. The dominant relief features are extensive level surfaces at various elevations, closed depressions like dolines, uvalas and poljes. The surface morphology is characterized by intermittent soil cover. Rivers only appear at the bottoms of poljes depending on the level of the groundwater. On the edges several surface rivers flowing from non-carbonate regions and sink into karst, often forming large cave systems.

Sediments on karst are accumulated in closed depression and in caves. Vertical cave entrances can act as a trap for animals. Mostly Quaternary sediments can be found at entrances to relict caves. More important are allogenic rivers that bring sediments into the large cave systems, which are often developed in levels, with active caves in lowest level and relict caves above them. Important feature on Dinaric karst are unroofed caves. They form when karst denudation dissolves the rock ceiling above old relict cave and expose old cave sediments. They represent the oldest cave sediment and are in Dinaric karst Miocene, Pliocene or younger.

Last interglacial climate variability observed in stalagmites from Central and South Eastern Europe

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Session 1: Oral

Since last 5 million years Earth climate has been dominated by characteristic for ice age cyclicity of climate change, long cold periods (glacials) were cyclically interrupted by short warm periods, known as interglacials. The last interglacial (LIG) time duration is conventionally set at 130 and 116ka, based on sea level variations and marine records. In marine sediments the LIG is defined as Marine Isotope Stage (MIS) 5e. LIG in continental Europe used to be defined as the Eemian, however Eemian doesn't cover the MIS 5e period. Eemian should be rather defined as the LIG optimum. In comparison to Holocene the LIG climate was unstable; this instability has been caused by changes in the dynamic of the North Atlantic Meridional Overturning Circulation. However, climatic mechanisms and the sequence of LIG events are only partially known. Key limitation is a lack of suitable radiometric dating techniques and precise absolute age benchmarks like: dated tephra layers or magnetic excursions. Therefore, many of LIG chronologies base on indirect approaches like record alignment strategies. In this context, speleothems are chronologically robust archives because of their capability to be dated by U-series method. In Europe speleothem LIG records are known mostly from west and central part of the continent.

In this study, we present speleothem isotopic ($\delta^{18}\text{O}$, $\delta^{13}\text{C}$) records from several caves located in Central and South Eastern Europe. Three from studied stalagmites come from Western Tatra Mountains. They were taken from three different caves: Brestowska Cave, Dziura Cave and Magurska Cave, located in Slovakia and Poland. One from studied stalagmites was taken from Slobody Cave, located in Low Tatra Mountains in Slovakia. The last from studied stalagmites was taken in Bulgarian cave Orlova Chuka.

All stalagmites were successfully dated by U-series method using mass spectrometry as a measurement technique. Stable isotopic records obtained from stalagmites located in Central Europe covers period of time from ca. 165 ka to ca. 90 ka. It is possible to distinguish the cold pulses during MIS 6, stage of last interglacial development, its optimum and transition into last glacial. Bulgarian stalagmite covers period of time from ca. 135 ka to ca. 114 ka which covers whole last interglacial period.

Previously the only known isotopic record of LIG age from Central Europe was known from Baradla Cave. Results of this study bring five new stable isotopic records from Central and South Eastern Europe. It gives possibility to make a regional comparison between Western and Central Europe.

Acknowledgments This study has been supported by grant of Polish Ministry of Science No-2015/19/D/ST10/00571.

Paleoglaciological record of the Scandinavian Ice Sheet advance during Mid-Pleistocene glaciation in Central Europe (Sudetes, SW Poland): an interplay of local topography and Quaternary stratigraphy reassessed

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Session 2: Poster

Quaternary sediments assemblages from the Central Sudetes area have been studied using a multi-proxy approach: geological mapping, well-logs data, LiDAR DEM data as well as petrographic and sedimentological analyses. The study area is located within the Krzeszów Basin, an NNW-SSE elongated syncline built of Permian, Triassic, and Upper Cretaceous volcano-sedimentary succession. During the Middle Pleistocene (Elsterian, MIS12) the research area has experienced a Scandinavian ice-sheet glaciation, resulting in a local topography re-modelling under glacial/periglacial conditions. Hitherto, neither number of glaciations nor their timing and maximum limits within the Sudetes Mts. are well documented, leaving several open questions and no consensus among research groups. The main reason hindering proper stratigraphic correlations of the Pleistocene sediments inside the Sudetes is their patchy-like, very often highly re-worked nature. With this poster, we do present a detailed study of the Pleistocene sediments at the southernmost limit of the Scandinavian ice sheet. By application of well-logs based isopach map, we roughly estimate possible paths for the Krzeszów ice-lobe transgression during MIS12 and its influence on local topography. We also present results of lithofacies and clasts' petrographic composition analyses from a newly described site of Pleistocene sediments found nearby Krzeszów. Referenced deposits chiefly represent a glacial and glaciofluvial sedimentary succession. Petrographic study of 5-10 mm in size gravel clasts revealed a high content of local material (>60% - Cretaceous sandstones and Permian clasts), suggesting NW ice-related transport component. Presented results confirm previously anticipated southernmost Scandinavian ice-sheet limit inside the Central Sudetes, however with a minor correction being applied, which shifts this line further to the SSE within a Krzeszów Basin.

First evidence of Barbary macaque (*Macaca sylvanus* Linnaeus, 1758) (Primates, Cercopithecidae) from Pleistocene sediments in Slovenia

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Session 1: Poster

In the active quarry Črni Kal in the SW part of Slovenia, fossil cave sediments occasionally appear on the surface due to quarry expansion and limestone rock exploitation. In one of such freshly opened erosive crack filled with sediments at the northern quarry edge, several Pleistocene faunal bone fossils were discovered in the last years. Besides from bones and teeth of deer (*Cervus/Dama* sp.), roe deer (*Capreolus* sp.), bovids (*Bos/Bison* sp.), bear (*Ursus* sp.), rhinoceros (*Stephanorynus* sp.), some small carnivores and small mammals, a single primate tooth has been found by the Author in February 2016.

The tooth appeared to be a permanent left upper premolar PM3 tooth, which belonged to an adult specimen of macaque (*Macaca*). Due to its dimensions and the occlusal morphology, the tooth is likely to have belonged to a male individual. During the quarry works the tooth was probably incidentally separated from the matrix cave sediment. It was found separately on the crack bottom soil and rock debris. The precise investigation of the stratigraphy where the tooth was originally embedded was thus impossible to do.

The Barbary macaque (*Macaca sylvanus* Linnaeus, 1758) appeared in Europe during Pliocene and went mostly extinct in Late Pleistocene. Although macaques' fossils are rare in Europe, fossil evidence show that the species was widely distributed throughout Europe. It is still present in North Africa and in isolated population in Gibraltar. The rock cliffs of the site Kraški rob where Črni Kal quarry is located might have been a suitable habitat for this primate. The finding from the quarry Pleistocene sediments in Črni Kal represents the first evidence of Barbary macaque in Slovenia. The presence of the Pleistocene macaque within Slovenian territory was actually expected, since fossil remains were found in neighboring sites in Italy and in southern Istria, Croatia.

Quaternary key sections in the north of European Russia – a contribution to DATESTRA

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Session 4: Oral

There are regional stratigraphic units for Timan-Pechora-Vycheгда part whereas stratigraphic chart for European Russia is used for Arkhangelsk region.

Timan-Pechora-Vycheгда region (W-Ib)

In the valid chart (Guslitser et al. 1986) there are the following Lower Neoplietocene horizons: Kama glacial = Likovo glacial (MIS 18), Tumskaya interglacial = Ilyinka interglacial (MIS 17), Beryozovka glacial = Don glacial (MIS 16), Visherka interglacial = Muchkap interglacial (MIS 13) and Pomus glacial = Oka glacial = Elster (MIS 12). Sediments of the Lower Neoplietocene are known only from boreholes. In the south of the region in the Pechora-Kama interfluvium, where more than 900 wells were drilled, three moraines and two separating them interglacial beds are known (Stepanov 1974). Two lower moraine horizons are referred to the Lower Neoplietocene, whereas the youngest glacial event of the Early Neoplietocene – Pomus glacial is represented by a remnant of limnoglacial sediments (Stepanov, 1974). By lithological and mineralogical traits till beds are slightly different from each other. The predominance of sedimentary rocks was noticed in the Beryozovka moraine (Stepanov 1974). A relatively high content of pyrite and epidote in Tumskaya deposits is typical for the Early Neoplietocene in eastern part of the Russian Plain (Stepanov 1974). A specific trait of interglacial sediments in these sections is the absence of spores and pollen of index Early Neoplietocene species such as subtropical Tertiary relics (*Liquidambar*, *Pterocarya*) and exotic plants (*Azolla*, *Ilex*, *Tsuga*, *Osmunda cinnamomea*, *O. claytoniana*), therefore these palynological assemblages do not differ from Chirva (Likhvin) ones. V. Astakhov (2004) suggests that not only two lower but all three moraine beds in the Pechora-Kama interfluvium may be correlated with Lower Neoplietocene moraines Likovo (MIS 18), Don (maximum) glacial (MIS 16), Oka glacial (Elster, MIS 12).

Interglacial sediments dated to Visherka horizon according to above mentioned palynological characteristics were found in boreholes and river sections in the north (sect. 343

in the Pay-Khoy; ditch 33 and borehole SDK-80 on the Moreyu River) and in the south (borehole 32 on the Vychegda River) (Duryagina & Konovalenko 1993). Cold marine transgressive Kolva formation in the borehole SDK-80 (a.s.l. 88-143 m) may most likely be dated to Tumsкая interglacial = Ilyinka interglacial (MIS 17); underlying glacial sediments may probably be correlated with Kama glacial (MIS 18) (Loseva 2000; Astakhov 2004).

The Middle Neopleistocene includes Chirva interglacial = Likhvin interglacial = Holstein (MIS 9-11), Pechora glacial = Dnieper glacial = Vologda glacial = Fuhne (MIS 8), Rodionovo interglacial = Shklov (Gorka) interglacial (MIS 7), Vychegda glacial = Moscow glacial = Saale (MIS 6) (Guslitser et al. 1986).

Chirva deposits are known in boreholes in the north in the basins of rivers Shapkina (borehole 8-U), Laya (boreholes 3-U, 5-U) and Kolva (borehole 71) and in the south (borehole 21 in the interfluvium of Pinega and Ilesha rivers). Chirva age is determined by the stratigraphic position of beds in the sections and by spore-pollen spectra, which lack Early Neoleistocene relics and exotic species but contain pollen of spruce sect. *Omorica*, pine sect. *Strobus*, broad-leaved species (up to 10%) *Quercus*, *Ulmus*, *Tilia*, *Carpinus*, *Corylus* and spores of *Osmunda claytoniana* (Duryagina & Konovalenko 1993).

Key sections of Pechora horizon are located on the Pechora River (Akis, Kipievo, Rodionovo) and on the Vychegda River (now not exposed sections Bolshaya Sluda and Gavrilovka) where Pechora beds occur in the lowest parts of sections down to water level. An independence of Pechora horizon is proved by the stratigraphic position of beds and lithological traits of till. Clast fabric orientation in Pechora till indicates glacier movements from north-northeast. Provenance-dependent erratics such as crinoid-bryozoan limestones from Novaya Zemlya show the connection of the till with Pay-Khoy-Novaya Zemlya glaciation center (Andreicheva 2002).

Stratotype section of Rodionovo horizon is located 6 km downstream Rodionovo village on the Pechora River (Loseva & Duryagina 1973; Guslitser et al. 1986). A series of U/Th and OSL dates was obtained from Quaternary sequence in the section (Astakhov 2004). In the stratotype section and in several boreholes Rodionovo sediments are found between two moraines attributed to Pechora and Vychegda by lithological traits. Palynological spectra from Rodionovo deposits show two thermal maxima but spore-pollen composition is very similar to Chirva interglacial (Duryagina & Konovalenko 1993). Sometimes Rodionovo and Chirva sediments are found at the same absolute levels (Loseva *et al.* 1992) that together with palynological resemblance of two horizons allowed V. Astakhov (2004) to assume that Rodionovo and Chirva interglacials may actually be the one event. It is very likely that Chirva and Rodionovo sediments were found in superposition in the borehole 21 located in the interfluvium of Pinega and Ilesha rivers in the south of Arkhangelsk region (Andreicheva & Konovalenko 1989).

There are several key sections of Vychegda horizon where the age of deposits is reliably proved by several methods (micromammalian remains, lithological traits of tills and dates). In sections at Shapkina River (Shapkina 1107, 1111) the Vychegda age of till is argued by remains of collared lemming and TL dates (Andreicheva 2007; Andreicheva & Ponomarev 2018). In section at the Seyda River (Seyda-1) the Vychegda moraine is proved by OSL dates (Astakhov 2004) and in Kipievo – by the morphology of collared lemming's remains and lithology of till (Guslitser 1981; Andreicheva & Ponomarev 2018). Clast fabric orientation from northwest as well as Fennoscandian erratics in Vychegda till indicate that the glacier moved from Scandinavia. An interesting section crossing an esker which was deposited at the limit of Vychegda (Moscow, Saale) glaciation is known in the abandoned quarry in the mouth of spring Iz'yayol in Komi Republic (Andreicheva 2002).

In the Upper Neopleistocene there are Sula interglacial = Mikulino interglacial = Eem (MIS 5e), Laya cold stage = Kalinin (Lower Valdai) = Early Weichsel (MIS 5-4), Byzovaya

interstadial = Leningrad interstadial (Middle Valdai) = Middle Weichsel (MIS 3), Polar glacial = Ostashkov = Late Weichsel (MIS 2) (Guslitser *et al.* 1986).

The Sula horizon is reliably established only in several sites along the Sula River where Sula marine deposits containing rich shallow-water boreal mollusk fauna are dated by OSL (Mangerud *et al.* 1999). Other sections with Sula spore-pollen spectra should be confirmed by dates.

Main sections proving the Early-Middle Valdai age of the last glaciation in the region are Paleolithic sites covered only by aeolian sediments dated in the range from 40 to 20 ka, OSL dates under the till and finite ^{14}C dates in the section Timan coast and numerous bones of mammoth fauna dated from 40 to 20 ka (Mangerud *et al.* 1999; Svendsen *et al.* 2010; Astakhov 2014). Main Paleolithic sites are Mamontovaya Kurya dated almost continuously from 50 to 14 ka, Pymvashor and Byzovaya. Other main sections for Late Neopleistocene deposits are Vastyansky Kon and Markhida which are important for understanding of the last continent glaciation, and also Medvezhya and Studyonaya caves with the rich Middle and Late Valdai fauna of mammals. Micromammalian fauna of Lateglacial and Holocene is known from several localities in the Timan Ridge and Urals (Ponomarev *et al.* 2012). One of the most interesting sections is Kur'yador in the upper Vychegda River where LGM loss sediments overlay deposits of the Middle Valdai with spore-pollen spectra and numerous radiocarbon and U/Th dates (Duryagina & Konovalenko 1993; Andreicheva 2011; Maximov *et al.* 2015). The key Holocene sites with pollen spectra and radiocarbon dates are Votcha-1 (Sysola River basin), Gam, 209-1, Sedkyrkesch, Kalya (Vychegda River basin), Sindorskoe lake; Chernutyev-15, Melentyevo, Pizhma-6 (Mezen River basin), Izhma-5 (Izhma River), Markhida, Okunev Nos, Karpushovka, Dutovo (Pechora River basin) (Andreicheva *et al.* 2015).

Arkhangelsk region (W-Ia)

The lowest part of Quaternary sequence exposed in river sections is Moscow till. Lower horizons were found only in boreholes. One of key sections is borehole 21 drilled in the interfluvium of Pinega and Ilesha rivers in the south of region (Andreicheva & Konovalenko 1989). Presumably sediments of Oka glacial = Elster (MIS 12), Likhvin interglacial = Holstein (MIS 9-11), Dnieper glacial = Vologda glacial = Fuhne (MIS 8), Shklov (Gorka) interglacial (MIS 7) and Moscow glacial = Saale (MIS 6) were described in the sequence.

Moscow reddish till (sometimes called "basal till") with Scandinavian erratics is exposed in many sections along rivers Severnaya Dvina (Ust'-Kanza, Krasnoborsk, Krasnaya Gorka, Chelmokhta), Vaga (Pasva, Koleshka), lower Pyoza (Devyatova 1982; Lavrov & Potapenko 2005; Demidov *et al.* 2007).

The Moscow till is overlaid by deposits of boreal transgression (Mikulino, Eem) which is exposed in many classical sections. The main sites are Yolkino and Bychye (Pyoza River) where Mikulino sediments are characterized by all ecozones of marine boreal mollusks and by six spore-pollen zones, Pasva (Vaga River) and Krasnaya Gorka (Severnaya Dvina River) (Devyatova 1982; Funder *et al.* 2002).

The Valdai interval in Arkhangelsk region was studied in detail in more than 100 sections with more than 200 dates (Demidov *et al.* 2006, 2007). The most important section for understanding complicated geological history during Valdai is Cape Tolstik where three pre-LGM moraines are exposed (Kjær *et al.* 2003; Demidov *et al.* 2007). Up to 12 stratigraphic levels (events) are distinguished for the Late Neopleistocene by I. Demidov *et al.* (2007) from the Mikulino (Eem) to Holocene. The oldest (100-90 ka) Valdaian glaciation advanced from Kara Sea and deposited Pesets moraine that is exposed in sections of Cape Konushin, hillock Pestsovaya and Tarkhanov spring. This till is overlain by interstadial sediments dated 90-75 ka and found in sections Yolkino and Safonovo on the Pyoza River. Next ice advance probably moved from Timan Ridge 75-70 ka as inferred from Yolkino till which was found in

Cape Tolstik, Yolkino and Safonovo. Yolkino till is overlain by Tolstik moraine (Cape Tolstik, Vzglavny) deposited by ice sheet moving from Barents sea 70-65 ka. After this ice advance there was Mezen interstadial (65-55 ka) with marine transgression described in key sites Cape Tolstik, Syomzha, Vzglavny, Zhelezny. Syomzha moraine of glaciation from Kara sea 55–45 ka was found in sections Cape Tolstik and Syomzha. Interstadial interval after Syomzha glaciation (45-20 ka) was followed by considerable Scandinavian glaciation 20-17 ka. This event is recorded as Bobrovo till which can be found in key sites Bobrovo, Trepuzovo, Kargovsky. Key section for Late- and Postglacial is (17–10 ka) Osinovskaya (Demidov *et al.* 2007).

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Bison priscus skull from the Eastern Europe and Siberia

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Session 3: Poster

The bisons probably originated in the southern and central Asia. The representatives of the genus *Leptobos* are considered to be their ancestors. The species *Bison priscus* (Bojanus 1827) is known from the Middle Pleistocene (Kahlke 1999; Brugal & Croitor 2007). In the Upper Pleistocene it was spread from the northern Spain and British Isles, through whole Europe and northern Asia to Alaska and Canada. In Europe *B. priscus* extincted in the end of the Pleistocene in a result of the environmental changes and human's pressure (Nadachowski et al. 2015).

Several ecological forms, like *B. p. mediator* (Hilzheimer 1918) or *B. p. gigas* (Flerov 1969), were distinguished on a basis of the different body size, height at the withers or the shape and placing of the horns. Since the most numerous finds of this species are the skulls,

the most common division is in the short- and longhorned forms. According to Kahlke (1999), the shorthorned forms were present in sylvatic habitats, while the longhorned ones preferred the open spaces.

20 skulls from Poland, 7 from Ukraine, 6 from Crimea, 1 from Belarus and 60 from Siberia were examined. The skulls from eastern Europe and Siberia showed some differences. The males from the Upper Pleistocene of Poland had more massive horn cores than the other specimens. The bison from Ukraine, Crimea and Kazakhstan had them in similar sizes. The smallest horn cores characterised the specimens from the end of the last glaciation (MIS 2) from France and the females from the Eemian from Siberia. The greatest length of the skull (acrocranium – nasal) compared to the frontal orbital width of the orbits, characterised the specimens from the Upper Pleistocene of Poland and the Middle Pleistocene (MIS 9-11) of Kazakhstan. The skulls from Siberia were shorter than those from the eastern Europe. The most robust cranium belonged to a male from the end of the last glaciation (MIS 2) from Habarra, France.

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Pleistocene fauna of the Emine-Bair-Khosar Cave (Crimea, Ukraine): new data

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Session 1: Oral

The Emine-Bair-Khosar Cave is situated on the Chatyrdag karst plateau on the Crimea peninsula. The known total length of the cave is 1630 m, and the depth is 125 m. The 13 m deep and 7-8 m wide pit-entrance to the cave is situated on the northern edge of the lower plateau northern slope (982 m a.s.l.), on a watershed between two gorges. At least since the Middle Pleistocene, the entrance shaft has functioned as a huge trap for numerous animals, mainly ungulates. We assume that at that times one more entrance existed, allowing penetration of carnivores into the cave. The third source of bone accumulation in the cave was

connected to birds of prey and some other bird species, which nested in the cave and provided accumulation of small mammals', birds', reptiles' and amphibians' remains.

Totally ten sites with bones were found in the cave: Ba1, Ba2, Bc, Bb, Bd, Be, Bf, Bg, Bh, and Bj. Approximately 8,000 bones only of big and middle size mammals were excavated. Most of the sites represent different sides of the huge debris accumulation under the entrance pit. Only two sites, Ba2 and Bc, are well stratified and recently they were connected into one sequence. The preliminary description of the stratigraphy and fauna on the Bc site was made by M. Vremir and B. Ridush (2005). The Ba2 site counts nine stratigraphical units (A, B, C, D, E, F, G, H, I). The complex description of the cave sites and their fauna as for 2011 was published by Ridush et al. (2013). The magnetic properties of the sediments at the Ba2 site were studied (Bondar, Ridush 2009, 2010). Also the pollen analysis for almost all sequence of the Ba2 site was fulfilled (Avdeienko 2015). The Equuids from the cave were described in a special publication (van Asperen et al., 2012). The good preservation of bone material allowed studying the genetic diversity of *Cervus elaphus* from different layers (Doan et al. 2018).

During 2012-2013 several expeditions by Chernivtsi National University (Ukraine) and Wroclaw University (Poland) obtained new paleozoological material in the cave, at the Ba2 site. In this abstract mainly the new results for the big and the middle size Mammals are presented.

At the site Ba2 the units A, B, C, D, and E correspond to Holocene and contain mainly small vertebrates' remains. Due to their inclined bedding, these units gradually decreased and finally disappeared from the sequence in the recently excavated squares.

The unit F correlates with Late Glacial. It contained only scarce remains of *Saiga tatarica*, *Cervus elaphus* and *Bison priscus*. Also the brown bear (*Ursus arctos*) remains were found here.

The sediments of unit G were accumulated during Late Pleniglacial. Big animals were represented mainly with *C. elaphus* (the most numerous), *S. tatarica*, *B. priscus*, *Megaloceros giganteus*, *Equus* sp., but also *Vulpes vulpes*, *Lynx lynx*. Later the partial skeleton, including two mandibles, of polar fox (*Vulpes (Alopex) lagopus*) was excavated.

The alternated interstadials and stadials of the *Middle Pleniglacial* are represented in the unit H. This layer is the richest in species and in bone remains. The almost complete and partly skeletons of *B. priscus*, *C. elaphus*, *S. tatarica*, *Equus hydruntinus*, *Equus ferus f. latipes*, *V. vulpes*, *V. corsac*, *V. lagopus*, *Lepus europaeus*, as well as isolated bones of Rhinocerotidae and Proboscidea were known from this layer. Recently, it was determined that a fragment of rhino's cranium belongs to *Stephanorhinus* sp. This species is unusual for the Late Pleistocene of Crimea and the specimen should be dated directly. There are few radiocarbon dates for this layer, but some of them, in the lower part of the layer, are open.

Due to the pollen analysis it was established that the unit I belongs to Eemian interstadial. Previously the fauna of this time was represented only by *B. priscus*, *S. tatarica*, *C. elaphus*, *Lepus europaeus*, *Mustela nivalis* and unidentified Proboscidea. Later, here the partial skeleton of *Bos primigenius* was excavated, as well as remains of *M. giganteus*, *E. hydruntinus*, *E. ferus*, *Rhinoceros* sp., *Vulpes corsac*, *Canis* sp.

The maximum thickness of the section that was achieved at the site Ba2 is -5,6 m. The Bc site is actually a continuation of Ba2 and is bedded below it. There are six stratigraphical units at this site. Because of the inclined bedding, the upper units of Bc could correlate with the lower units (H and I) of the Ba2. Besides the most of large herbivorous species, *C. elaphus*, *B. priscus*, *S. tatarica*, *E. hydruntinus*, *Coelodonta antiquitatis*, the Bc contains the remains of *Panthera leo spelaea* and *Canis lupus*. The almost complete skeleton of a young mammoth was excavated there and the remains of few other specimens of mammoths remained not excavated. The measurements of one of the mammoth teeth from the lower layer (2a) of

the Bc site fit into the values of *Mammuthus intermedius*, that can date this layers to the MIS-7 or MIS-9.

The Bb site is a huge bone breccia, weakly cemented by calcite. The bones of *E. hydruntinus*, *C. elaphus*, and *S. tatarica* are the most abundant at this site, but also *E. ferus*, *B. priscus*, *C. antiquitatis*, *Mammuthus* sp., *Canis* sp., and *Ursus* cf. *spelaeus*. There are two radiocarbon dates for this site (40510 ± 630 BP (Poz-41676) and 32430 ± 150 (GdA-4617)), corresponding it with Middle Pleniglacial, but there are also remains of species which are unknown in the Middle Pleniglacial of Crimea. For example, *Sus scrofa* and *Capreolus capreolus*, those are characteristic for Eemian or other interstadials.

In general, the bone accumulations in the Emine-Bair-Khosar cover the time from at least MIS-7 till Holocene. The bone accumulations in the cave correlate almost exclusively with interstadials and interglacials. Such an interruption could be caused by a snow-ice plug, which most likely formed in the entrance pit of the cave with the beginning of the cold phase. The good preservation of bone material allows providing of complete measurements and fulfilling of DNA analyzes.

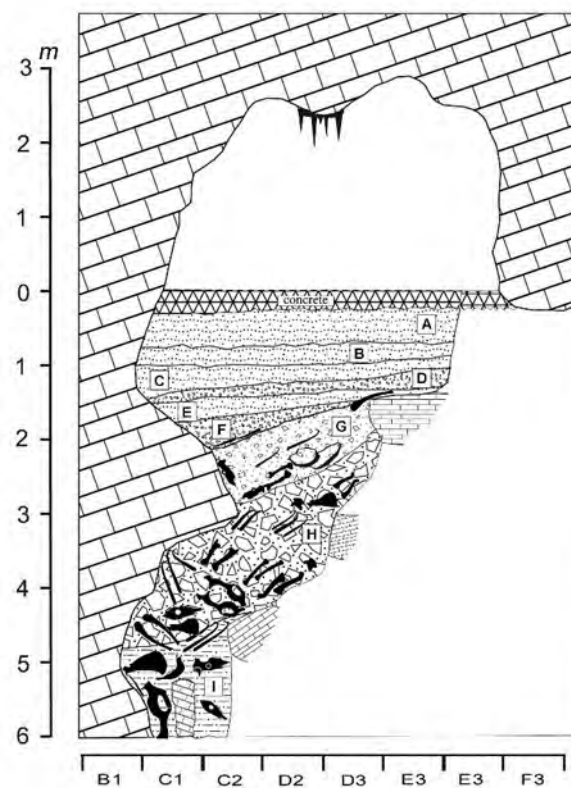


Figure 1 (Ridush et al.): Emine-Bair-Khosar Cave, Ba2 site, cross-section. A, B, C, D, E, F, G, H, and I - stratigraphic units (Ridush *et al.* 2013, with corrections).

Relict of Pleistocene permafrost in North-Eastern Poland – one of the proposal for datestra

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Session 4: Poster

The relict permafrost (paleopermafrost) was found in the village of Udryn (NE Poland) in 2010 (Fig. 1). The Udryn PIG 1 borehole (54°14'49,44"; 23°03'29,38") was done above Suwałki anortosite magma massif. The upper limit of paleopermafrost has been documented at 357 m depth (-134 m a.s.l) because the thermal inversion was between -0.34 and -0.39 °C. The permafrost includes sediments from Lower to Upper Cretaceous (alb-turon). The overall thickness is 93 m (Szewczyk & Nawrocki 2011).

The sediment grain size and micromorphology of sand quartz grains were analysed under a scanning electron microscope (SEM) into sediments associated with the relict permafrost.

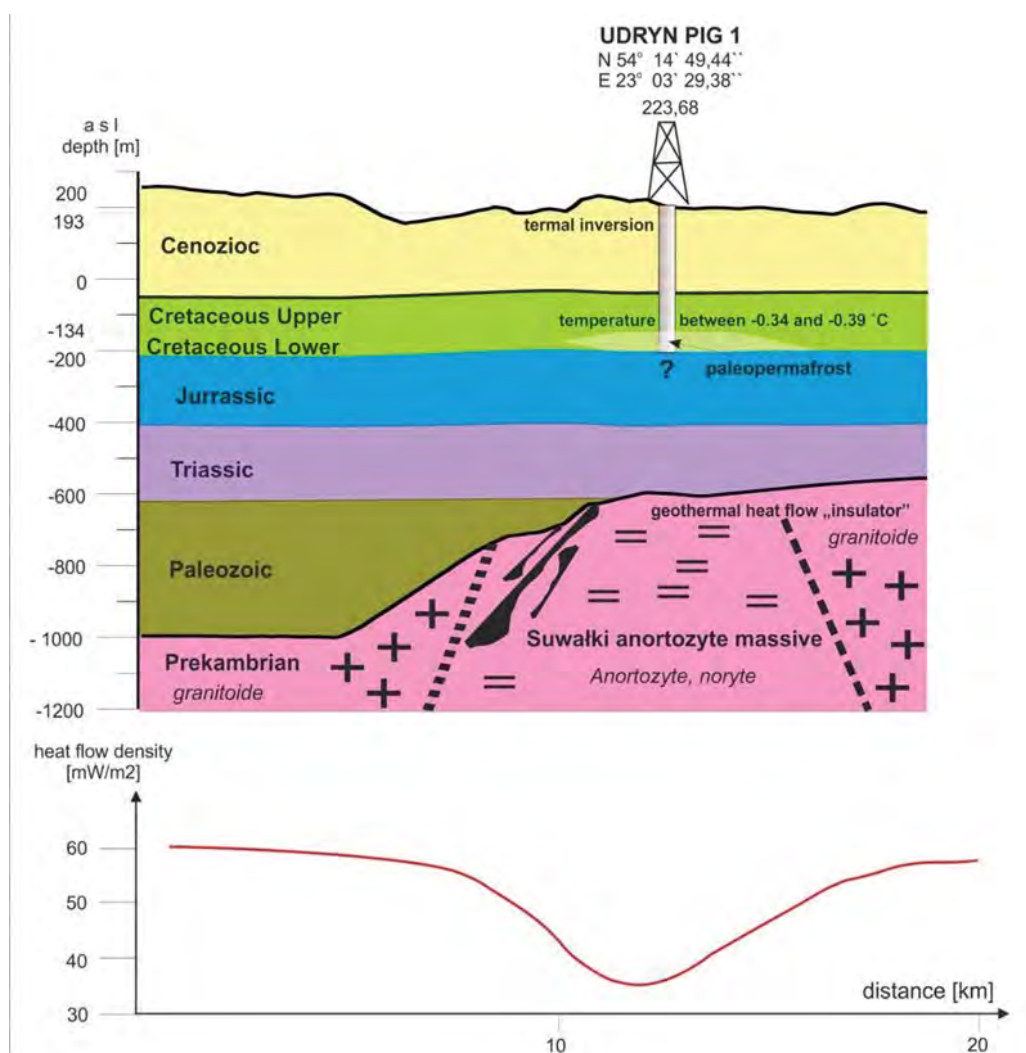


Figure 1 (Rychel *et al.*): Conditions for the occurrence of paleopermafrost in borehole Udryn PIG 1 (after Szewczyk, changed).

The most intense effects of frost weathering of sand quartz grains were observed at depth of 396.75 – 401.75 m. The grain size composition analyses show that sandy sediments from this depth are not frost-susceptible, and the ice occurs in the form of pore ice. Breakage blocks, small conchoidal fractures and scaling are microtextures resulting from frost weathering. The grain's weathering took place during repeated freezing and thawing of water in sediments. It means that the analysed deposits were probably created in a few glacial cycles (Woronko *et al.* 2015).

The preservation of the permafrost in the Udryn region is related to: 1) the low subsurface heat flow ($<35 \text{ mW/m}^2$) occurring above the anorthosite magma massif (the low level of background radiation and the presence of radioactive elements); 2) the very high porosity of the overlying sediments.

It can mean that preserved paleopermafrost may be waiting to be discovered also in other parts of Poland, where there is a similar thermal "insulator" - an intrusive anorthosite magma massif and porosity of the overlying deposits (Rychel *et al.* 2015).

The Udryn site it is the only place in Europe where Pleistocene permafrost was found. It seems to be a good candidate for Database of Quaternary Terrestrial European Stratigraphy (DATESTRA).

Acknowledgement This study is a contribution to the scientific project financed by the National Fund for Environmental Protection and Water Management as part of the Polish Geological Survey. The SEM analyses have been supported by the grant No. N306034639.

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Key-sites of the Belarus Upper Pleistocene

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Session 3: Oral

The Upper Pleistocene of Belarus is represented by sediments of Murava (Eemian) Interglacial and Poozerje (Vistulian) Glacial.

The stratotype of Murava Interglacial is located in the gully «Glavny» on the right bank of the Berezina river between Murava and Poberezhe villages about 30 km downstream of Borisov town and 70 km to the north-east from Minsk. The interglacial deposits of the Glavny gully (Figure 1) consist of an almost 7-m-thick profile. Interglacial peat has been studied by many scientists, including G.F. Mirchink, V.S. Dokturovsky, M.M Tsapenko, N.A. Makhnach, L.N. Voznyachuk, P.I. Dorofeev, F.Ju. Velichkevich, M.A. Valchik etc. The key-site also includes three different facies of Muravian Interglacial deposits: Chertov Kust, Poberezhe and Murava III.

Deposits of Muravian horizon are widely distributed on the territory of Belarus. They are known in several hundred locations studied by paleontological (palinological, seed flora,

malacofaunistical, diatomical, ostracodical, etc) and partly geochronological (U/Th dating) methods. The key-sites Cherny Bereg of the Western Dvina, Bogatyrevichi on the Neman river, Komorovo on the Kotra river, Loev on the Dnieper river, Doroshevichi on the Pripyat river are the parastratotypes of Muravian Interglacial. Sections with Muravian Interglacial sediments according to geological structure can be divided into two groups: covered moraine of the last glaciation and not covered by the moraine. The thickness of Muravian deposits is 2-5 m on average, but sometimes reaches 17-20 m, as for example, near the city of Svetlogorsk.

Poozerje (Vistulian) glacier covered only the Northern part of Belarus, approximately corresponding to the region of the Belarusian Poozerje, but the complex of water-glacial and periglacial formations of this time are much wider. Deposits of the glacier, is the better understood ones of the older glacial horizons. Therefore, the regularity of the formation of Poozerje deposits can serve as a model for understanding the stages of development of all Pleistocene glaciations.

The deposits of the Poozerje time accumulated during three stages, unequal in their duration: a) the stages of the growth of the ice cover until it reaches its maximum; b) the time of the glacier's stay on the territory of Belarus; c) the stage of the glacier's degradation and its retreat outside the territory of Belarus. The first stage was the longest, covering a time of more than 90 thousand years. It presented by several stadial of cooling and interstadial warming. The second shorter (about 3-5 thousand) stage was accompanied by the deposition of the moraine, which is a marking horizon. Lateglacial deposits formed during the third stage.

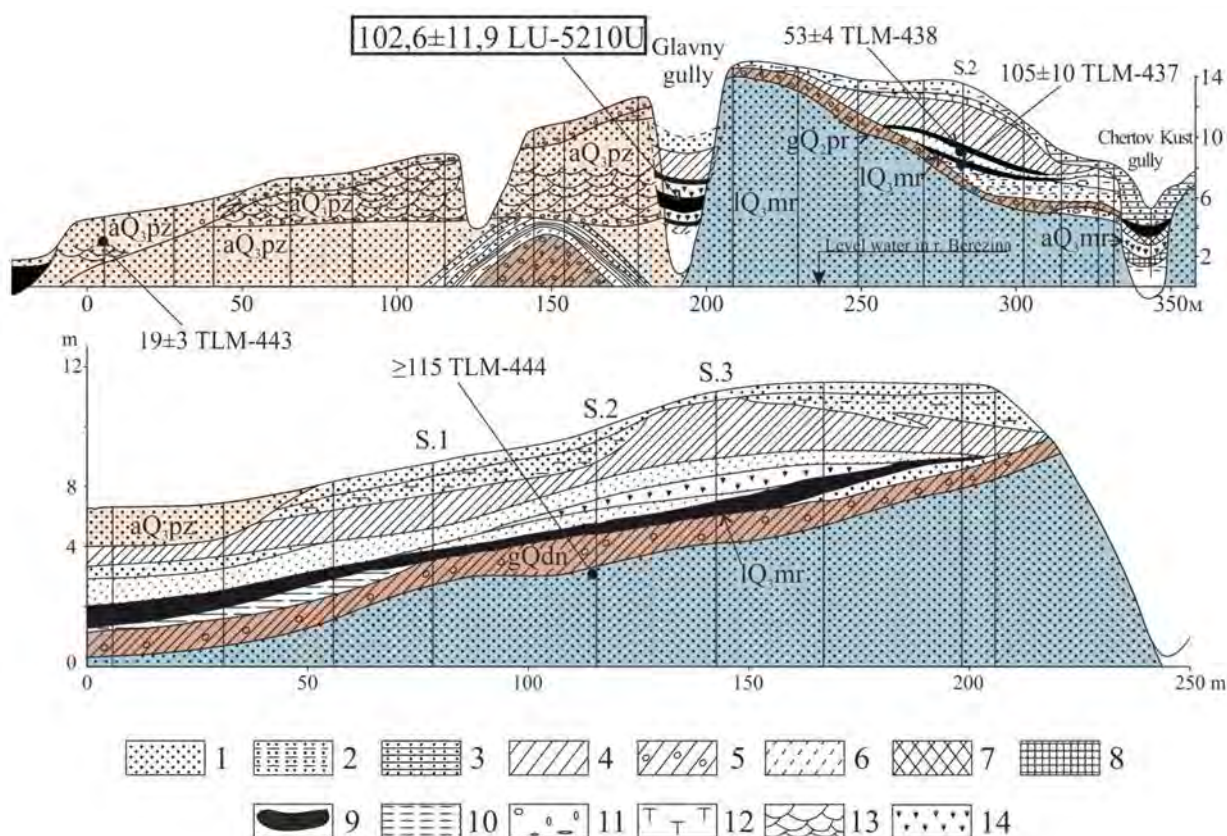


Figure 1 (Sanko et al.): The key-site of the Muravian Interglacial on the right Bank of Berezin river in the Borisov district of Minsk region: 1 – sand, 2 - clay sand, 3 - diluvia deposits, 4 - loam, 5 - moraine, 6 - sandy loam, 7 – gittja, 8 - gytja dark brown, 9 - peat, 10 - clay, 11 - gravel, 12 - buried soil, 13 - stratified sand, 14 - peat and sand.

Deposits of the first stage were found in many sections of Belarus (Murava, Komatovo, Cherikov, Borkhov Rov, etc.), where they usually put on Muravian interglacial seiments. Stadial (bluish-gray loam, sandy loam, sand, siltstone with traces of permafrost processes) and interstadial (peat, peaty sandy loam and sand, lime sapropel etc.) layers with thickness from a few to 20 m or more occur at the depth 24-47 m in the Poozerje district and from 2-3 to 12 to 20 m on the Belarusian ridge and in Polesie.

Moraine deposits of the Poozerje horizon (second stage) are developed only in Northern Belarus. Poozerje glacier formed the regional end moraine. The thickness of moraine varies from 1.5-2 to 70 m, averaging 10-15 m. Moraine is represented by boulder sandy loam and red-brown, brown or yellowish-brown loam. Fluvioglacial and lacustrine-glacial deposits are widespread in the Belarusian Poozerje. They are closely related to moraine.

Alluvial, loess-like and sandy eolian deposits accumulated during the third stage.

Loess-like deposits are spread in the Eastern part of Belarus and in the territory of Minsk, Novogrudok, Mozyr end moraine hills. They are overlain by moraine and marginal glacial deposits. The maximum thickness of loess-like deposits (over 10 m) is confined to the Eastern regions of the territory of Belarus and Mozyr upland. Aeolian sand deposits are found in those areas of Belarus, where alluvial or glacial-lacustrine sands come to the earth's surface. The largest areas of Aeolian formations are confined to Polesie, terraces of the Neman, Berezina and some other large rivers.

Site Korochevshchina on Oshmiany upland should recognize as the key-site of Poozerje glaciation in Belarus. Thermokarst depression of site Korochevshchina contains the most complete sedimentation of Poozerje time, from Muravian interval to the Holocene.

Stratigraphy of Eemian deposits near the classic type locality at Amersfoort (NL)

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Session 2: Oral

The Netherlands hosts a long tradition in Quaternary research. Being situated at the southern edge of the subsiding North Sea Basin, a thick stack of Pleistocene glacial and interglacial deposits has been preserved. As such, the area is also one of the classic areas to study the Last Interglacial or Eemian (MIS 5e). Eemian deposits have been exceptionally well pre

served in deep glacial basins that were formed in the central Netherlands during the Saalian (MIS 6) glaciation. Internationally renowned research by Van der Vlerk & Florschütz (1950, 1953) and Zagwijn (1961; Fig. 1) made the Amersfoort Basin the informal type area of the Last Interglacial in North-Western Europe.

In the last decade, the classic Eemian type area near Amersfoort has been revisited. TNO-Geological Survey of the Netherlands (TNO-GSN) retrieved several new high-quality cores, which enables us to relate current geological mapping and 3D modelling activities in the Amersfoort Basin to the original palynostratigraphical framework of Zagwijn (1961) and Cleveringa *et al.* (2000). The new cores -or key sites- were described in detail and interpreted in terms of sedimentology and lithostratigraphy. Selected intervals were also sampled for pollen and diatom analyses and optically stimulated luminescence dates were obtained.

Based on detailed information from the key sites, nearby low-quality core descriptions and cone penetration test data could also be interpreted. This enabled us to make high-resolution cross sections and allows to reconstruct the palaeogeographical development of this part of the basin in greater detail than hitherto possible. It also sheds new light on the completeness of the Eemian and Early-Weichselian sedimentary record in the Amersfoort Basin.

Some of the remaining questions we hope to resolve, include:

- How did the deep holes at the base of the Eemian ('kettle holes' as described by Zagwijn, 1961) originate?
- What causes the sharp lithological transitions within the marine part of the Eemian succession?
- How to reconcile the Eemian sea-level history in the Amersfoort Basin (Zagwijn, 1983) with sea-level reconstructions from nearby areas?

Eventually, this may lead to a better correlation between land and sea records spanning the Last Interglacial (cf. Sier *et al.* 2015). It also strengthens the case to continue to use the Amersfoort Basin as a stratotype area for the Eemian Interglacial Stage.

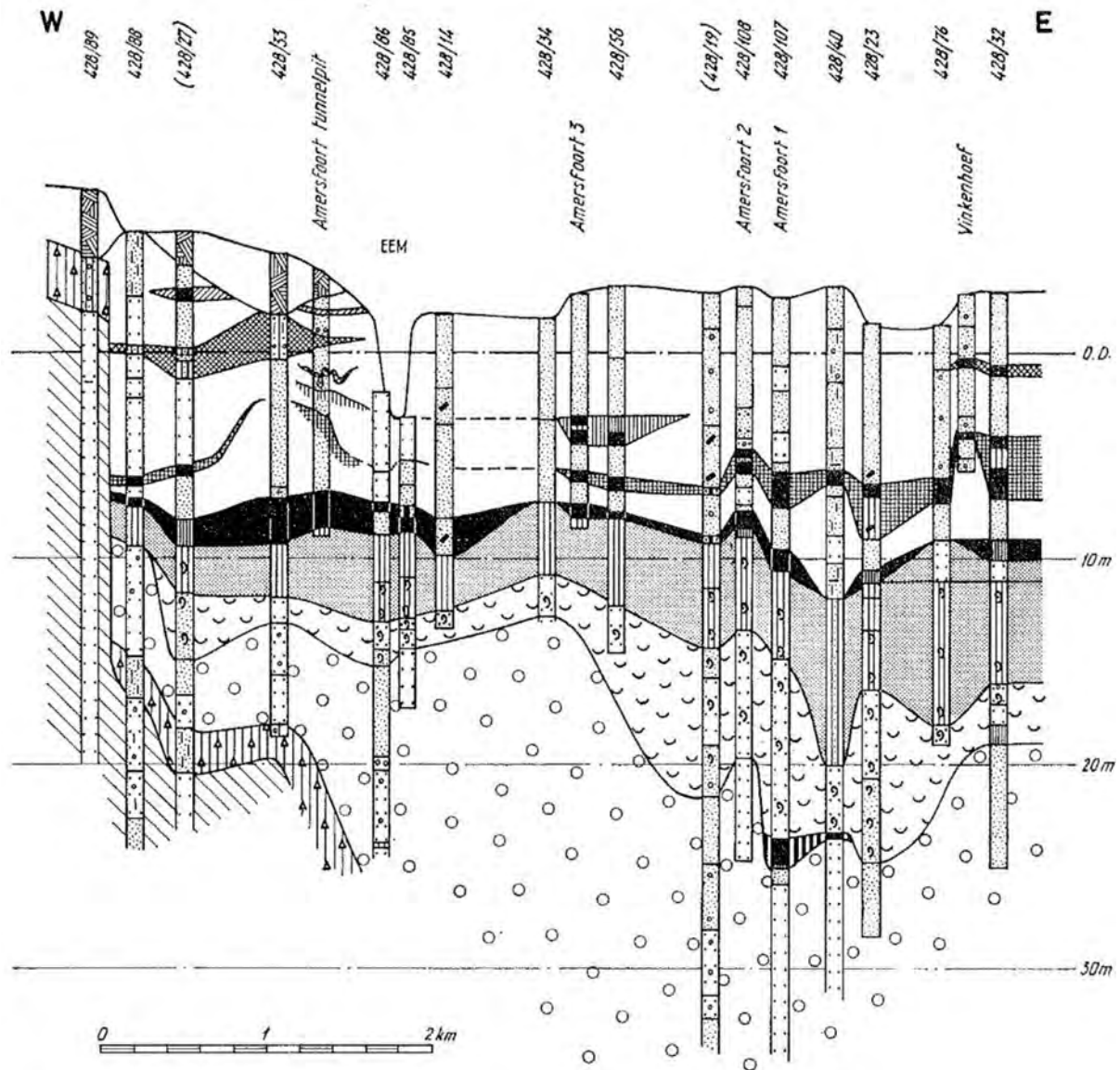


Figure 1 (Schokker & Busschers): East-West section through the westernmost part of the Amersfoort Basin, showing the context of the classic type locality Amersfoort. In the traditional interpretation, the Eemian stage starts with peat formation (~25 m below O.D. in core Amersfoort 1), followed by deposition of marine shell-rich sand and clay layers. Eventually, continental conditions return to the basin, as evidenced by widespread peat formation (~10 m below O.D.) (after: Zagwijn 1961).

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The paleoclimate reconstruction of Pliocene–Pleistocene transition: oxygen and carbon stable isotopes from flowstones in the cave Račiška pečina (SW Slovenia)

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Session 1: Poster

The cave Račiška pečina is located in the south-eastern part of the Podgrajsko podolje in the SW Slovenia. The cave length is 304 m and maximum height of passages is 10 m. The unique series of deposits was deposited in the main cave passage. Various types of flowstones alternate with fine-grained siliciclastics (redeposited weathering products of Eocene flysh sequences and red soils) in a large dome-like structure. Deposits were cut during military occupation into a form of ca 13 m long section with a composite thickness of nearly 6.5 m. Based on paleomagnetic and magnetostratigraphy analysis, mammalian zoopaleontology and some numerical datings, the flowstones started to deposit before more than 3.4 Ma with the termination at ca 6 ka. The profile contains Pliocene/Pleistocene (at ca 1.8 Ma) and Pleistocene/Holocene transition periods as well as well-developed segment belonging to Olduvai normal magnetic subzone (ca 1.95 to 1.77 Ma) within reverse Matuyama Chron (Zupan Hajna *et al.* 2008).

The section consists of three main segments (Zupan Hajna *et al.* 2008). The lowest one (180 cm), represents the stages of large stalagmites growth and consists brown and red-brown, massive, porous speleothems with interlayers of red clay sediments (1–2 cm thick). The lowest part terminates with a distinct unconformity. The middle part (368 cm) is built by laminated, porous flowstones in central profile part densely interbedded with red clays (1 mm to 10 cm thick). Huge blocks of rock detached from the ceiling part of the cave and fauna can be seen at the base of this segment. The upper segment (96 cm) is represented by bright, massive, laminated speleothems with two inserts of grey-brown/yellow clays with cave bear bones.

Speleothems represent a relevant source of information on the paleoclimatic condition in the past. Among the numerous physico-chemical parameters dependent on palaeoclimatic conditions, the variability of oxygen and carbon isotopic composition is particularly often used. O and C isotopic records preserved in the speleothem allow the reconstruction of the isotopic composition of water from which speleothems crystallized and it allow the reconstruction of climatic conditions (e.g. the amount of the rainfall or temperature) in the area of the cave.

Stable isotopic composition analyses of flowstones were performed in the Institute of Geology PAS (Warsaw, Poland). The value of $\delta^{18}\text{O}$ changes within the range of ca 3 ‰ (from -4.27 ‰ to -7.17 ‰). The extent of the carbon isotopic composition changes is wider and reaches 6 ‰ (the $\delta^{13}\text{C}$ changes from -3.36 ‰ to -11.02 ‰). Obtained isotopic records were

correlated with global and regional paleoclimatic data. The analysis resulted in new information on Pliocene/Pleistocene transition climatic conditions in the studied area.

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Poland during the Eemian (MIS 5e) stage: a project of the Web GIS interactive database

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Session 4: Oral

The main aim of the project is providing a new Web GIS technology-based application which would give end users fast and convenient access to the Polish Eemian Interglacial sites. Our online platform works as an interactive database of geological sites combined with background maps and thematic layers. User active layers allow displaying maximum extents of Pleistocene glaciations (Elsterian, Saalian, Vistulian) across Poland. First, for the database construction, we studied geological literature thoroughly. Next, for each identified research site we attributed geographic coordinates following the WGS84 (PUWG 1992) system. We classified Eemian locations into three separate groups: sites for which only Eemian flora have been described (62), boreholes or outcrops containing Eemian sediments (20) and Eemian deposits reported from the caves (8). Additionally, we introduced also a separate layer reserved for the Early Vistulian and Late Saalian flora locations (33), to make a better picture of Quaternary studies state of the art in Poland. For each site, an interactive pop-up window provides additional information about, e.g. site location (X, Y, Z) and name, sediments depth and their thickness, lithology, faunistic findings, dating results (14C, OSL, TL) and literature reference. We hope the presented database will improve information transfer within the Quaternary research community, allowing promotion of recent studies and planning new research activities. Concluding, we would like to invite international collaborators to contribute to the new version of the service. We believe that introducing the pan-European Eemian database would significantly improve service utilities and its scientific impact.

Polyphase evolution of the karst system of the Jaskinia Niedźwiedzia Cave (Sudetes, SW Poland) – a review

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Session 1: Oral

Jaskinia Niedźwiedzia Cave in Kletno (Śnieżnik Massif, Sudetes, NE Bohemian Massif) formed within marbles has been known to science since its discovering in 1966. Cave exploration and scientific research during the last 50 years of its history had noticed an unexpected increase after 2011 when over 2.5 km of new cave passages were discovered. New systematic cave survey, geomorphological and geological research have been started, supported with biological and geochronological studies. In the next step, underground data have been combined with results coming from the surface – shallow geophysical prospecting (ERT, GPR), LiDAR DEM data and geological mapping. According to our data, the formation of the Jaskinia Niedźwiedzia was firmly controlled by local structural planes, wherein marbles foliation played a crucial role in S–N-oriented cave passages formation in “new parts” (Mastodont). On the contrary, within located to the north “old parts”, faults and joints weakness zones replace foliation as a critical guidance structure. We also use, a vast database of new U-Th and ¹⁴C ages to reconstruct a Pleistocene–Holocene evolution of the cave. Herein, a particular emphasis goes to one of the most significant characteristics of new cave passages represented by large collapsed cones within cave chambers (e.g., Mastodont, Kutaśnik, Humbaki). Preliminary results of U-series dating of broken stalactites and stalagmites, allow us to point out at least two separate phases of intensive cave chambers deformation related to MIS 9 and MIS 6 isotopic stages. A new interdisciplinary model of polyphase evolution of the Jaskinia Niedźwiedzia karst system during the Late Cenozoic will be compiled as a result of the presented research project.

Acknowledgments This project has been supported by the Faculty of Earth Sciences and Environmental Management, University of Wrocław, projects no 2170/M/IGRR/14, 1233/M/IGRR/15 and 0420/1459/16. Part of the results relating to U-Th dating arose as a contribution to the National Science Centre project no. DEC-2017/01/X/ST10/00375 and MOBILITY PAN-17-22 initiative.

Stratigraphic significance of Polish Pliocene and Quaternary deer

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Session 1: Poster

In Poland, cervid remains were found in more than 60 localities: 6 Neogene (4 Miocene and 2 Pliocene localities), 2 Lower Pleistocene, 2 from the middle part of Middle Pleistocene and more than 50 major cave and open localities from the upper part of the Middle Pleistocene and the Upper Pleistocene. This material exceeds 5 500 remains, representing 3 subfamilies, 6 tribes, 17 genera and 25 lower-rank taxa (16 species, one of them new to the fauna of Poland). Only one species - *Euprox furcatus* – is known from the Miocene. In the Pliocene the number of cervid taxa increased to eight. The numerous Lower Pliocene remains from Węże 1 (MN 15) represent 4 species: *Muntiacus polonicus*, *Praelaphus warthae*, *Arvernoceros* cf. *ardei* and *Procapreolus moldavicus*. The genera *Muntiacus* and *Procapreolus* represent older forms of cervids, known already from the Miocene. The genera *Praelaphus* and *Arvernoceros* appeared in Europe during the Pliocene. The Middle and Upper Pliocene cervids present in one locality only - Węże 2 (MN 16). It yielded remains of 4 cervid taxa: *Croizetoceros ramosus*, *Metacervoceros pardinensis*, *Arvernoceros* cf. *ardei* and *Procapreolus moldavicus*. The first three had a pan-European distribution and appeared in the Lower and Middle Pliocene. *Procapreolus moldavicus* was known from earlier periods and Węże 2 is a site of its last occurrence in Poland; the same is true of the genus *Arvernoceros*. The Pliocene/Pleistocene boundary was a period of profound climatic changes. The representatives of cold climate faunas arrived in Europe from Central and Northern Asia. That period is represented by Rębielice Królewskie (MN16-Q1). Compared to Węże 2, the cervid fauna is much poorer. It is represented, mainly as teeth, by two cervids: *Croizetoceros ramosus* known from the Pliocene, and a representative of the genus *Eucladoceros*. The Lower Pleistocene witnessed considerable changes in the cervid fauna. In Poland the forms known from the earlier periods of the Villafranchian became extinct, to be replaced by taxa which were characteristic of the later parts of the Quaternary. Cervids of that period were found only in Żabia Cave (MIS 58-40). The most abundant cervid in the locality was *Dama* cf. *farnetensis*, the only representative of *Dama* in the Lower and Middle Pleistocene of Poland. Large cervids were represented by one of the earliest elks, *Cervalces carnutorum*. It was the first occurrence of elk in Poland. The locality was also the earliest occurrence of the genus *Capreolus* in Poland; it was represented by few remains, with size close to that of *Capreolus cusanoides* from the Lower Pleistocene locality Untermassfeld. There are no Lower-Middle Pleistocene sites with cervid remains, and sites with any faunal remains are few. In the middle part of the Middle Pleistocene (2 localities) (MIS 19-17) four cervid species occurred: *Cervus elaphus* ssp., *Praemegaceros verticornis*, *Capreolus suessenbornensis* and *Cervalces latifrons*. In the Upper-Middle Pleistocene the number of species increased to six: *Cervus elaphus*, *Megaloceros giganteus*, *Capreolus capreolus*, *Rangifer tarandus*, *Cervalces* sp. and *Alces alces*, and most sites held four species each. The reindeer appeared in Poland during MIS 11 or 9. In that period the most abundant remains were those of the red deer. The dominance of the red deer persisted till the end of the Middle Pleistocene. In that period, besides the large form of the red deer - *Cervus elaphus spelaeus*, also the giant deer *Megaloceros giganteus antecendens/germaniae* was present; its occurrence in Poland was recorded since the period Röpersdorf-Schöningen Interglacial/Saalian (MIS 8/7-MIS 7). The last representative of *Cervalces* in Poland was *Cervalces* sp., which was present since the Odra Glaciation (Saalian). A species of roe deer *Capreolus priscus*, not

recorded from earlier periods in Poland, was relatively abundant in this time. The cervid occurrence differs significantly between the glacial and the interglacial periods. The recent elk, the recent *Dama dama* and roe deer appeared in the area of Poland during the Eemian Interglacial and at the beginning of the last glaciation. In the latter period the red deer was still the most abundant species. The second dominant species was the reindeer. Two forms of the giant deer, *Megaloceros giganteus germaniae/ruffi* were present in Poland during the last glaciation. The elk's distribution in Poland became considerably limited in the Upper Pleistocene. Few localities of the species date from the beginning of the last glaciation and the Interplenivistulian. Also the roe deer, though initially more abundant than the elk, became increasingly rare; like the elk, it disappeared in the consecutive cold periods of the Vistulian and was scarce in the Interplenivistulian. Since the Older Plenivistulian, the reindeer became the dominant cervid and also one of the dominant large mammals. Considerable changes in the cervid fauna took place at the end of the Pleistocene and in the beginning of the Holocene. The giant deer became extinct while the reindeer retreated into Northern Europe and Asia. The elk was the first to recolonise Poland, and was followed by the red deer and the roe deer. Since the Middle Holocene, the elk's abundance decreased, and the red deer and roe deer became the dominant species. During historic times fallow deer and the sika deer got introduced.

Biomarkers and paleolandscape indicators in early Pleistocene mountain soils and pedolithic sediments in the Caucasus

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Session 3: Oral

The most informative paleolandscape indicators and biomarkers in the Early Pleistocene soils and soil-like bodies are the magnetic susceptibility, the content of n-alkanes and carbon isotopic composition of organic matter.

Early Pleistocene palaeosols and pedolithic sediments have described in the Paleolithic sites and quarries in tephro-soil and lagoon-marine series of plateau-like surfaces of the Lesser and Northern Caucasus. In the Lesser Caucasus, the objects of research were located in the Lori and Upper Akhuryan depressions (north of Armenia).

A tephro-soil sequence with two palaeosols has discovered in the Early Paleolithic site Karakhach (1800 m above sea level), dated by the subchron Olduvai (Trifonov *et. al.* 2016). The cultural layers and buried soils are covered with powerful (4 m) ash-volcanic sediments with low acidic pH values (pH_{KCl} 4.9-5.1; pH_{H2O} 5.6-6.0). The upper palaeosol (layers 1-3) formed on the pebbled deposits, lies at a depth of 6.2-7.4 m and has a reddish brown color. Lower pebbly and sandy sediments (layers 4-10) have signs of hydromorphism (blue-gray shades of color, Fe-Mn plots, redeposited ash layer). The second buried soil (layer 11, at a depth of 10.8 m) has a brown Pitura n color, relative increase in the content of organic carbon and nitrogen. The values of magnetic susceptibility decrease in paleosols due to the stagnation of volcanic activity (χ up to $643.4 \cdot 10^{-6} \text{ cm}^3/\text{g}$, CGS). The content of inorganic phosphorus diagnoses the presence of two stages of volcanic activity. $\delta^{13}\text{C}_{\text{org}}$ in palaeosols diagnoses a humid climate with a predominance of C3 type vegetation (-25.9-26.4 and -26.8 ‰).

Similar hydromorphic reddish-brown paleosol on gravels has found in the Early Pleistocene deposits of the Upper Akhuryan basin (2033 m above sea level). Relative minimum of the magnetic susceptibility, the heavier isotope composition (-25.5‰), in comparison with the enclosing sediments, indicate the stagnation of volcanic activity and soil formation in the humid conditions.

Low salinity (Stolpnikova & Kovaleva 2016) paleohydromorphic pedolitic sediments has found in excavations in the territory of Dagestan (Russia, Northern Caucasus) at altitude of 1629 m above sea level in Early Paleolithic site Muhkai Ila (Amirkhanov *et.al.* 2016). $\delta^{13}\text{C}_{\text{org}}$ (25.1-26.4‰) diagnoses a humid climate with a predominance of C3 type vegetation. Low values of magnetic susceptibility and abundance of Fe-Mn ortstein indicate the hydromorphic coastal landscape at the beginning of the Pleistocene.

The distribution of n-alkanes content of in the paleosols in the Lesser Caucasus objects showed the contribution of microorganisms activity to the organic matter formation. This fact is reflected in the predominance of medium-chain alkanes and the predominance of even alkanes. Especially for this contribution, the cultural layer 11 of the Karakhach excavation is allocated. This circumstance may indicate the formation of organic matter under water conditions. The horizon 35.0-35.16 m in the Mukhkai Ila (Dagestan 2014) excavation differs most strongly in this component. A small amount of alkanes C_{27-29} , which are biomarkers of woody vegetation, is also fixed for Muhkai II and Ila excavations (2014, 2017). The dark brown layer beneath the cultural layer 25c contains the largest number of these alkanes. However, alkanes C_{31-33} - biomarkers of grassy vegetation were not found in any object. A low amount of long-chain alkanes (C_{27-33}) indicates a possible predominance of aquatic plants.

Thus, the paleosols and pedolithic sediments of the Early Pleistocene in the investigated paleolithic sites have formed in hydromorphic conditions in the immediate vicinity and participation of water.

Acknowledgments Financial Support: RSF №17-14-01120.

The skin of Quaternary: Meghalayan stratigraphy and land use in small karst basin (Southern Tuscany, Italy)

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Session 2: Oral

The sedimentary fillings within fluvial valleys are excellent archives for landscapes changes since valleys work as a trap for sediments. In small karst basin, affected by calcareous tufa deposition, the trapped sediments provide also information about the physical and associated biological landscapes.

This is the case for the Pecora river basin, located in the Maremma region of south-west Tuscany, between the towns of Massa Marittima and Follonica (Grosseto, Italy). The basin has a relatively small catchment of about 250 km²; the morphology of the area in the proximal reach (close to Massa Marittima) is characterized by hilly and tabular landscape, corresponding to alluvial terraces and calcareous tufa system, while downstream the landscape grades into an alluvial plain which ends in the Follonica coastal plain.

Engineering works for the excavation of a retention basin on the left bank of the distal reach of the river allowed the observation of ca. 8 m of alluvial sedimentary succession. The combined sedimentological, geomorphological, anthracological and geochronological analysis revealed a human induced abrupt change of the river dynamics and associated landscape that mainly occurred between VIII and XIII centuries.

The lowermost part of the succession is made up of palustrine lagoonal, thinly bedded, bioturbated clays; microfossiliferous analysis revealed an abiotic environment. Upward, sand and gravels filling channels unconformably rests on top of the clays, buried paraconformably by coarse-grained gravels. This part of the succession forms a terrace hanging ca. 6 m from the present day thalweg.

The uppermost part of the succession is the filling of a wide complex palaeochannel that shows the presence of two main sedimentary phases. The older, dated to the Bronze-Iron Age, is typical of sand-bed sinuous river, made up of loose planar crossbedded fine to coarse gravels, with rounded to subrounded polygenic clasts and variable amount of sandy matrix. The younger, dated to the Early Middle Age, is typical of braided river, characterized by loose through crossbedded or massive fine to coarse gravels, made up almost exclusively of rounded to subrounded calcareous tufa clasts; a large amount of coarse charcoals is also detected.

Thus, the younger phase derives from the erosion of the calcareous tufa environments and associated wetlands that characterized the middle and upper reaches of the river basin. More importantly, the strong presence of charcoals documents a human induced dramatic land use change for the former wetlands.

Pleistocene stratigraphy and key sites in Lithuania

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Session 4: Oral

Based on the investigation results, collected from the thousands of boreholes drilled during the medium and large scale mapping several reasonable Pleistocene stratigraphic schemes of Lithuania were compiled in the mid-nineties (Gaigalas & Satkūnas 1994; Kondratienė 1996) and later, the corrections were proposed by J. Satkūnas and others (Guobytė & Satkūnas 2011). Within the last decades, the drilling possibilities became very limited and the probability to get new cross-sections has decreased. Therefore, much attention was paid to the use of new methods and the search for possibilities of a sediment dating.

Stratigraphy of the Lower Pleistocene is negotiable in Lithuania because of a limited distribution of sediment layers, poor paleontological findings, high redeposition. It is represented by Anykščiai and Daumantai Formations which are distributed in eastern Lithuania. Palaeomagnetic studies capacitate to fix a Brunhes/Matuyama boundary and Jaramillo subchron in several outcrops: Daumantai 1; 3 and Šlavė 2 (Baltrūnas *et al.* 2013, 2014). However, detail subdivision of these sequences and detection of the lower boundary of Pleistocene are still complicated.

The oldest glacial sediments of Middle Pleistocene in Lithuania are represented by Kalviai Formation (Satkūnas 1993; Gaigalas & Satkūnas 1994). The Butėnai (Holsteinian) Interglacial Formation is marker of the Middle Pleistocene. Sediments of this interglacial are established in more than 40 sections and correlated palynologically, some sections ESR and TL dated. Most of the sections have been examined in the northeastern Lithuania (Utena

region) regarded as a stratotypical region. Two more interglacial layers: Vindžiūnai and Turgeliai were fixed between Butėnai (Holsteinian) and Lower Pleistocene sediments. The pollen composition from Vindžiūnai Interglacial sediments indicated that the vegetation does not represent a complete interglacial climatic cycle and the fragmented sequence can be mainly attributed to the first part of an interglacial. For this reason, chronostratigraphy of these sediments is unclear. Other interglacial – Turgeliai occurring between Dzūkija and Dainava Formations represents full interglacial cycle, however due to limited sediment spread and absence of absolute dates chronostratigraphical attribution of sediments is questionable. The Žemaitija Formation overlaying Butėnai (Holsteinian) Interglacial layers consists of sediments of the largest Pleistocene glaciation. The dark brown colour and high hardness Žemaitija till is of 23 m thick and reaches over 100 m in some sections. The stratotype of this unit was recognised in north-eastern Lithuania. The Medininkai till is represented by loam and sandy loam and texturally and structurally is quite similar to that of the Žemaitija. The areal stratotype of the Medininkai glacial unit is the Medininkai Heights in the Nalšia (Ašmena) Upland, south eastern Lithuania. The Žemaitija and Medininkai Formations in Lithuania are separated by the Snaigupėlė Interglacial sediments. They were discovered in eastern part of Lithuania and well-studied palaeobotanically. Most investigators point on the correlation of Snaigupėlė Interglacial sediments with marine isotope stage 7, but only in one section this age was proved by $^{230}\text{Th} / \text{U}$ isochron method.

The Upper Pleistocene marker sediment layers are the Merkinė (Eemian) Interglacial sediments which are studied from about 35 sections. They are mainly distributed in eastern Lithuania and reach up to 10 m in thickness. The data of investigations points to the presence of non-glacial palaeoenvironments since the end of the Merkinė Interglacial, during the Early and Middle Nemunas (Weichselian). The alternation of stadial and interstadial environments is characteristic for this time and it is rather well studied and correlated with other European sections (Satkūnas & Grigienė 2012; Satkūnas *et al.* 1998, 2003, 2009). The Middle Nemunas (Weichselian) is still problematic from the point of view of stratigraphy and palaeogeography. The Upper Nemunas (Weichselian) is subdivided into two stratigraphical units: the Grūda and Baltija Subformations corresponding to stadials. No interstadial sediments of this period were determined in Lithuania.

Late Glacial and Holocene sediments are well studied and have a good chronostratigraphy.

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Key sections of Pleistocene continental deposits from North-Eastern Sea of Azov region

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Session 4: Oral

The Sea of Azov Region is important for the Quaternary stratigraphy due to the geographical position at the boundary between Europe and Asia, belonging to shallow-water inland sea, etc. Lagoon, alluvial deposits, and the loess-paleosol subaerial sequences are well exposed here in coastal escarpments and sand pits. These layers produced numerous remains of small and large mammals, reptiles, freshwater fishes and mollusks. Many sections are characterized by palaeomagnetic, palynological and other micropaleontological data. These sections were well studied by numerous investigators starting from the early 20th century (Popov 1948; Vasiliev 1969; Lebedeva 1972; Markov *et al.* 1976; Tesakov 2004; Tesakov *et al.* 2007, and many others).

Three main terrace levels have been identified in the coastal area (Lebedeva 1972; Velichko *et al.* 1973; Velichko 1975). The highest, the Khaprovian terrace of 40–45 m a.s.l. contains Upper Pliocene to earliest Pleistocene sediments. It is developed on the right bank of the palaeo-Don River Valley. It corresponds to the Melekino level, which consists of lagoonal-marine sediments at the base of sections exposed along the northern coast of the Sea of Azov. Another terrace is arbitrarily established at a height of 30 m. It is composed of upper Lower Pleistocene lagoon deposits. This Margaritovo terrace occurs along the southeastern coastal area of the Taganrog Gulf and corresponds to the Nogaisk level of the northern coast of the Sea of Azov. The next, topographically lower level is associated with Middle Pleistocene fluviodeltaic or lagoon sediments and is termed the Platovo or Semibalki terrace. The height of the latter is no more than 20–25 m a.s.l. There are up to 5 paleosols at the cross-sections of most high terraces. The most ancient of them has the late Early Pleistocene age (Velichko *et al.* 2009, 2012). Some sections also document older Early Pleistocene hydromorphic soils.

The most important sites from the region are Melekino, Platovo, Beglitsa, Taganrog, Morskaya, Liventsovka, Kagalnik, Semibalki 1-4, Chumbur Kosa, Margaritovo 1, 2, Port-Katon 1, 2, Shabelskoye. These sections are located along the northern and southern coasts of Taganrog Bay of the Sea of Azov. The Quaternary geological sections of the eastern part of the Sea of Azov Region presents a detailed record of the succession of the Pleistocene

landscape–climatic cycles and faunal associations of the arid zone of southern European Russia.

3D near-surface basin modelling and faulting styles of the Lake Erçek Basin, Eastern Anatolia (Turkey), from high-resolution seismic reflection images

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Session 2: Oral

Lake Erçek (Figure 1) is a shallow terminal lake and an endoreic basin located 30 km east of the Lake Van endoreic basin in the Van region of the eastern Anatolia situated at 1803 m (masl). Lake Erçek is characteristic one of the smallest soda and highly alkaline lakes in the world, with a range pH of 9.4 to 10.75, a surface area of 106.2 km², a volume of 65 km³, a maximum depth of 40 m, an average depth of 18.45 m and a maximum length of 15 km N-W (Figure 1). Lake Erçek was a typical of the young tectonic lake (e.g., Upper Pleistocene-aged) physically located in a faulted basement subjected to lava flows. Lake Erçek occupies E-parts of the Lake Van basin that has developed from the collision of the Arabian and Eurasian plates (Figure 1) (the collision at ~13 Ma), as evidenced by regional volcanism, magma-hydrothermal-gas activity and significant seismicity, including the 2011 Van earthquake. The geologic history of the Lakes Van and Erçek basins in eastern Anatolia was formed from the interaction of the Arabian, Anatolian and the Eurasian Plates. However, it is still not known how Lake Erçek basin was structurally related to this plate interaction. Previous studies suggest that the tectonic evolution of the basins in eastern Anatolia was brought about by lithospheric thinning and mantle upwelling related to the gravity-controlled escape of the Anatolia plate (Figure 1). The plate interaction is manifested in the Lake Van region by the occurrence of several strike-slip and reverse faults, intense volcanic activity and normal fault-controlled extensional basins in the area surrounding Lake Van. The tectonic activity is still ongoing in the Lakes Van and Erçek regions as shown in the occurrence of several earthquakes during the past 100 years (Figure 1).

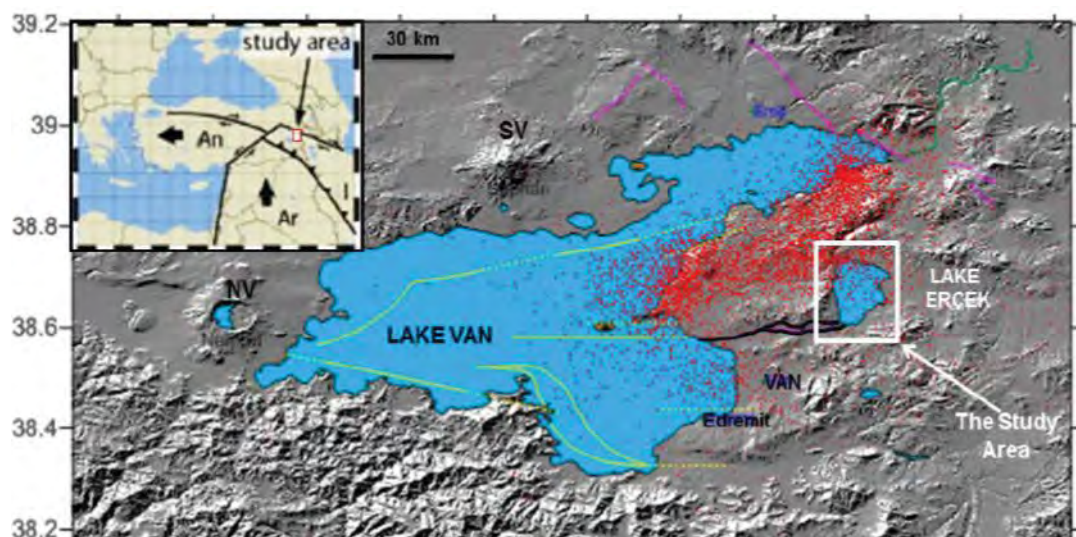


Figure 1 (Toker & Tur): Aftershock seismicity of Lake Van and Lake Erçek areas and faulting patterns of Lake Van Basin. Aftershock sequence (red dots) of the 2011 Van event and study area (white square). The inset map shows regional plate motions (An: Anatolian, Ar: Arabian).

In this study, we identify the near-surface faulting features within the Lake Erçek Basin by analyzing 100 km of high-resolution single-channel seismic reflection profiles to observe the fault deformation styles and support future hydrocarbon exploration studies for this tectonically active lake. 3D modelling of morpho-tectonics and near-surface deformation patterns of the Lake Erçek Basin observed from high-resolution seismic reflection images demonstrates the important constraints on the extensional regime of the Lake Erçek Basin and the adjacent areas (e.g., Lake Van Basin). As observed in the Lake Van Basin, the imaging of near-surface faulting patterns can provide an excellent natural example of faulted and/or stratigraphic trap mechanisms for hydrocarbon explorations that can be compared with existing intra-plate extensional lakes (e.g., Lake Van Basin). Therefore, the aim of this study is to observe and evaluate the deformation and distribution of shallow faulting structures in Lake Erçek.

The high-resolution single-channel shallow seismic reflection data was acquired in the summer of 2015, during survey proposal for the “Lake Erçek Seismic Survey” project (Figure 2). The seismic system consists of a 5-m-length single-channel streamer with 8 units, a Geo-Boomer 300-500 seismic system, and a recording unit. A total of 12 profiles were collected with a length of ~110 km in Lake Erçek by a private research vessel (Figure 2). The GeoSuite All Works® software was used for seismic data processing applied to all the single-channel seismic reflection profiles. After or during the acquisition phase GeoSuite Allworks is used for the final processing and interpretation. The processing operation includes automatic gain control (AGC), TVG (with editable curve), static correction, normalized, trace mixed-equalization, Swell filter, IIR filter (Band-pass; 200-2250 Hz; Dominant frequency is bandwidth 2000-4000 Hz), velocity analysis (1700 m/sec for the sediments, 2000 m/sec-2500 m/sec for the basement), signature deconvolution, and source and receiver-depth correction. The sediment thicknesses and water depths were calculated from the seismic reflection profiles using a P-wave velocity of 1600 m/sec for sediments and 1500 m/sec for water depths.

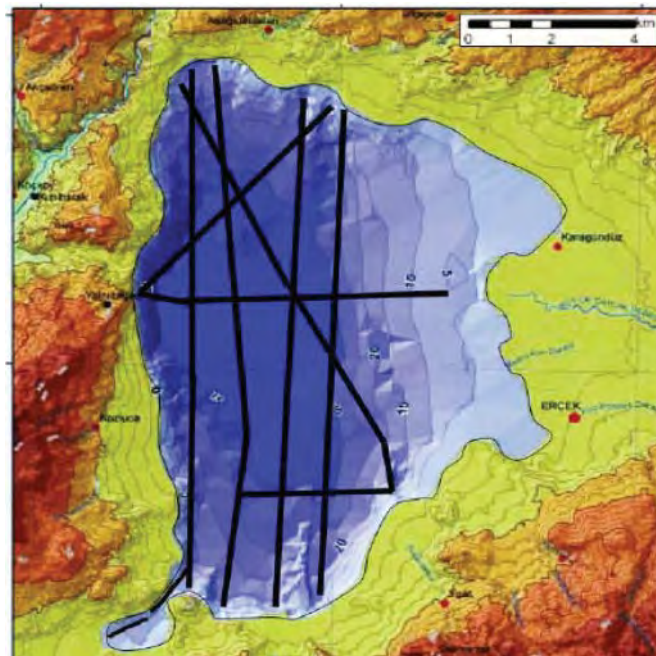


Figure 2 (Toker & Tur): Bathymetric map of Lake Erçek showing the distribution of the high-resolution seismic reflection profiles collected from the lake.

3D-structure of the acoustic basement (Figure 3) is observed and modelled from seismic reflection data. The acoustic basement is cut by dominantly WE-trending reverse and NS-

trending normal faults. The basement topography is asymmetrically controlled by W- and E-bounding normal faults, mainly oriented N-S, parallel to the general trend of the major stress direction. The acoustic basement is roughly in the range of ~90-100 msec in the basinal section of the lake and deepest in the lake center (Figure 3). Maximum depths of more than ~100-125 msec occur in the lake center, immediately next to the W-bounding normal fault. This suggests that the maximum subsidence is located in this area. The total sediment thickness shows a pattern similar to the topographic structure of the acoustic basement (Figure 3). The total sediment thickness ranges from 4 m to 15 m above the bounding faults and from 15 m to 30 m toward the deep basin and exceeds 80 m in the lake center. The thickness distribution in the lake directly defines the shape of the acoustic basement. 3D-seismic images of all the reflection profiles are performed to indicate the overall structural pattern of Lake Erçek (Figure 3). A simple structural analysis of reflection profiles indicates that the S- and N-margins of the lake are cut and controlled by very steep reverse faults (Figure 3). Thinning of sedimentary layers against the marginal reverse faults, tilting of higher sedimentary sections along these faults and the basement highs are evident (Figure 3). The overlying sediment strata, abutting against the marginal fault scarps, are tilted upward. The tops of the basement highs are eroded and evident as erosional unconformities. This suggests that the basement highs and the overlying sedimentary units appear to be folded and faulted. Gentle symmetrical folds are also present in the N-part of the lake (Figure 3). These structures are mainly oriented E-W, perpendicular to the general trend of the major stress direction. The W- and E-margins of the lake are cut and controlled by major NS-trending normal faults downthrown to the lake center (Figure 3). The lake sediments including the acoustic basement dip gently westward toward the W-bounding normal fault. These faults appear to be active today, offsetting the lake floor.

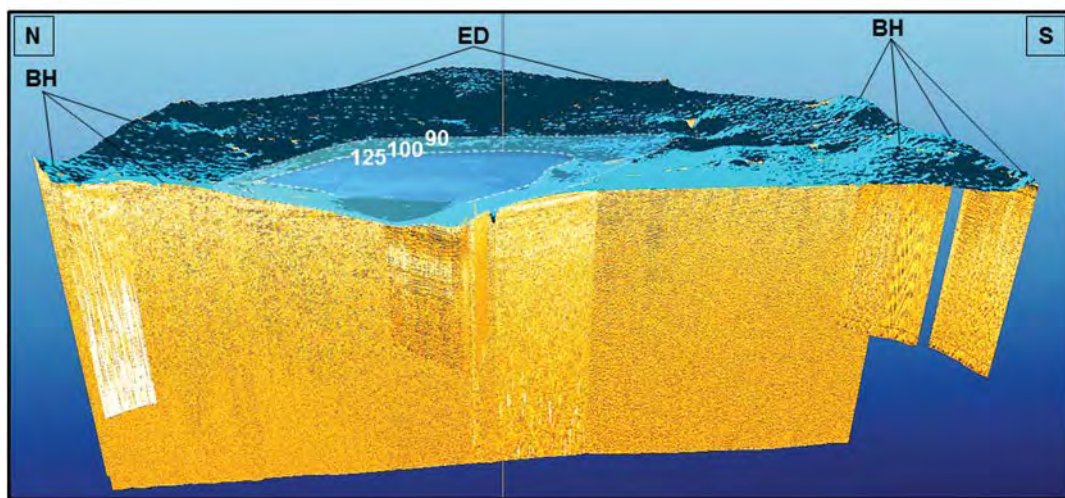


Figure 3 (Toker & Tur): Simplified topographic structure of the acoustic basement showing major structural elements using averaged values of TWTT observable along the lake margins (BH; basement high, ED; eastern delta).

In Lake Erçek, the NS-trending normal faults asymmetrically control the steeper W-margin and the gentler E-delta section, while the WE-trending reverse faults are more apparent in the N- and S-margins. The NS-trending normal faults, half-graben structure, and the gradual thickening of sediments in the Erçek basin toward the fault scarps are strongly suggestive of an extensional regime resulting from an N-S compression. In the N- and S-margins of the lake, there is evidence of folding, faulting and accompanying block uplifting, suggesting a significant N-S compressional regime that results in the reverse faulting and basement highs along the marginal sections. The folding and faulting caused strong uplift of

the basement blocks in the N- and S- margins, subsequently exposing the shelf and slope areas. The exposed areas are evident in the erosional unconformity of the surface of the basement highs and thinned sediments. New high-resolution seismic data reveals the faulting patterns and structural elements of Lake Erçek and provides strong evidence for an ongoing extension and subsidence in the Erçek basin as documented by the occurrence of the NS-trending normal faults along this basin. The present study provides new structural insights that will support future tectonic and sedimentary studies and the development of strategies related to active earthquake faults and hydrocarbon explorations in the region of Lake Erçek.

Acknowledgements This research was undertaken as part of a multidisciplinary Lake Erçek Seismic Survey (LESS-2015) project of Istanbul University (IU), Department of Geophysical Engineering, Istanbul and Yuzuncu Yıl University (YYU), Division of Earth Physics, Van (Turkey). The LESS-2015 project was supported by Research Fund of the Yuzuncu Yıl University (under Scientific Research Project Number: 2015-MİM-B119), and was partly supported by the University of Oulu (Oulu, Finland) post-doctoral research grant.

Brackish-water Caspian-type Upper Pliocene deposits in the western Shirak Basin (NE Turkey), applied to estimation of the Quaternary uplift of the Lesser Caucasus

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Session 2: Oral

The Pliocene-Quaternary Shirak Basin occupies NW Armenia and the adjacent part of NE Turkey. The 90-m thick clay and silt section that is covered by 5-m thick alluvial gravels is exposed in the Turkish side of the Akhurian River valley to the south of the Akyaka town (N 40°42.897'; E 43°40.367'; H = 1570 m a.s.l.). The whole section shows normal magnetic polarity. The Caspian-type dinocysts of the Lower Akchagylian (Upper Pliocene) aspect were identified by G.N. Aleksandrova from the lower part of the section. The presence of dinocysts in several layers denies their accidental appearance within the sediments. The maximum Akchagylian transgression level was probably ca. 100 m higher than the world sea level and decreased up to 0 to the Quaternary (~ 2.5 Ma). Therefore, the western Shirak Basin rose during the Quaternary to 1400–1500 m. The rise was caused mainly by total uplift of the region and partly by movements on the NE-trending Akhurian Fault. The similar fine-grained deposits were found by boreholes in the Armenian part of the Shirak Basin near the Marmashen Monastery. The top of these deposits is situated at the height of 1440 m a.s.l. and they are covered by basaltic trachyandesites with K-Ar dates 2.0–2.3 Ma.

According to the Sayadyan (2009) data, the mollusk fauna was found in the drilling probes. The mollusks were dated to Upper Akchagylian at 4–8 m under the top and to Lower Akchagylian at 43–126 m under the top of fine-grained deposits. Therefore, the vertical offset on the Akhurian Fault is about 170 m. The fault displacement occurred in the Early Pleistocene after accumulation of the Lower Akchagylian deposits and before the Ani unit sedimentation finished. This is proved by geomorphological position of the deposits: the Upper Pliocene section with dinocysts in the Turkish side of the fault and the Ani unit (ca.

1.5–0.75 Ma) in its Armenian side compose a single terrace, and the Arapi unit terrace (0.70 + 0.05 Ma) is incised into it.

The represented data show that the average rate of the Quaternary rise is about 0.6 mm/year. According to the data on NW Armenia, the uplifting accelerated about 0.6 Ma, when its rate reached 1.1–1.8 mm/year in the Lori and Upper Akhuryan basins and 2.0–2.3 mm/year in the adjacent ridges (Trifonov *et al.* 2017).

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Late Pleistocene – Holocene transitional complexes in the TransBaikal region: stone industries and oldest ceramics

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Session 3: Oral

During last years, the discussion about the appearance and distribution of ceramic traditions has become a topical one due to new discoveries of Late Pleistocene ceramics in China, Japan, Russian Far East and the Transbaikal region (Derevianko & Medvedev 1993; Boaretto *et al.* 2009; Jordan & Zvelebil 2009; Wu *et al.* 2012; Sato *et al.* 2011; Hommel *et al.* 2012; Shewkomud & Yanshina 2013; Kuzmin 2015; Jordan *et al.* 2016).

The Transbaikal region in Siberia is one of regions in Eurasia where pottery was already used in the Late Pleistocene and Early Holocene. Such early pottery complexes were identified in Ust'-Karenga XII (7), Studenoye 1 (7-9), Ust'-Menza 1 (5-8), and Ust'-Khyakhta 3 (Jull *et al.* 2011; Razgildeeva *et al.* 2013; Hommel *et al.* 2013) dated at about 12-11 ka BP. The comparative technological and typological analysis of the assemblages of the Pleistocene-Holocene transition reveals a continuity of lithic techniques. The Initial Neolithic pottery of the Transbaikal region has its similarities and differences. Both of them, stone industry and pottery, are important objects for study.

Neotectonic vertical-axis rotations in the Adria-Eurasia collision zone revealed from Paleomagnetic data of Pliocene-Quaternary cave sediments (Slovenia)

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Session 1: Oral

Vertical-axis rotations in the upper crust, inferred from paleomagnetic declinations recorded in rocks and unconsolidated sediments, are produced by various tectonic mechanisms such as large-scale plate motion, propagation and rotation of thrust sheets, or by rotation of rigid blocks in strike-slip fault zones. Paleomagnetic records can therefore provide important information about the timing and magnitude of tectonic episodes, but the consolidated rocks suitable for paleomagnetic analysis are often significantly older than the deformations which produced the rotations. We used paleomagnetic data obtained from cave sediments to document neotectonic (0 - 5 Ma) vertical-axis rotations in the northeastern corner of the Adria-Eurasia collision zone.

Magnetostratigraphy, radiometric dating, biostratigraphy, and geomorphologic constraints were combined to establish a robust chronology in the spatially and temporally highly discontinuous sediment record preserved in karst areas. Derived rotation rates range from 2 to 10°/Ma with peak activity from 3.0 to 1.5 Ma. The data provide new constraints on the Pliocene to Recent tectonics in the Adria collision zone and suggest that the northeastern peri-Adriatic belt is fully detached from the Adria microplate, which rotates <0.5°/Ma in a counterclockwise sense.

Our study demonstrates the potential of using cave sediments to provide robust and consistent paleomagnetic declination datasets, which bridge the gap between short-term deformation-rate determinations from geodetic and tectonic geomorphology studies, and long-term geological- time scale observations, therefore they can provide important new data for quantitative neotectonic studies.

Acknowledgements The research was supported by the Slovenian Research Agency (research core funding Nos. P1-0195 and P6-0119), by the CAS/SLO bilateral mobility cooperation grant (No. SAZU-16-03), and by the Plan of the Institutional Financing of the Institute of Geology of the CAS (No. RVO67985831).

Late Cenozoic uplift history of the Peak District, Central England, inferred from dated cave deposits and integrated with regional drainage development

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Session 1: Oral

The White Peak uplands in the Peak District region of central England extend over an area of >100 km² reaching up to ~400 m above sea-level, formed in limestone of Early Carboniferous (Dinantian) age. This extensively karstified region is also mineralized, having been mined for centuries for metalliferous minerals and fluorite. Historically regarded as palaeo-karst, following the availability of U-series dates since the 1980s, it has become apparent that the superimposed cave levels in this region formed during the succession of Pleistocene interglacials, their differences in height reflecting fluvial downcutting in response to regional uplift. However, quantitative interpretation is made difficult because of effects of glaciation, most importantly because of glaciation causing diversion of rivers in adjoining lowland regions, making the determination of uplift from fluvial incision particularly difficult.

Data from key sites will be discussed and used to quantify this region's uplift history. Uplift by ~150 m since the Mid-Pleistocene Revolution, and by ~300 m since the Mid Pliocene, is thus inferred. These amounts exceeds the uplift deduced over corresponding timescales in surrounding lowland regions, indicating that the Quaternary uplift has slightly

accentuated the overall domal form of this Carboniferous limestone inlier. The results establish, for the first time, the Quaternary uplift history of a wide region of Britain, through the integration of karstic and fluvial datasets.

Rethinking stratigraphy and site formation processes of the Ciota Ciara Cave (Monte Fenera, Italy)

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Session 1: Poster

In this poster we present the results of the geoarchaeological investigations at the Ciota Ciara Palaeolithic site (Piedmont, Italy). Ciota Ciara (meaning “bright cavern” in local dialect) is an active karstic cave that is opened on the west slope of Monte Fenera in the Borgosesia municipality. Monte Fenera, that reaches a maximum elevation of 899 metres a.s.l., stands isolated on the left side of River Sesia at the foot of the western Alpine relief. Western Alps are mostly composed of igneous and metamorphic rocks, but Monte Fenera includes sedimentary strata, mostly carbonate. This geological setting has led to the development of a karstic network which probably began during the Pliocene or the Messinian and that reached its full development in the Quaternary. To this day, seventy karstic caves have been reported. The cavities are found within the Middle Triassic “San Salvatore Dolomite” formation, a 300 metres thick succession mostly consisting of dolostone. This process was favoured by the permeability barrier provided by the underlying Permian Volcanic Complex. Most of the karstic cavities open on the west slope of the Monte Fenera and are oriented along two main directions (ENE-WSW and NNW-SSE), roughly parallel to the Cremosina and Colma tectonic lines.

Among these, Ciota Ciara is the best known thanks to the archaeological deposit predating the Alpine Last Glacial Maximum that the cave preserves. The cave develops for about 80 metres along its main axis and reaches a depth of 15 metres. Nowadays, it is accessible from two entrances, linked by a NE-SW oriented passage: a lower one facing south (665 m altitude a.s.l.), and an upper one facing west (named “the window” - 670 m a.s.l.). Other inner cavities develop at higher elevations. The Ciota Ciara cave has long been known and explored, and during the 19th century it has been interested by several archaeological excavations. However, proper documentation dating back to these investigations is missing. In 2009, a team from the University of Ferrara has resumed the fieldwork at the lower south-western entrance and Ciota Ciara is now the only systematically excavated Pleistocene site in the Piedmont region. Since then, interdisciplinary study has been carried out and has yielded information on anthropic and paleoenvironmental features, the site's biochronology, formation processes and stratigraphy.

The geoarchaeological study at the site has started in 2015 and has focused on the Palaeolithic succession that was unearthed at the cave south-western entrance. Investigations have included field description and sampling, routine sedimentological analyses, basic geochemical characterisation and micromorphological observation. The data shows that the deposit consists of mostly brownish, silty-loam sediments with variable quantity of coarser components and massive, often chaotic arrangement. The coarse components derive from the collapses of the ceiling and walls of the cave and from the Mesozoic sedimentary formations

which feed the upper part of the karstic network. The sediment preserved at the south-western entrance was mainly deposited by debris-flow and runoff events coming from the inner karstic system, suggesting that also a part of the archaeological assemblage has been slightly reworked. The entrance functioned as a 'cave exit' (a point of emergence of karstic water), but episodes of éboulis accumulation and short phases of surface stabilization were recognized as well. Micromorphological observation has demonstrated a high influence of the post-depositional processes that have selectively affected both the geogenic and the archaeological components. These include hydromorphism (Fe-Mn oxide coatings and stains), secondary accumulation of soluble substances (mainly phosphates), diagenesis and weathering dynamics, which lead to distinct degrees of preservation of the materials. Evidence of frost action was also detected in the lower part of the examined succession and is probably related to an early phase after the accumulation of the deposit.

The geoarchaeological investigation at the Ciota Ciara site has shown that this cave still bears important information on the Pleistocene archaeology in the Western Alps. These results highlight the relevance of these studies and the need to extend them to the other sites of Monte Fenera and its surroundings, as they can be crucial to understand the human occupation patterns.

Cave sediments and their research in Slovenia

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Session 1: Oral

Broad variety of karst sediments, from caves and surface, represents archives of past geologic and environmental records in spite of the fact that cave sediments mostly document the latest episodes of deposition. Sediments from diverse karst environments are many times the only deposits representing terrestrial phase of the landscape evolution. They (in)directly indicate the manner, phases and age of various geologic/geomorphic processes, speleogenesis and karst evolution.

Cave sediments are well preserved in underground (internal cave facies), as they are protected against weathering caused by the daily and seasonal fluctuations of climate parameters typical for the surface. Therefore they cannot be classified as soils. However, when the allogenic sediments, as a load of sinking river, are transported into the underground, they reflect changes in river catchment(s) due to changes e.g., of tectonic regime, environment or erosion intensity. They can hold also information on: mechanics of sediment transport; mode of deposition (sedimentary structures); sedimentary facies (cave specific environments); provenance of clastic sediments; diagenesis (e.g., drying, oxidation, hydrolysis, bioturbation, cementation); paleoclimate and time of sedimentation (age).

Cave sediments represent the most complex terrestrial depositional environment due to its mechanism (pipe system): the law of superposition is often violated (shrinking, slumping, burrowing, sandwiching etc.); facies usually are diachronous (differ in age and type laterally); variation in deposition rates can be extreme with subsequent erosion; reworking and redeposition along the same cave passage/system is very often. The systematic research of cave sediments in Slovenian caves has been carried out during the last 20 years with the application of number of different numerical and correlated dating methods and sedimentological approaches. The research clearly proved that the ages of cave sediments are

often up to 5 Ma old and even older. Studied sediment sequences are characterized by alternation of normal- and reverse-polarized magnetozone and short-lasting excursions of magnetic field. The Pliocene/Quaternary boundary was detected in some of them. The continuous Pliocene to Pleistocene deposition is characteristic for most of studied sections. Distinct phases of massive deposition in caves with as yet still preserved sediments were dated to about 5.4–4.1 Ma, 3.6–1.8 Ma and Quaternary, following the cessation of Miocene deposition in the Pannonian Basin in the central, E and SE Slovenia and post-Messinian evolution in the SW and W Slovenia. These depositional phases in underground suggest relief evolution in relation to surface climatic changes with massive flood events and to changes of the tectonic regimes since Neogene.

Acknowledgements The authors acknowledge the financial support from the Slovenian Research Agency (research core funding No. P6-0119), the CAS/SLO bilateral mobility cooperation (No. SAZU-16-03), and the Plan of the Institutional Financing of the Institute of Geology of the CAS (No. RVO67985831).

Pleistocene chronostratigraphy and key-sections of the Vychegda River Basin (European North-East)

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Session 4: Poster

According the current Quaternary System subdivisions for Russian European North-East (Tyman-Pechora-Vychegda subzone W-Ib, Zastrozhnov et al., in press), the Neopleistocene record within the Vychegda basin begins with the Rodionovo (Gorki, Schoningen, MIS 7a) horizon. The unique section containing the corresponding deposits is Kur'jador in the upper reaches of Vychegda: these are coarse alluvial (fluvial channel) sands and gravels with the OSL dates ~243-209 kyr BP (Lyså *et al.* 2011).

The next stratigraphic unit is the Vychegodsky (Moscow, Saalian, MIS 6) horizon. The deposits comprise glacial diamicton with rock clasts usually covered by glacio-fluvial sands and gravels/cobbles, sometimes including flaciolacustrine varved clays or silts. The numerous outcrops are known through the Vychegda valley from upper to lower reaches. Dated sections (glacifluvial sediments) are as follows: Myjoldino in the very upper reaches of Vychegda with the OSL-dates ~135-111 kyr BP (Lyså *et al.* 2011) and Don 1-2 in the middle reaches with IRSL dates 130.8 ± 12.8 (RLQG 2359-085) and 124.6 ± 14.3 (RLQG 2360-085).

The lower Sulinsky (Mikulino, Eemian, MIS 5e) horizon is not represented in the Vychegda river basin. The closest section with Sulinsky peat and loamy peat of oxbow lake origin dated by ²³⁰Th/U to 120-104 kyr BP, containing *Picea* logs and megafauna remnants is Tolokonka located 100 km downstream the Vychegda- Severnaya Dvina confluence (Zaretskaya *et al.* 2013).

Fluvial deposits of the upper Sulinsky (lower Weichselian, MIS 5d-a) and Laysky (early Valdai, lower-middle Weichselian, MIS 4) horizons are represented in the lower parts of the 3rd 18 m terrace sections in lower Vychegda. These are coarse-grained sands with

gravel beds. Two exposures could be considered as key-sections: Gam with OSL-dates ~101-92 kyr BP (Lyså *et al.* 2014) and Yaren'ga (Zaretskaya *et al.* in press).

Two key sections of the 2nd 15 m river terrace are located in the very upper (Kur'jador) and lower (Baika) reaches of Vychegda and contain the continuous record of MIS 3 and 2 (Byzovo, upper-middle Weichselian, Leningradsky and Polar, upper Weichselian and Ostashkov horizons). Fluvial deposits forming the Byzovo horizon are different facies of alluvium (from active channel to oxbow lake) containing organic layers. OSL dates comprise the time interval 67-47 kyr BP (at Kur'jador, Lyså *et al.* 2011), radiocarbon - ~ 44 – 26 ¹⁴C (48 – 30 cal) kyr BP and ²³⁰Th/U – 50 – 38 kyr BP (Maksimov, Zaretskaya *et al.*, 2015). Pollen data shows the presence of *Picea* in the organic-bearing sediments (Andreicheva *et al.* 2015).

Sediments of the LGM Ostashkov (Polar) horizon are represented by the 1st terrace alluvium with cryoturbations (IRSL date of 23.1±2.0 (RLQG 2362-085)) and aeolian silts and sands of the upper parts of Kur'jador and Baika sections. Another generation of the 1st terrace contains the deposits of deglaciation time (17-11 cal kyr BP) (Zaretskaya *et al.* 2014). Holocene is represented by floodplain deposits dated from 11700 cal BP till now (Chernov *et al.* 2015).

This is a contribution to the DATESTRA project.

Acknowledgements Investigations of alluvial section stratigraphy were supported by Russian Science Foundation (RSF), project no. 17-17-01289. Financial support for geochronological studies was received from the Russian Foundation for Basic Research (RFBR), project no. 17-05-00706, following the plan of the scientific research of the Geological Institute of RAS № 0135-2018-0037.

Variations in yellow-necked mouse (*Apodemus flavicollis* Melch., 1834) dental morphologies of the Nizhneirginsky Grotto sediments (Middle Urals) in a phylogeographical context

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Session 1: Poster

The yellow-necked mouse (*Apodemus flavicollis* Melch., 1834) is a typical representative of the European fauna, whose distribution range is confined to the broad-leaved forest zone and occupies a considerable territory of Eurasia from Great Britain and northern Spain to the Urals [1,2]. The Urals is the eastern boundary of the distribution of the yellow-necked mouse. More recently, the most northeastern habitat for the yellow-necked mouse has been described [3]. Also in this area the yellow-necked mouse molars were found in the late Holocene sediments of Nizhneirginsky Grotto (56°51' N, 57°24' E). In our work, we analyzed the variability of molars of the yellow-necked mouse from modern populations (marginal and from the main part of the range) and fossil molars in the phylogeography context of the yellow-necked mouse.

A comparative analysis of the morphological variability of the yellow-necked mouse molars was performed using a set of the non-metrical dental characters. The complex of the non-metrical dental characters was based on those described earlier and on own research [4,5].

We considered the first and second upper and lower molars of the yellow-necked mouse of recent populations: Zhitomir region (Ukraine), $n(\text{molars})=76$; Republic of Bashkortostan (Russia), $n(\text{molars})=84$; Sverdlovsk region (Russia), $n(\text{molars})=68$ and of Grotto Nizhneirginsky sediments (Sverdlovsk Region, Russia), $n(\text{molars})=43$.

Populations from the main part of the range (Zhitomir region, Republic of Bashkortostan) have a similar phenotypic. Late Holocene molars from the territory of the Middle Urals are phenotypically close to the recent populations from the main part of the range. The population from the northeastern edge of the yellow-necked mouse range is characterized by greatest specificity of the molars morphology that may indicate isolation of this population due to a reduction in the range of the yellow-necked mouse in the Middle Urals in the late Holocene.

Acknowledgments This study was performed within the frameworks of state contract with the Institute of Plant and Animal Ecology, Ural Branch, Russian Academy of Sciences, and partly supported by the Russian Foundation for Basic Research (project no 18-34-00270).

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Afternoon field trip (A):
TOURIST VISIT OF POSTOJNSKA JAMA
 Wednesday, 12.9.2018, 15.00–17.00

Nadja Zupan Hajna

LOCATION

Postojnska jama (Postojna Cave; Reg. No. 747) is developed in Postojnski kras (Postojna karst) between Pivka Basin and Planinsko polje (karst polje; Fig. 1). The surface is at about 600 to 650 m a.s.l. The evolution of the Pivka basin (flysch rocks) is defined by the altitudes of the ponors of Pivka river that drain into this cave.

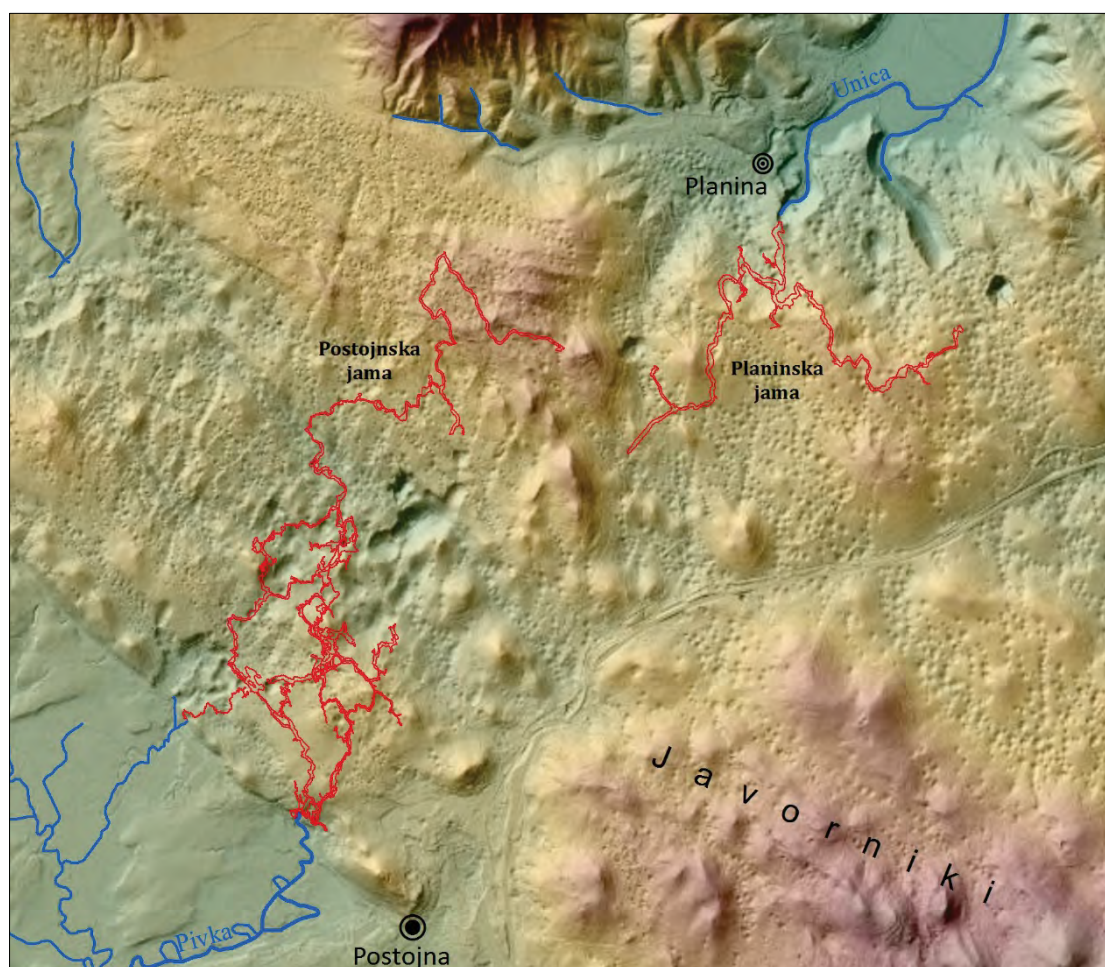


Figure 1: A geomorphological map of the Postojnski kras between the Pivka Basin and Planinsko polje with the location of caves Postojnska and Planinska jama.

The gentle fluvial surface of the Pivka basin itself stands out in sharp contrast to the karst lands above the cave and to other higher karst plateaus, where there are no traces of fluvial valleys or other elements of the early fluvial relief today (Fig. 1). These surfaces are dissected with numerous dolines. Sixteen large collapse dolines developed above some parts of Postojnska jama, blocking some of the passages. The thickness of bedrock above the cave is 60 to 120 m.

The cave was formed by the river Pivka. Its modern ponor is at 511 m a.s.l. and the sump in Pivka jama (Pivka Cave) is at 477 m a.s.l. There are still more than 800 m of unexplored galleries before the

river re-appears in Planinska jama at 460 m a.s.l. In May 2015 the cave divers started to explore the most remote parts of the cave after siphons in Pivka jama (Fig. 1).

GEOLOGY

Surface geology of the Postojna karst terrain between caves Postojnska jama and Planinska jama bases on studies of Buser *et al.* (1967), Gospodarič 1976, Čar & Gospodarič (1984), Placer (1996), Rižnar 1997 from which results was compiled on new geology map for the purpose of exhibition at Postojna Expo (Zupan Hajna 2015).

Karst between Postojna and Planina builds up about 800 m thick limestones and dolomites of Cretaceous age. Carbonate beds of various thicknesses are overthrust, folded and faulted due to regional tectonics (Placer 1996). Important structural elements of folding are Postojna anticline and Studeno syncline, which are oriented in SE–NW direction. Significant faults are in Dinaric direction (SE–NW; dextral strike-slip fault) and in Cross-Dinaric direction (sinistral strike-slip fault); some of them are vertical.

River Pivka flows on impermeable Eocene flysch and on the contact with limestones sinks into cave Postojnska jama. River Pivka flows underground towards cave Planinska jama, from where then emerges as river Unica. The entire cave is developed in an 800-meter thick sequence of limestones confined by two distinctive dextral strike-slip fault zones in the Dinaric trend (Predjama and Idrija faults). Cave passages were mostly formed following inter-bedded slips (Šebela 1998) in the limestones of the Postojna anticline, which is oriented in the NW–SE direction (Gospodarič 1963, 1964, 1976). The cave is intersected by several fault zones in the Dinaric and cross-Dinaric direction; some faults were important for guiding the direction of the water flow and for the formation of passages, while others were simply traversed by the water flow. Large breakdown halls in caves are formed in thick-bedded and tectonically collapsed limestones in the fluctuation zone of the groundwater that dissolves the collapsed blocks.

THE CAVE

The total length of known passages is (in May 2017) more than 24 km and the calculated volume of all cave passages is 1.7 million cubic meters (Glažar & Drole 2015). The ground plan is on Figure 2 (Glažar *et al.* 2015). The passages were formed in two levels. The upper dry section of the cave lies between 520 and 530 m.

The altitude difference between the highest point at the entrance to Magdalena jama and the lowest point at the siphon in Pivka jama is 115 m. The distance from the ponor of River Pivka into Postojnska jama to the siphon in Pivka jama is approx. 3.5 km. The known section of the Rov podzemne Pivke (Passage of the Subterranean Pivka) ends about 800 m before reached Planinska jama passages (Fig. 1). The source of River Unica is in Planinska jama, from where the river flows on the surface of the Planinsko polje.

Active water passages are on average smaller than the passages in the presently dry sections. Flysch gravel and sand are predominant in the rocky bottom. The average water discharge is 5.2 m³/s. During flooding, the water in passages can raise by 10 m. Signs of flows with various velocities are visible on walls in scallops of different sizes.

POSTOJNSKA JAMA



Figure 2: The ground plan of Postojnska jama with its entrances.

Passages in the presently **dry section** of the cave were likewise formed by the water flow when the river was flowing at this level. Later, the flow of water moved lower due to a reduction in the gradient. The dry passages up to an altitude of 520 m can now only be reached by the highest waters. Passages in the presently dry section are large – up to 10 m high and wide. Their profiles here are rounded and show traces of paragenesis (transformation through sediments), such as levelled ceilings and side notches on the walls.

The stable **cave temperature** in Postojnska jama is 8.5 °C, but this is only the case for the cave's isolated parts. In other parts, the temperature ranges from 3 to 13 °C, depending on the surface temperature. In all passages, the sinking river used to deposit **various sediments**, including gravel, sand, clay and loam. Deposits originate from weathered flysch rocks of the Pivka Basin and are in terms of their mineral composition therefore more or less the same: the predominant kinds are quartz, plagioclases and clay minerals (Zupan Hajna 1992). The remnants of deposits in the cave are aged over 2 million years (Zupan Hajna *et al.* 2008a, 2008b, 2010); in terms of their composition they are identical to the current deposits of River Pivka. Throughout their history, cave passages were repeatedly completely filled with sediments and then eroded again (this can be inferred from the remains of the ground, walls and the ceiling, as well as between layers of flowstone).

Dry passages are for the most part full of **speleothems**; especially those were not filled with sediments for a long time. Speleothems are of different shapes, colours and ages (Fig. 3) and large numbers of them can be seen by visitors during cave tours, although in some of the non-tourist parts of the cave, speleothems are likewise in abundance. The oldest known speleothem from Postojnska jama's is from Pisani rov (Coloured Passage). Its core was dated by using ESR and U/Th methods to approximately 530,000 years (Ikeya *et al.* 1983; Zupan 1991). Outer rings of the same speleothem the same passage have given the ages of 23,000, 12,000 and 6,000 (Zupan 1991). Dated speleothems from the Velika gora (Great Mountain) uncover periods of growth in warmer climes and the time of the ceiling collapses in colder climes (Mihevc 2002). Obtained speleothems ages on the collapse rocks at 527 m a.s.l., dated by U/Th, were 152,000 47,000, 43,000, 37,000 years.

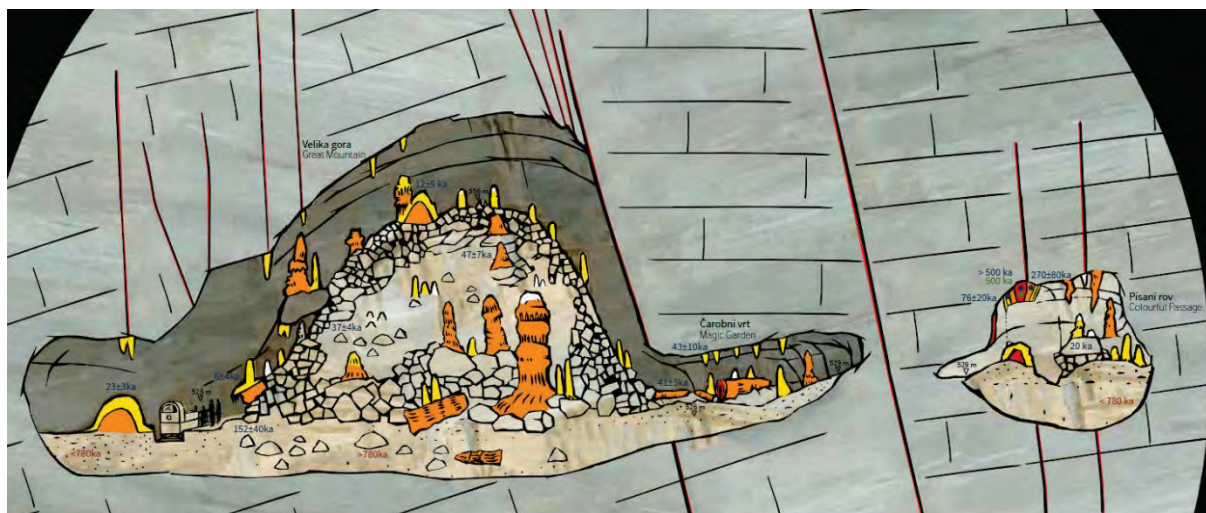


Figure 3: Schematic cross-section of cave passages Velika gora, Čarobni vrt and Pisani rov with dating results; speleothems: U/Th, ESR, C^{14} ; and fluvial sediments: paleomagnetic (from Zupan Hajna 2015).

SPELEOBIOLOGY

Postojnska jama is known after the first discoveries of cave-dwelling animals (troglobiontes) in the world. In 1797 in the cave Črna jama *Proteus anguinus* (Cave salamander or human fish; Fig. 4a) was found for the first time. In 1831 one of cave guides, Luka Čeč, found the first cave beetle *Leptodirus hochenwartii* (the Slenderneck beetle; Fig. 4b). With these first discoveries the new explorations were done in the cave and many new species were found and described from the cave: the cave

spider (*Stalita taenaria*), the Postojna Cave pseudoscorpion (*Neobisium spelaeum*), the cave amphipod (*Niphargus stygius*), the giant cave trichoniscid (*Titanethes albus*), the cave snail (*Zospeum spelaeum*) and the cave centipede (*Lithobius stygius*); consequently, Postojnska jama is known also as a cradle of speleobiology as a science (Pretnar 1968). Postojnska jama is a hot-spot regarding biodiversity as 114 species of cave-dwelling animals (Zagmajster *et al.* 2014) have been discovered and described in the cave; for 84 of them the cave is the type locality (*Locus typicus*).



Figure 4: a) *Proteus* is endemic species of Dinaric karst and was found for first time in the cave in 1791 in cave Črna jama, which is part of Postojnska jama; b) *Leptodirus* is the first cave beetle in the world which was discovered in Postojnska jama in 1831 and was a year later, in 1832, recognised and scientifically described by Ferdinand Schmidt as a true cave-dwelling animal.

TOURISM

Postojnska jama is the biggest show cave in Slovenia and in Europe with a total number of 37,000,000 recorded visitors in August 2016.

The entrance part, named Veliki dom, is a hall that had been known to Postojnska jama visitors even before the inner parts were discovered. River Pivka flows into the bottom of this chamber through the siphon from the outside ponor. In this part of the cave is also small narrow passage with many old signatures on the cave wall, the oldest is from year 1213. The inner parts of the cave were discovered only in 1818.

Postojnska jama's worldwide fame was achieved through almost 200 years of intensive tourist development: discovery of inner parts in 1818, guided tours since 1819, railway since 1872, permanent electric lighting since 1884 and another thing of great importance: despite its continuous use for the purposes of tourism the cave remains a natural attraction in excellent condition with over 500,000 visitors per year.

Sustainable management is a big challenge in show caves with such large visitor numbers. While direct physical impact of the touristic infrastructure on cave environment can be relatively easily assessed, the assessment of indirect impact of tourism is much more difficult. To this extent, long term monitoring and the analysis of the environmental parameters are crucial. Chemical and physical parameters of percolating water and allogenic recharge have been monitored for decades in the cave, but temperature, moisture, wind and CO₂ only for a few years. Monitoring intends to determine the human impact on natural cave environment. Monitoring of cave air temperature began in 2007. As proved by the results, Postojnska jama is a well ventilated system; external temperature dynamics penetrate deep into the cave. More on climate and tourist visit influence on the cave you can get from e.g. Gabrovšek (2012), Gabrovšek *et al.* (2014), Gregorič *et al.* (2014), Šebela *et al.* (2013) and Šebela & Turk (2014).

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Whole-day field trip (B):

CLASSICAL KARST: CAVES ŠKOCJANSKE JAME, ČRNOTIČE QUARRY AND SOCERB

Friday, 13.9.2018, 8.30–19.00

Andrej Mihevc, Nadja Zupan Hajna

Stops

- 1 – Škocjanske jame (cave)
- 2 – Lipove doline (unroofed cave)
- 3 – Črnotiče Quarry
- 4 – Socerb (outlook)



KRAS PLATEAU

Kras (Karst; Fig. 1) is a carbonate plateau in SW Slovenia which is spread out between Trieste Bay, the Vipava valley and the river Soča in the NW-SE direction (i.e. the “Dinaric” direction). Kras is 40 km long and up to 13 km wide. The main part of the plateau is essentially levelled and inclined slightly towards the NW, surface is dotted with dolines, larger collapse dolines, cave entrances, dry valleys and other karst features. Kras Plateau became a textbook example for such landscapes because of the extraordinary karst phenomena, and explorations done in the 19th Century. The name Kras in the German form of the word (*der Karst*) became an international scientific term.

The Reka is the main sinking river at the edge of the Kras Plateau (Fig. 1). Water from the Reka and water in the form of precipitation infiltrate into the Kras and surfaces again at the springs along the NW coast of Adriatic, mainly at the springs of Timavo about 35 km NW from Škocjanske jame (Fig. 1). The springs are additionally recharged from the Soča, Vipava and Raša rivers. Three main springs with a mean discharge 30.2 m³/s are connected by a network of passages that reach a depth of about 80 m below the sea level.

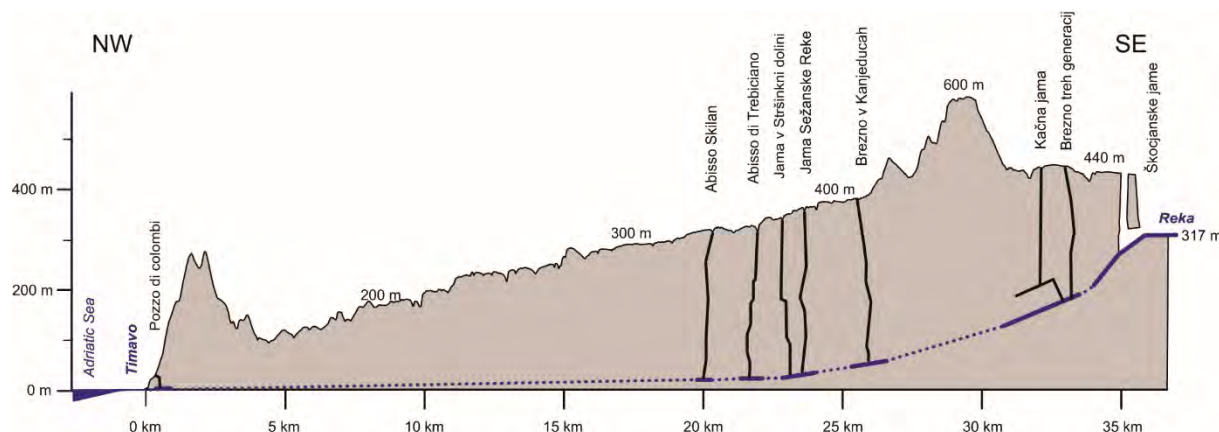


Figure 1: Geomorphology of Kras Plateau (up) and its cross-section (down) from the sink point of the river Reka in Škocjanske jame to the springs of Timavo, with caves in which the underground water flow can be reached. Source of data: Geodetski oddelek ARSO.

The plateau consists of Cretaceous and Paleogene limestones and dolomites and it is surrounded by Eocene flysch sediments (Fig. 2). From a tectonic point of view, the Kras belongs to the Komen nappe of the NW part of External Dinarides (Placer 1999, 2008, 2015). Two basic groups of tectonic structures can be distinguished here. They resulted from: the Cretaceous–Paleogene NE–SW-directed compression and the Neogene and Quaternary N–S-directed compression

In the NW part, the plateau descends to below 50 m a.s.l.; on its SE edge, altitudes are about 500 m a.s.l. No superficial streams occur on the Kras surface, because all rainwater immediately infiltrates the carbonate rocks. There are two dry valleys crossing the plateau. A NW–SE-trending belt of lower relief in the center of plateau is a result of younger tectonics. About 3,490 caves are known on the plateau.

The climate of the Kras is sub-Mediterranean with warm dry summers. Most of the precipitation occurs in autumn and spring. Cold winters, with the NE wind "burja" (bora = borealis), show the strong influence of the continent. Average yearly precipitation varies from 1,400 to 1,650 mm. Because of intensive pasturing in past centuries, Kras was bare, with a rocky and grassy surface. In recent decades the trees have overgrown the landscape.

Kras receives water from precipitation (ca. 1200–1600 mm), allogenic rivers like Reka in the SE, some smaller brooks in the NE and strong inflow from alluvium along the Soča River to the N. Because of the flysch barrier along the coast, water emerges as springs only where this is below the water table. The largest springs join into the river Timavo.

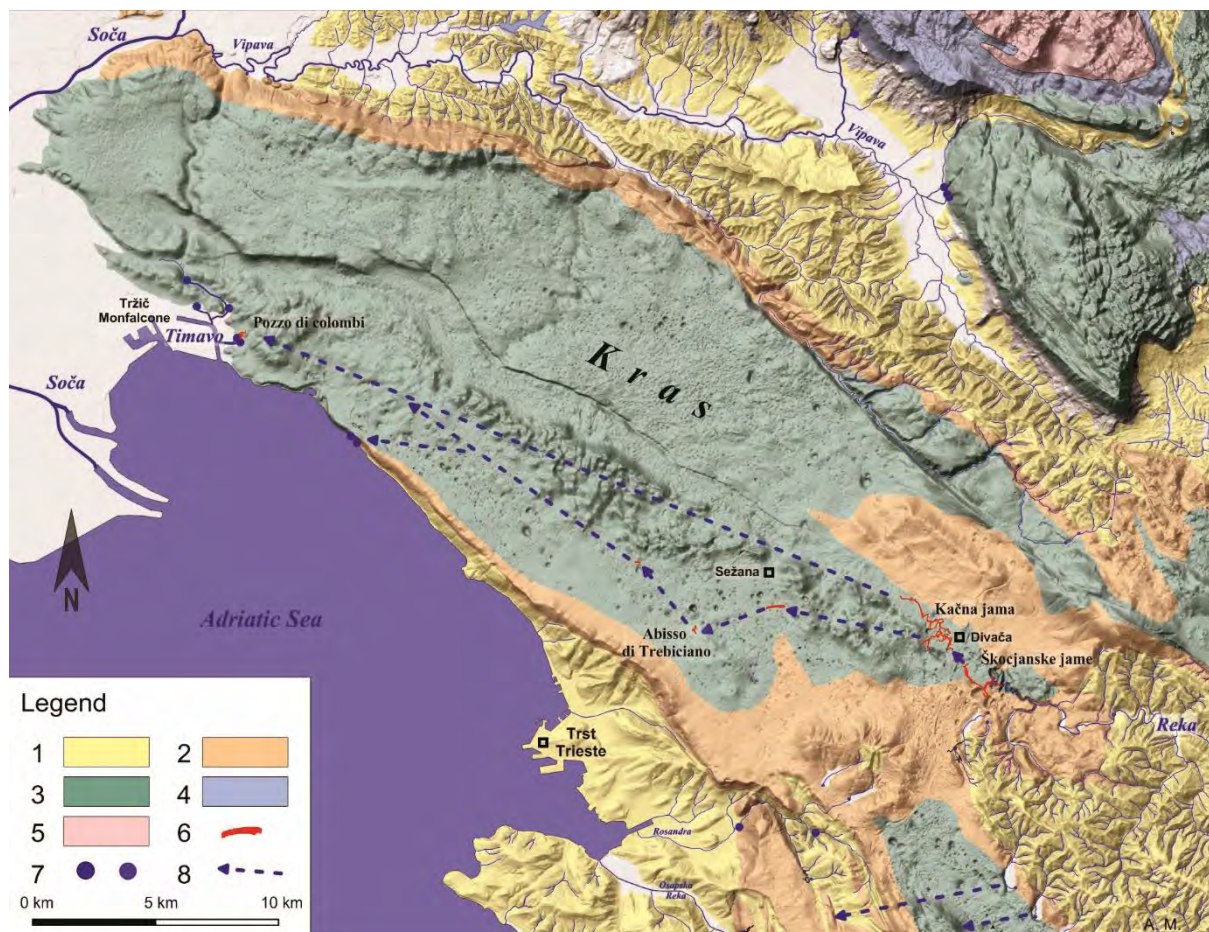


Figure 2: Lithology and hydrology of Kras Plateau. Legend: 1. Eocene flysch; 2. Paleocene limestone; 3. Cretaceous limestone and dolomitic limestone; 4. Jurassic limestone and dolomite; 5. Triassic dolomite; 6. important cave; 7. main spring; 8. presumed flow of underground river Reka. Source of data: Geodetski oddelek ARSO.

The age of the Kras Plateau can be defined as the time when the karst rocks were uplifted out of the sea in the late Eocene, since after that there is no evidence of younger marine sediments. As soon as the carbonate rocks were exposed, we presume that the karst was formed, but there are no remnants of karst relief or other features from that time. The age of karst evolution of the area can be gained by dating of karst surface and caves sediments. Since 1997 eleven sites on Kras were studied regarding the origin and age of the sediments (e.g. Bosák et al. 1998, 2000; Zupan Hajna et al. 2008, 2010). The oldest cave sediment analysed is over 10 Ma old, and most sedimentary profiles studied in the caves represent some distinct phases of massive deposition in caves, dated to about 5.4–4.1 Ma (Miocene–Pliocene), 3.6–1.8 Ma (Pliocene–Pleistocene) and the Pleistocene.

DIVAŠKI KRAS

Divaški kras (Divača Karst) is a karst surface between the ponor of the Reka River to Škocjanske jame and the village of Divača (Fig. 3) and represents the extreme SE part of Kras.

The karst morphology of Divaški kras is exceptional: on a small area there are sinks of the river Reka, 15 large collapse dolines and hundreds of dolines. These features represent about 12 % of the area (Mihevc 2001). Numerous caves are known; the biggest among them are Škocjanske jame, Kačna jama, Divaška jama and Trhlova.

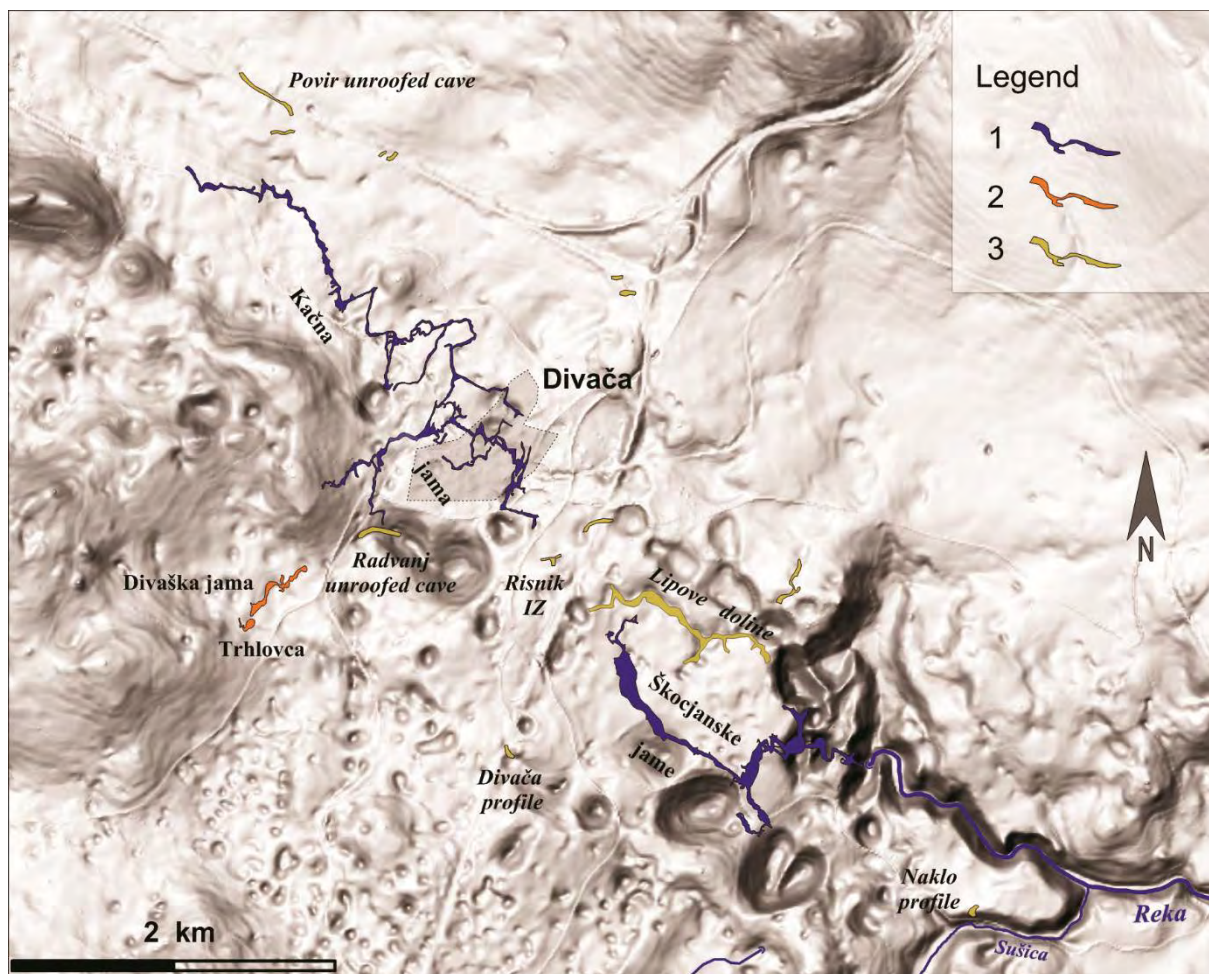


Figure 3: Divaški kras with studied caves and unroofed caves. Legend: 1- caves with active water flow; 2 - relict caves with sediments; 3 - unroofed caves. Source of Lidar data: Geodetski oddelek ARSO.

The main morphological element of the Divaški kras is a levelled surface with inclinations less than 10° (Fig. 3). This type of surface represents about 87% of the total area. It is dissected with numerous dolines. Most of them (740) are small, their diameter is about 50 m and they are about 8 -10 m deep. We presume that they are solution dolines. They cover about 5% of the area and their total volume is estimated to $6-10 \times 10^6 \text{ m}^3$. There is another group of dolines, which are clearly of collapse origin. This is evident from their morphology, size, position above the active caves and recent debris flow or collapsing. The largest are more than 500 m across, and the deepest are more than 150 m deep. The largest collapse doline is the 122-m deep Dol Sekelak, with a volume of $8.5 \times 10^6 \text{ m}^3$. Dol Globočak is smaller, 90 m deep, and has a volume of $4.8 \times 10^6 \text{ m}^3$. Dol Risnik is 86 m deep, and has a volume of $1.7 \times 10^6 \text{ m}^3$. The group of the largest 15 collapse dolines covers only 4% of the area, but their total volume is about $38 \times 10^6 \text{ m}^3$.

ŠKOCJANSKE JAME

Škocjanske jame are 5.8 km long cave (Fig. 4) formed by the river Reka that enters the cave at an altitude of 314 m a.s.l., flows towards Martelova dvorana at 214 m a.s.l. and to terminal sump at 190 m a.s.l. (i.e. 124 m lower). At low water levels the Reka sinks 7 km before it enters the cave. Floods usually reach up to 30 m. The largest known flood in the 19th century raised the water table level for 132 m. The largest chambers are Martelova dvorana, with a volume of $2.1 \times 10^6 \text{ m}^3$, and Šumeča jama with $0.87 \times 10^6 \text{ m}^3$. Some of the big chambers have been transformed into collapse dolines like Velika and Mala dolina.

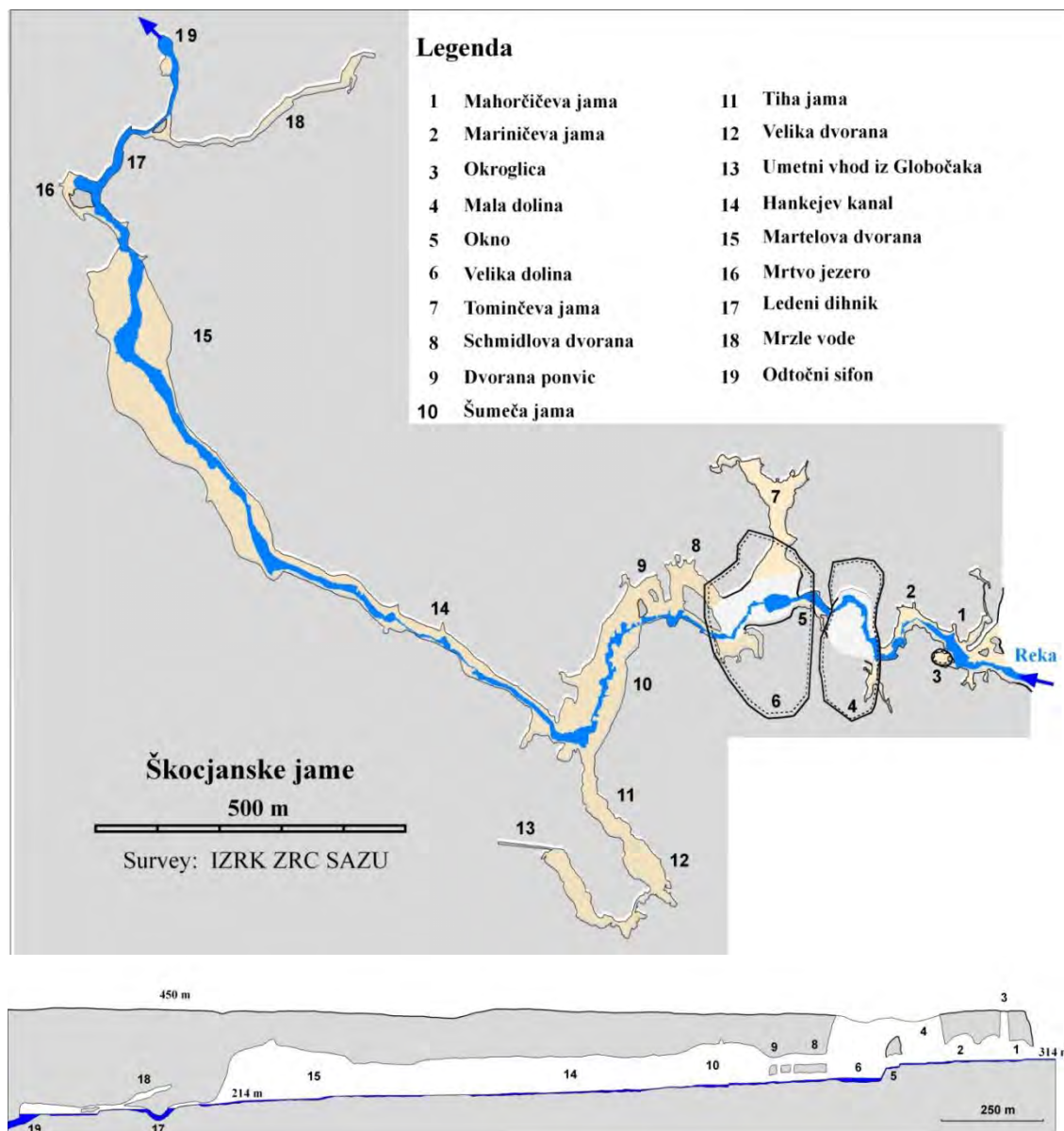


Figure 4: Ground plan and profile of Škocjanske jame.

Škocjanske jame developed in Cretaceous thick-bedded rudist limestone and Paleocene thin-bedded dark limestone (Gospodarič 1983, 1984; Knez 1996; Šebela 2009, 2016).

The cave is composed of passages that were mostly formed in phreatic conditions but later modified by paragenesis or gravitational entrenchments of underground Reka and collapses. The proto-channels of today's cave developed in phreatic conditions, formed along tectonized bedding-planes. Large quantities of water could only slowly flow through these passages. Therefore fine sediments, clays and silt are preserved in them. Coarser material, sand and rubble were transported through epiphreatic caves about 150 m above them. A remnant of such a cave is the unroofed cave at Lipove doline, located on the surface above the present cave at an altitude of about 450 m a.s.l.

The water flow demanded a high degree of vertical phreatic circulation between individual bedding planes which are in the area of the chambers Šumeča jama approximately 175 m. As these circulation utilize fractured zones they destabilize them with the formation of parallel shafts. These shafts were the basis for the extensive passages collapses and widenings.

The reveals present morphology of the cave a long stable period expressed by paragenetic features and the deposition of sediments comprised mostly of quartz sands. For a long period of time

the water table in the cave was 340–300 m above sea level and the gradient was towards the SW. The Reka formed new passages or adopted old passages by bypassing or paragenesis, respectively. The large galleries with paragenetic ceilings were formed (Mahorčičeva and Mariničeva jama, Tominčeva jama, Schmidlova dvorana and Tiha jama).

The next phase of the cave evolution included important changes. Gradient increased and turned towards NW. This resulted in the entrenchment of the main stream passage. In the inner parts of the cave, in Hankejev kanal, cutting resulted in an 80-m gorge, while in the entrance part of the cave, down cutting did not exceed 10 m. These changes can be connected with regional tectonic activity, i.e. uplift and tilting of the whole Kras delayed by the time needed for adaptation of all caves in the Reka system.

The first paths in the cave area were explored in 1823, but construction of paths for exploration and for the visitors started in 1884. By 1891 they explored most of the known cave. Today explorations are focused to diving in the sumps and prolongation along underground river.

Škocjanske jame were included in UNESCO's World Heritage List in 1986 and the surface around the caves is included for protection into Škocjanske jame Regional Park.

CAVE SEDIMENTS

The Reka, with its tributaries, is typical allogenic river bringing sediment load into Škocjanske jame (Fig. 3). From the ponor, and along the riverbed, various clastic sediments are present. In the gravel clasts of flysch sandstone dominate, but in the parts before the terminal siphon, limestone pebbles prevail (Kranjc 1989). Recent flood clay from end part of the cave (Martelova dvorana at 214 m a.s.l.) consists mainly of quartz. Some other minerals such as plagioclase, illite, kaolinite, chlorite and calcite and montmorillonite are present in traces (Zupan Hajna 1995). In older flood loams from the upper part of the caves (Tiha jama at 334 m a.s.l.) quartz also prevails, with some traces of plagioclase, illite, chlorite, and microcline. In Černigojeva dvorana (at 334 m a.s.l.) Gospodarič (1984) described fossil deposits of chert, flysch sandstone and limestone pebbles. Various fluvial sediments are also preserved in other parts of the caves but flood loams prevail. Their characteristic colour (always a yellow tint) and position indicates their origin of weathered flysch (Zupan Hajna 1998). Sediments from unroofed caves above the Škocjanske jame have very similar mineral composition; alluvial sediments were also found in Divača Industrial Zone (IZ) Risnik unroofed cave (at 455 m a.s.l.) and in a completely filled cave at Naklo (slope of Sušica valley, at 385 m a.s.l.). These sediments were mainly flysch sandstone pebbles and sand. The sand consists of quartz, calcite, muscovite/illite group of minerals, montmorillonite, microcline and plagioclase in traces (Fig. 5).

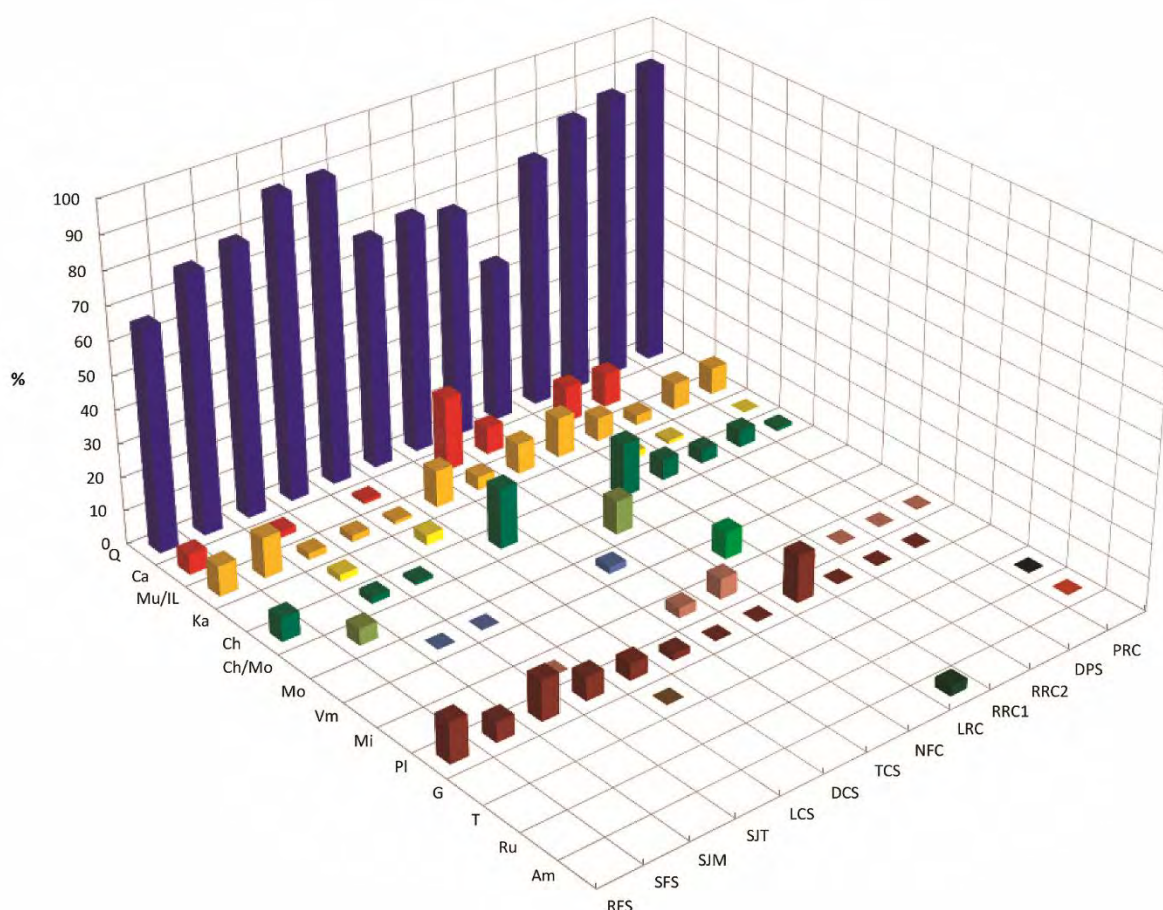


Figure 5: Mineral composition of samples from Reka catchment area, caves and unroofed caves (from Zupan Hajna *et al.* 2017). Legend: RFS- Reka (Zemon), river sediment; SFS- Sušica, river sediment ; SJM- Škocjanske jame (Martel d.), flood loam; SJT- Škocjanske jame (Tiha j.), loam; LCS- Labodnica, flood loam; DCS- Divaška jama, laminated sediments; TCS- Trhlovca, sand; NFC- Naklo, filled cave sand; LRC- Lipove doline roofless cave, soil; RRC1- Risnik IZ roofless cave, sandy clay from bottom; RRC2- Risnik IZ roofless cave, yellow sand from upper part; DPS- Divača profile filled cave, sand; PRC- Povir roofless cave, sand; Q- quartz; Ca- calcite; Mu/IL- muscovite/illite minerals; Ka- kaolinite; Ch- chlorite; Ch/Mo- chlorite/ montmorillonite group of minerals; Mo- montmorillonite, Vm- vermiculite, Mi- microcline; Pl- plagioclase; G- goethite; T- tourmaline; Ru- rutile; Am- amphibole.

Studied paleomagnetic properties of the sediments in the caves Divaška jama, Trhlovca and in Divača profile (in Fig. 3; Bosák *et al.* 1998, 2000; Zupan Hajna *et al.* 2008), gave results that the age of the alluvial sediments is most probably up to 5 Ma. Studies of sediments from IZ Risnik unroofed cave indicate the same age. Clastic fills of unroofed caves and extant caves of Divaški kras consist mainly of weathering products of Eocene flysch rocks eroded from the Reka catchment. In all cases relatively equal mineral composition prevailed, indicating the main source was from flysch sediments which were weathered in different degrees. The mineral composition of the Eocene flysch sandstones of Brkini SE of Divača, which is the catchment area of the Reka, varies more in the quantity of individual minerals than in the presence of different minerals. On Divaški kras, fluvial sediments from unroofed caves are also an important source of superficial soils.

UNROOFED CAVE IN LIPOVE DOLINE

On the surface, at elevations 400–450 m a.s.l., there are numerous unroofed caves, as demonstrated by allogenic cave sediments and massive flowstone). The first recognized unroofed cave was a 350 m long cave near Povir village, which was filled by fluvial sediments and speleothems (Mihevc & Zupan Hajna 1996; Mihevc *et al.* 1998; Knez *et al.* 2016). Morphological analysis of several

unroofed caves on the Divaški kras (Mihevc 2001) and paleomagnetic dating of sedimentary fills (Zupan Hajna *et al.* 2008, 2010), have indicated cave origin and the age of a several million years.

The largest cave exposed to the surface by denudation is the unroofed cave in Lipove doline (Fig. 6). The unroofed cave is located on the surface above Škocjanske jame and is named after the group of dolines Lipove doline. In the western part of this unroofed cave, quartz sand was extracted (Pleničar 1954), during which a large amount of flowstone and a large stalagmite (Fig. 24) were exposed. From Lipove doline unroofed cave comes a yellow/brown soil consisting of quartz, muscovite/illite group of minerals, plagioclase, chlorite, vermiculite and amphibole (Fig. 22). Amphibole has no origin in flysch, but indicates an eolian origin (e.g. from some volcanic eruption, desert sand or even loess) and represents admixture in the top layer of the soil developed from the weathered flysch material.

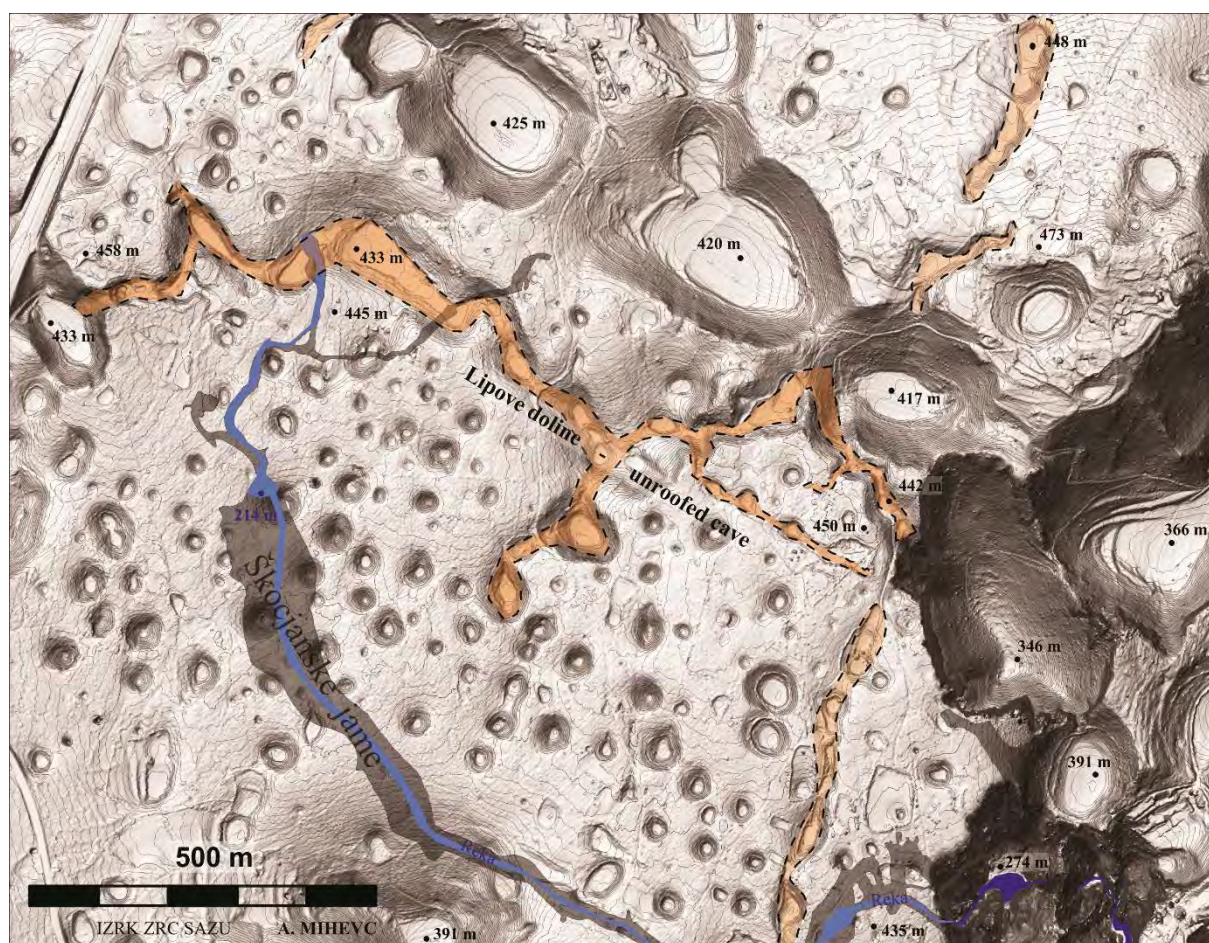


Figure 6: Lipove doline and other small unroofed caves (brown) above Škocjanske jame (grey) with underground flow of Reka (blue). Source of Lidar data: Geodetski oddelek ARSO.

The mapping (Mihevc 2001) of the surface revealed that the unroofed cave is exposed in an 1,800-m-long series of dolines and elongated doline-like depressions at an elevation about 450 m a.s.l. NE of Škocjanske jame, where the Reka flows at 214 m a.s.l. The bottoms of the dolines are 5 m to 10 m below the level of the rest of the surface; the depressions are 20 m to 30 m wide. Siliciclastic fluvial deposits, sandy clays and massive flowstone fill the bottom of the dolines. The existence and layout of the denuded cave passages are also evident from DEM (Lidar data, grid 1 m; 2016).

Quartz pebbles and sands which were found on the karst surface were in the past associated (e.g. Radinja 1986) with fluvial transport of weathered remains of flysch rocks over karst in the so-called pre-karstic phase. New interpretations (Mihevc 2001) of these localities together with geomorphologic and sedimentary studies (Zupan Hajna *et al.* 2008) reveal that allogenic sediment is

actually cave sediment exposed to the surface because the denudation removed the rock above the caves and made the cave roofless. Unroofed caves and relict caves are very good sediments traps. Analyses of those, especially allogenic sediments – paleomagnetic, dating, paleontology, mineralogy and granulometry – can reveal the origin of the sediment, sedimentation environments, condition of allogenic input to karst and later karst relief evolution. Therefore, special attention is devoted to them.

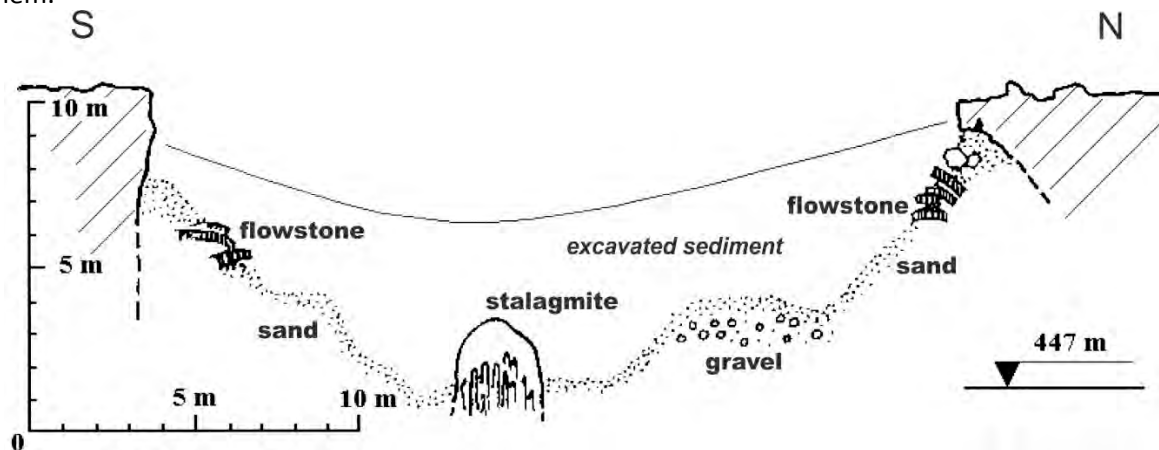


Figure 7: Cross section of the unroofed cave with alluvial sediments and stalagmite at N part of Lipove doline (from Mihevc 2001).

The unroofed cave in Lipove doline is similar to Škocjanske jame in its dimensions, as the width of the passage was in some places likely to be more than 20 m. Concerning the massive stalagmites and flowstone, the ceiling was a least 100 m thick during the time flowstone was depositing in the cave. Flowstone was deposited between phases of sedimentation of allogenic fluvial sediments. The origin of the sediments is Eocene flysch, transported to the cave by a sinking river. A rough estimate would be that there are still approximately 45,000 m³ of allogenic cave sediments preserved in the unroofed cave. The process of flysch transport into the caves of Divaški kras has continued from about 5 Ma ago until now, though the intensity has varied during that time (Zupan Hajna *et al.* 2017).

EDGE OF THE KRAS AND ČRNOTIČE QUARRY

The western edge of Kras Plateau and NW edge of Podgorski kras (Podgora Karst), known as Kraški rob (Karst Edge), rises above Trieste Bay (Fig. 8). The edge is a distinctive geomorphologic step which was formed where carbonate layers were thrust over flysch rocks (Placer 2007). The term "kraški rob" ("karst edge") in general denotes a geomorphologic step of vertical cliffs and steep carbonate slopes along the whole length of the Underthrust Belt from the Timavo river mouth and towards SE. These rocky cliffs and slopes mark the border between karstic plateaus Kras on one side, and the flysch of the Istria and Trieste coastline on the other side.

The Podgorski kras is a karst plateau about 5-km wide, extended in the NW-SE direction at the foothills of the Slavník Mt. Its surface is located at 500 to 450 m a.s.l. The plateau surface is levelled and pitted by numerous dolines and roofless caves. The surface is stony, covered by a discontinuous coverage of thin soils of the rendzina type. The surface inclination is gentle, only a few degrees. The plateau descends by several structural steps to the depression of the Rižana and Osapska reka valleys, which are developed in flysch. The karst springs of the Rižana and Osapska reka (maximum discharge of several m³/s) are located under the plateau's structural edge at altitudes of 50-100 m a.s.l. Over 90 caves are known on the plateau; the deepest has a depth of 150 m. Črnotiče Quarry located at the Podgorski kras edge is known by cutting and revealing numerous old caves filled with sediments.

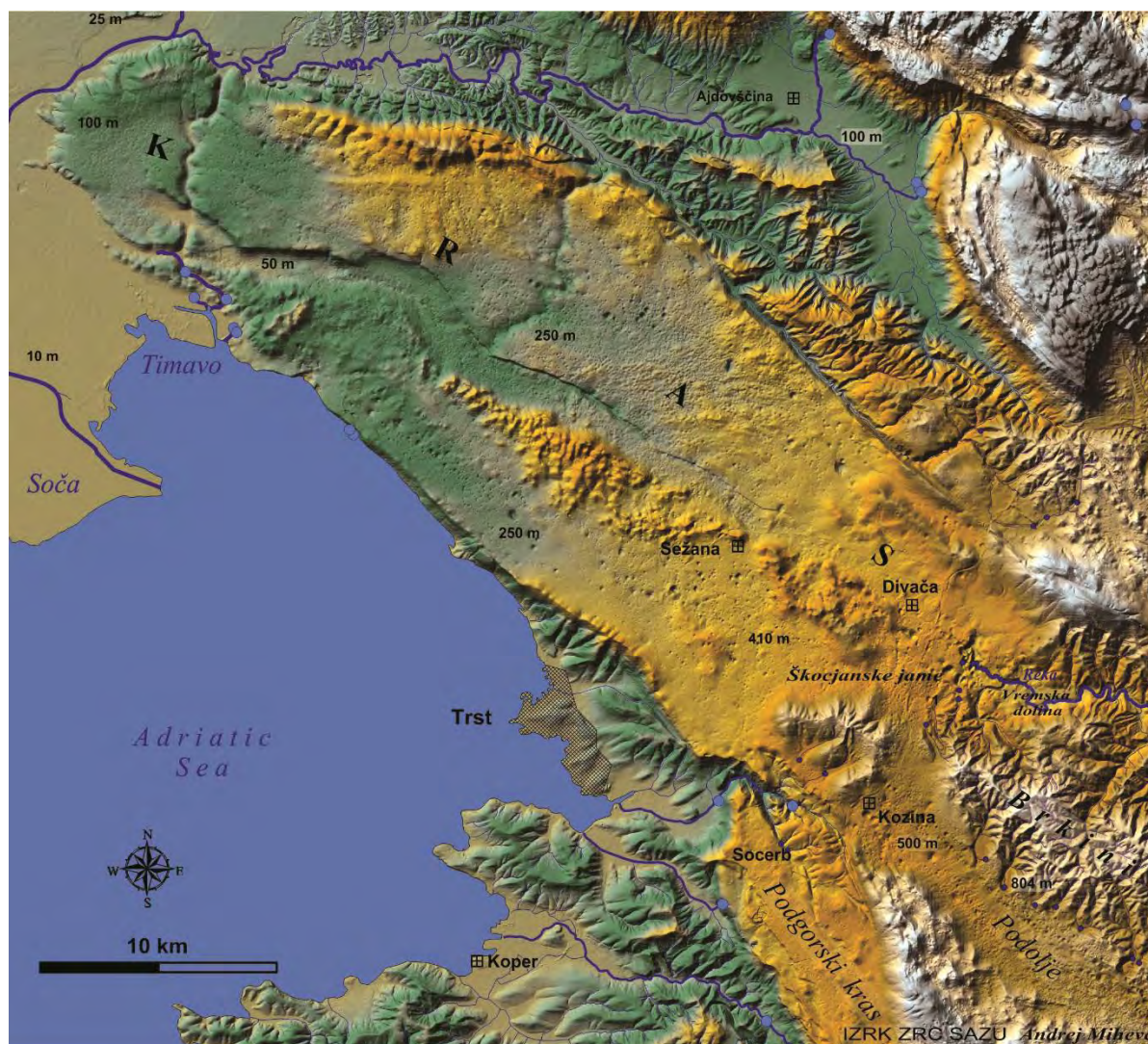


Figure 8: Location of Kraški rob (Karst Edge) and Socerb above Trst (Trieste). DEM made on 12.5 m grid, Geodetski oddelek ARSO.

ČRNOTIČE QUARRY

The Črnotiče quarry is situated on the western margin of the Podgorski kras, ca 6 km from the Adriatic coast. Quarry is about 60 m deep and has an area of about 300 by 500 m carved in the levelled surface at an elevation of 440 m a.s.l. (45°33' 57"N, 13°52' 48"E).

A cave inclined from the north-west to south-east and about 200 m long was opened progressively by quarry operations in 1990–2000 (Fig. 9). In successive years it was quarried away. It was not possible to contour the cave shape precisely owing to strong impacts of blasting. Only remains are left today in the faces on the edge of the quarry. The cave represented a relic of a huge passage about 15 m wide and more than 17 m high. The passage was filled by allogenic fluvial cave sediments overlain by several meters thick flowstone and some collapse material. The flowstones extended up to the present surface where they were exposed by karst denudation as an unroofed cave.

Two profiles from the cave were studied, the first, was situated in the main cave passage and was destroyed shortly after documentation. Črnotiče II profile is situated in a side passage of former cave and is still preserved.



Figure 9: Cave sediments of section Črnotiče II.

Črnotiče I is about 7 m wide and 17 m high exposed profile in completely filled cave passage cut by a quarry. Laminated and cyclically-arranged fluvial sediments composed the lower part of the fill. They were covered by breccia formed of blocks and fragments of massive flowstone. The modern land surface cuts across the flowstones, exposing them in the form of an unroofed cave. The lower part (from 0 up to 7.3 m) was composed of siliciclastic fill. It was separated from the over-lying sequence by a sharp erosional boundary. The upper part of the profile (from 7.3–8.8 m up to the surface) consisted of flowstone clasts.

To obtain remains of fossil serpulids, about 30 kg of material was sampled (Mihevc 2000; Mihevc et al. 2001, 2002). The subsequent sampling of about 300 kg provided a rich hoard of microscopic fragments of vertebrate and non-vertebrate fossil remains (Horáček et al. 2007).



Figure 10: Soricidae and Muridae of the Črnotiče II site (from Horáček et al. 2007, with permission). Legend: 1 – *Deinsdorfia* sp. – left I/1; 2 – *Deinsdorfia* sp., right I/1; 3 – *Beremendia fissidens* (Petenyi 1864), left M/1; 4 – *Beremendia fissidens* (Petenyi 1864), left M/2; 5 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, left M1/; 6 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, right M/1; 7 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, right M/1; 8 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, left M/2; 9 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, left M/2; 10 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, right M/3; 11 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, left M1/; 12 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, right M2/; 13 – *Apodemus* (Sylvaemus) cf. *atavus* Heller 1936, right M3/.

Marifugia cavatica

Fossil calcareous tubes were attached to the wall in the lower part of the profile between 426 and 427 m a.s.l. (Fig. 11). The tubes were very densely packed together in groups. The end of the tubes, which were perpendicular to the wall, were often broken off but we could find them in the sediment that covered the wall previous the exposure by quarry. The tube diameters were from 0.2 to 0.85 mm, max. 1.5 mm.

The fossils were compared and they match with the recent serpulid tubes of *Marifugia cavatica* (Mihevc 2000; Mihevc et al. 2001, 2002). *Marifugia cavatica* is the only recent fresh-water species of the Serpulidae family (Annelida: Polychaeta) and the only known tube worm inhabiting continental caves within the Dinaric Karst. It is never found even in brackish waters. It is a filter feeder with free-swimming larvae. It is supposed recently that it has colonised cave waters from a habitat in fresh-water lakes since the Miocene.

Selected tubes of *Marifugia cavatica* in a weight of about 2 g were sent to U/Pb dating, but because of high contents of detrital Th no dates could be obtained. To obtain remains of fossil serpulids, about 300 kg of material was sampled (Mihevc 2000; Mihevc et al. 2001, 2002) and screened. Besides tubes of *Marifugia* sampling provided also fragments of vertebrate and non-vertebrate fossil remains (Horáček et al. 2007).



Figure 11: Fossil calcareous tubes of *Marifugia cavatica* from Črnotiče Quarry.

Non-mammalian rests were represented by 15 small conical and flat lanceolate teeth tips of *Chondrichthyes*, probably redeposited from Eocene marl. The vertebrate record consists of 58 items, mostly poorly preserved and corroded fragments of teeth enamel. Some of them allow at least a tentative identification. Mammalian remains: Eulipotyphla (4): *Deinsdorfia* sp. (2I/1), *Beremendia fissides* (Petenyi, 1864): M/1, M/2; Rodentia (39): indet. fragments of incisor enamel (15 items), *Glirulus* aff. *pusillus* (Heller 1936): 1 M3/, *Apodemus* (*Sylvaemus*) cf. *atavus* Heller, 1936: 9 fragments (2 M1/, 1M2/, 1M3/, 2M/1, 1M/2, 2M/3), *Rhagapodemus* cf. *frequens* Kretzoi, 1959 (1 M/2), Arvicolidae indet. (13 fragments of molar enamel): sp. (cf. "*Cseria*" *carnutina* Rabeder 1981), sp. 2 (cf. *Mimomys* (*Cseria* s.s.) *gracilis*) and belong to MN15–MN16b mammalian biozones (about 3.2–4.1 Ma) (Horaček 2007).

A total of 54 oriented laboratory samples from the main and right profiles were studied in detail to detect their palaeomagnetic properties. The MS was measured in the field every 5 cm

Palaeomagnetic analysis of 54 oriented laboratory samples from the sedimentary fill at Črnotiče II. indicates the Gauss chron (2.581–3.58 Ma). This is supported by biostratigraphic determination of the mammalian fauna. Horaček et al. (2007) proved that this fauna belongs to MN15–MN16b mammalian biozones (about 3.2–4.1 Ma). The combination of palaeontological and palaeomagnetic data indicates that the fauna cannot be older than about 3.6 Ma, due to the reverse polarized magnetozone at the top of the Gilbert chron terminating at 4.18 Ma. This level represents approximately also the base of the MN15 mammalian biozone. Therefore, the fauna belongs to the MN16 mammalian biozone and cannot be older than 3.58 Ma.

For the first time, a combination of vertebrate fossil records and magnetostratigraphy, have proven the expected antiquity of the cave infilling and related surficial landforming processes. One of the most important older phases of speleogenesis in the region finished during MN15–MN17.

The development of vertical drawdown shafts with a predominance of later autochthonous fill resulted from vadose speleogenesis caused by the drop of karst water level related to tectonic uplift, which followed tectonic unrest during the MN 15 to MN16b mammalian biozones. Drawdown shafts connected the land surface with the active zone of phreatic speleogenesis in the depths. The uplift detached horizontal caves from the hydrological system, causing their fossilization

SOCERB

Socerb village and the fortress are named after a hermit and martyr from 3rd Century – St. Socerb, who lived in a cave which was later transformed into the pilgrimage church. The fortress was built after 1382 against the Venitian republic when House of Habsburg gained the control above Trst (Trieste).

Trieste was an important multinational port during the Austro-Hungarian Empire. Its fast growth started in 1719 when it became a free port. Because of a growing population in the 19th Century, they began to search for water on Kras. Therefore, many deep shafts were explored in 1841, among them Labodnica (Abisso di Trebiciano). This cave, with a depth of 320 m, was for 60 years the deepest cave of the world. The railway from Wiena was built in 1857. In 1893, Deutschen und Österreichischen Alpenverein was founded in the city with a section devoted to cave exploration. The society explored Škocjanske jame and many other caves. The society, with Anton Hanke and Joseph Marinitsch, Friedrich Muller, and Karl Moser, published or provided cave surveys of the entire area and assisted Alfred Penck, Jovan Cvijić and E.A. Martel, Franz Kraus and many others. Soon after the Italian and Slovene cave societies were founded. To date, Trieste is probably the town with largest number of caving societies in the world.

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Whole-day field trip (C):

CONTACT KARST OF MATARSKO PODOLJE: ODOLINA BLIND VALEY, CAVES RAČIŠKA PEČINA AND ULICA PEČINA

Saturday, 15.9.2018, 8.30–20.00

Andrej Mihevc

Stops:

- 1** – Odolina blind valley
- 2** – Račiška pečina cave
- 3** – Ulica pečina cave and Ulica unroofed cave



THE CONTACT KARST OF PODGRAJSKO PODOLJE

Karst formed by the influence of the allogenic rivers with large quantity of water, specific water regime and sediment inflow, could be designated by the term of contact karst. The term grows familiar in Dinaric karst where are several such areas, which sharply contrast the karst without such influence. In the international karstological literature such forms and phenomena are treated as karst influenced by allogenic rivers. This type of karst is rich in cave and surface sediments.

On the SE edge of Kras plateau is an area built of Eocene flysch with developed surface drainage and fluvial morphology. Most of the flysch area belongs to Brkini hills. All surface waters from flysch flow and sink in the karst (Fig. 12). Water from the northern side of the flysch hills as well as water from some karst springs is collected into the river Reka which sinks in Škocjanske jame. On the

southern side of Brkini are 18 separately sinking streams, which all sink in Podgrajsko podolje, a 20 km long and 2–5 km wide levelled karst surface between mountain Slavnik and the Brkini hills (Fig. 12).

Water tracing showed that the sinking streams flow to three groups of springs: submarine springs along the coast in the Kvarner Bay on the south, springs in Istria on the south-west, and the Rižana springs on the west (Krivic et al. 1987).

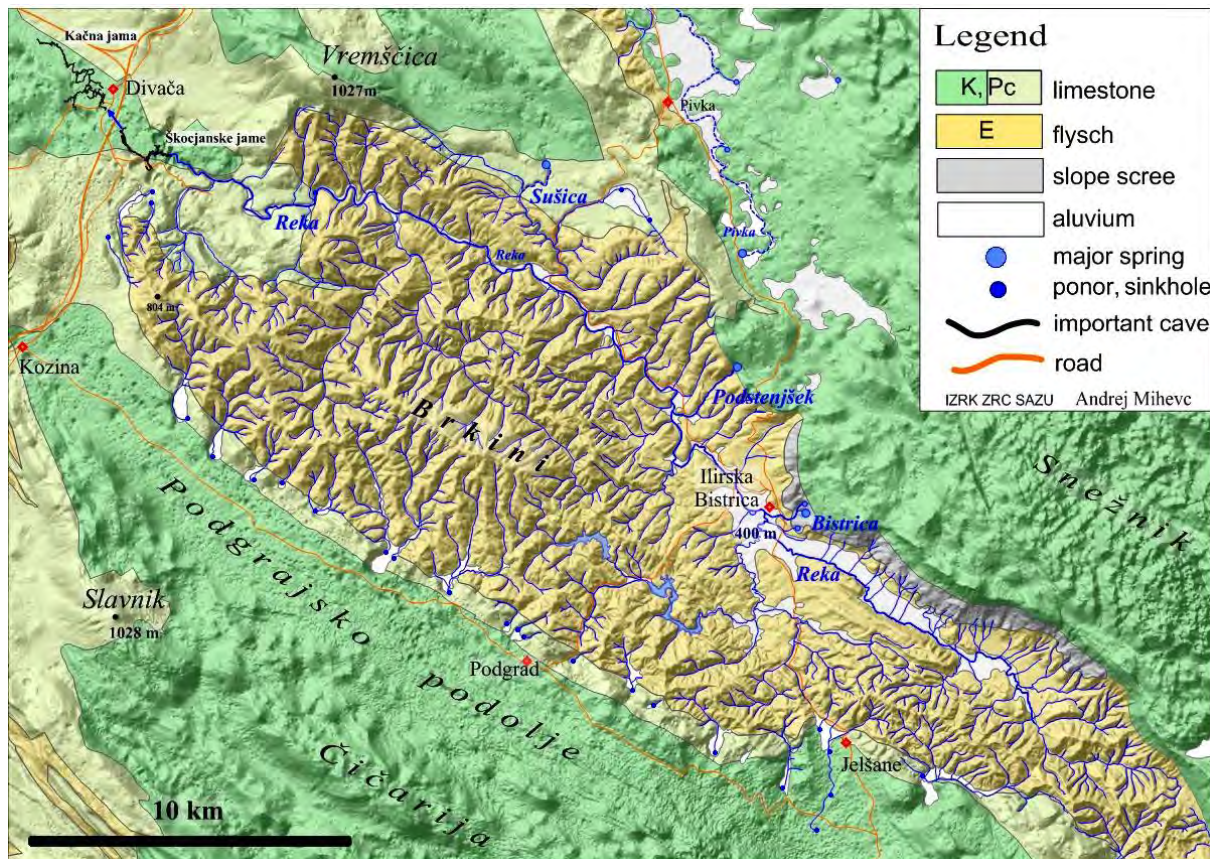


Figure 12: Flysch landscape on SE edge of the Kras Plateau with fluvial topography and surface rivers that all sink on the edge into karst. DEM made on 12.5 m grid. Source of DEM data: Geodetski oddelek ARSO.

The allogenic discharge into the karst formed large blind valleys and caves filled with allogenic sediments. Streams sink at 490 to 510 m a.s.l.; some can be followed in accessible caves down to terminal sumps at about 400 m a.s.l. The deepest cave is 150 m deep, and the longest is more than 6 km long. Besides that, more than hundred relict vadose caves, some filled with sediments are known in the karst plain.

Surface of the Matarsko podolje probably developed as a base-levelled plain. Low gradient in the karst caused the deposition of the allogenic fluvial sediments on the edge of the karst in front of ponors. The sedimentation was caused because of fast drop of transporting capacity of rivers which were losing water in karst in many separated small swallow holes and by limited capacity of the ponors which caused back flooding and sedimentation. The flood water and specially sediments enhance the dissolution of limestone below sediments, so blind valleys start for by cutting down by corrosion into previous base levelled surface.

As the in blind valleys is a contact between surface and underground flow which is limited by the capacity (diameter) of the ponors, floods and resulting sedimentation are normal and depending on distribution and intensity of precipitations. The sedimentation was especially intensive in the cold periods of the Quaternary and such deposits are preserved on the bottom of most of the blind valleys. In present conditions sediments are eroded by the sinking rivers or are washed deeper into the karst by suffusion processes.

ODOLINA BLIND VALLEY

The blind valley Odolina (Fig. 13) was formed by the sinking stream draining 4.3 km² large water basin. The average discharge of the brook is about 15 l/s, but oscillations due to precipitation regime are large. The floods are rare and reach the narrow belt along the brook only. Periodical water hardness measurements indicated 111 mg of dissolved carbonates originating from the flysch marls.

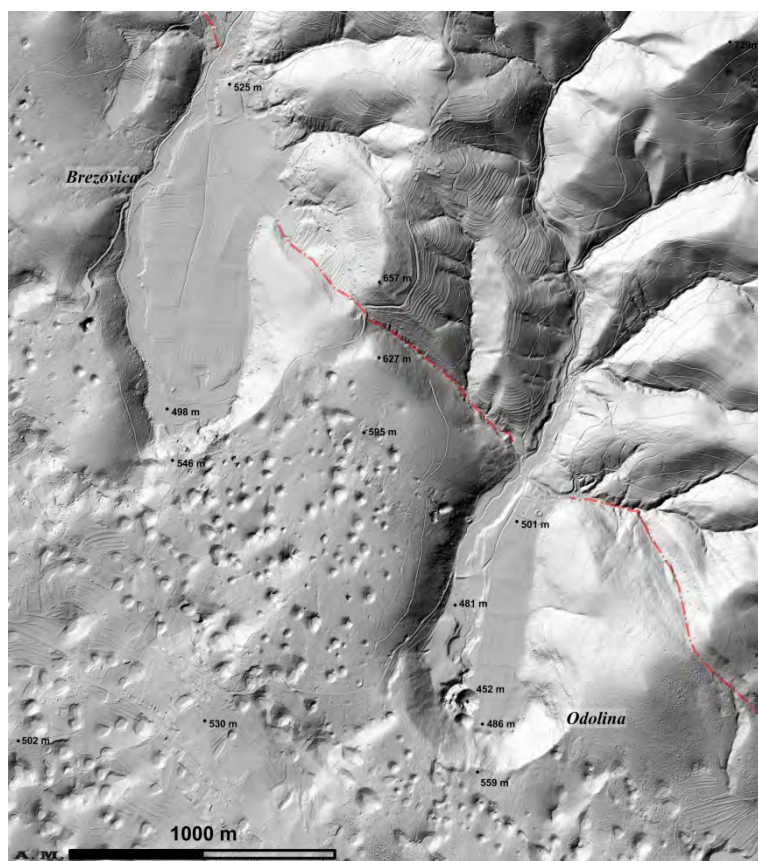


Figure 13: Blind valleys Brezovica and Odolina. Red dashed line shows the limestone (bottom) and flysch contact (top). It also delineates between fluvial and karst topography. Allogenic sediments are deposited in the bottom of the blind valley with erosional terraces and suffusion funnel shaped dolines. DEM made on 1 m grid. Source of DEM data: Lidar data, Geodetski oddelek ARSO.

At the brook's passage to the limestone the narrow fluvial valley widens. A blind valley, 1 km long and 300 m wide, developed on the limestone, on the southern end it is deepened into the karst plain for 60 m. During the normal water level, the brook sinks in the riverbed immediately after the passage to the limestone, during higher water level it flows into 117 m deep ponor cave composed by potholes and shorter channels. The cave is basically phreatic with strong traces of vadose transformation. It ends by the siphon of captured water on 370 m a.s.l.

Allogenic sediments are cut by erosion of the brook and the piping or subsidence of the sediments into the karst. Up to 25 m deep suffusion doline was formed close to ponor cave. In the alluvial dolines, sinks and in the riverbed the limestone is exposed showing uneven relief of blind valley bottom below the sediments.

According to shape, sediment on the bottom and the depth of the accessible caves other blind valleys situated along the contact of flysch hills and Matarsko podolje are alike Odolina blind valley.

JEZERINA

The age of the sediments and sedimentation phases in Odolina is not known. But it is possible to compare in with Jezerina, blind valley which is only 5 km apart. In Jezerina sediment fill of the blind valley continues and can be observed also in Mitjina jama cave (Fig. 14).

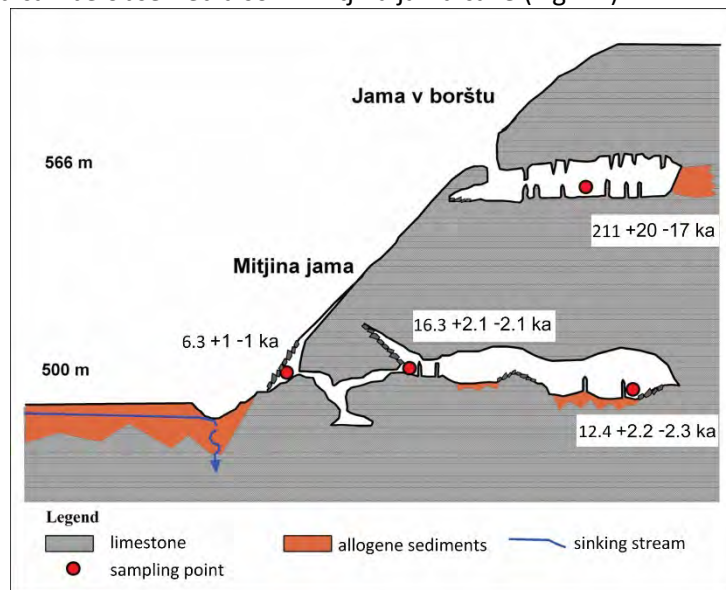


Figure 14: Schematic cross section of the Jezerina blind valley with known caves. Stalagmites from two caves that are accessible were dated. The deposition of sediment in Mitjina jama stopped about at the time when stalagmite which base was dated to 12.4 +2.2-2.3 start to grow.

A stalagmite that was growing on the top of sediment infill was taken and cut to half along the long axis. Subsample at the bottom of the stalagmite was dated by Th/U method to 12 ka. This give firm date of the end of allogenic sedimentation. In the lower part of stalagmite cross section rear flood events are still expressed by clay layers, but upper parts show no flood events any more (Mihevc 2001).

RAČIŠKA PEČINA

The Račiška pečina (45°30'12,10"N; 14°09'00,83"E; 590 m a.s.l.) is situated in the south-eastern part of the Matarsko podolje (Fig. 15) at the foot of Stržen ridge (681 m a.s.l.).

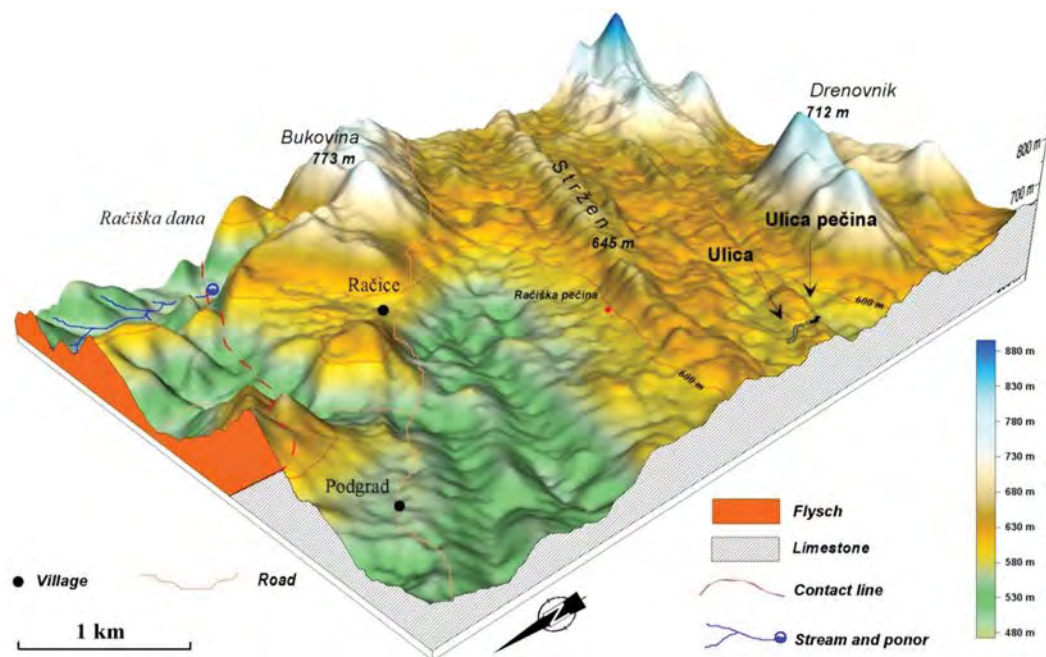


Figure 15: DEM of the segment of Podgrajsko podolje with position of Račička pečina and Ulica pečina.

The development of caves in this part of Podgrajsko podolje was connected with the ponors of allogenic streams from flysch which at present lie only 2.5 km to the north of the cave. The recent streams sink at about 500 m a.s.l.; i.e. 90 m lower than the Račička pečina (Fig. 16).

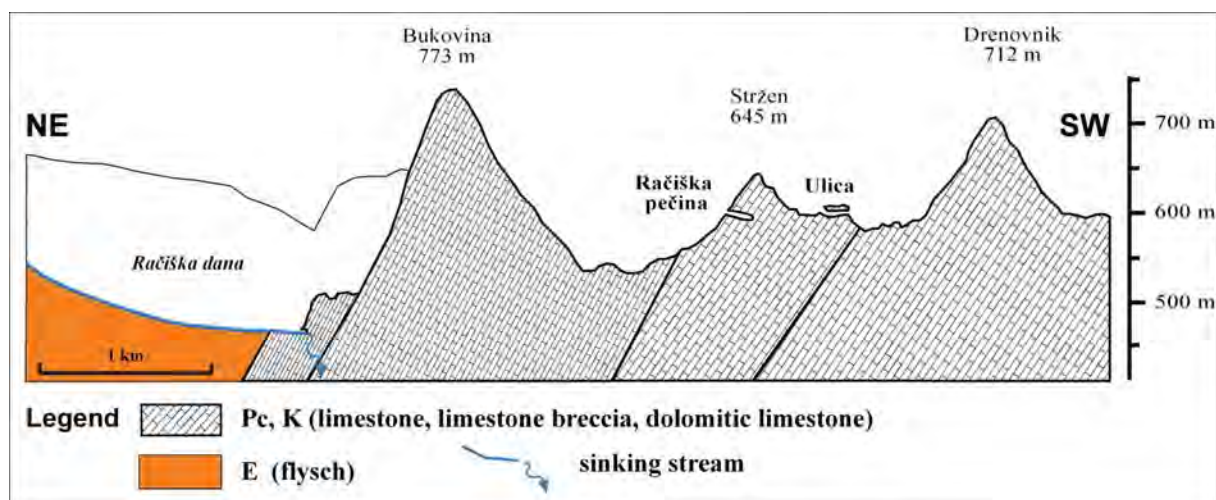


Figure 16: Schematic cross section of the Podgrajsko podolje from NE-SE. Recent brook sinks in blind valley Račička dana below 500 m. Relict caves, filled partly with allogene sediments and most likely formed by the same sinking stream are now at about 600 m.

The 304 m long relict cave is formed in the Lower Cretaceous thick-bedded limestones and dolomite with limestone breccia and dolomitised limestone (Zupan et al. 2008). Strata dip generally towards the NE at an angle of about 30°. It consists of a simple southwards dipping gallery, a relict of a large cave system. The cave passage is mostly over 10 m wide and 5–10 m high. On the southern side, it terminates with a collapse choke and sediment fill. Allogenic sediments, mostly clays and sands of unknown thickness form the bottom of the cave. On some places they are covered by massive flowstone. One large flowstone mass about 200 m from present entrance broke apart due to the unstable sediments on which it was deposited, exposing good profile to study. In the first half of 20th Century the cave was used as a military magazine. The floor was levelled and filled with sand.

The studied section is about 13 m long (Fig. 17). The composite thickness of the sampled profile reaches 634 cm, but the true thickness exposed is only about 300 cm.

Vertically the section is composed of three principal parts: the lower part at bottom of the NW side of the profile; the second part is mainly in the middle of the profile; and the third part represents the top portion.

The lower part (180 cm) is composed of three sequences, representing the growth stages of a huge vaulted stalagmite. They consist of brown to reddish brown massive but porous (corroded?) speleothems with some interbeds of red clays (1–2 cm) and two angular unconformities. At the top of the sequences II and III broken remains of stalagmites are preserved.

The middle part (180–368 cm) consists of sub-horizontal laminated, mostly porous flowstones intercalated by a number of flowstone beds with gours and abundant red clays (1 mm to up to 10 cm thick); thin calcitized siltstones with flowstone fragments and iron-rich spherules occur in places. Collapsed blocks from the ceiling cover clays with finds of fauna (F) in the exposed lower part of the sequence.

The upper part (368 cm up) is represented by light-coloured, massive, mostly laminated speleothems with two lens-like interbeds of brownish grey loams with bone fragments. Some flowstone layers contain several series of distinct greyish black laminae enriched in organic carbon (soot), which can be attributed to Palaeolithic visitors of the cave.

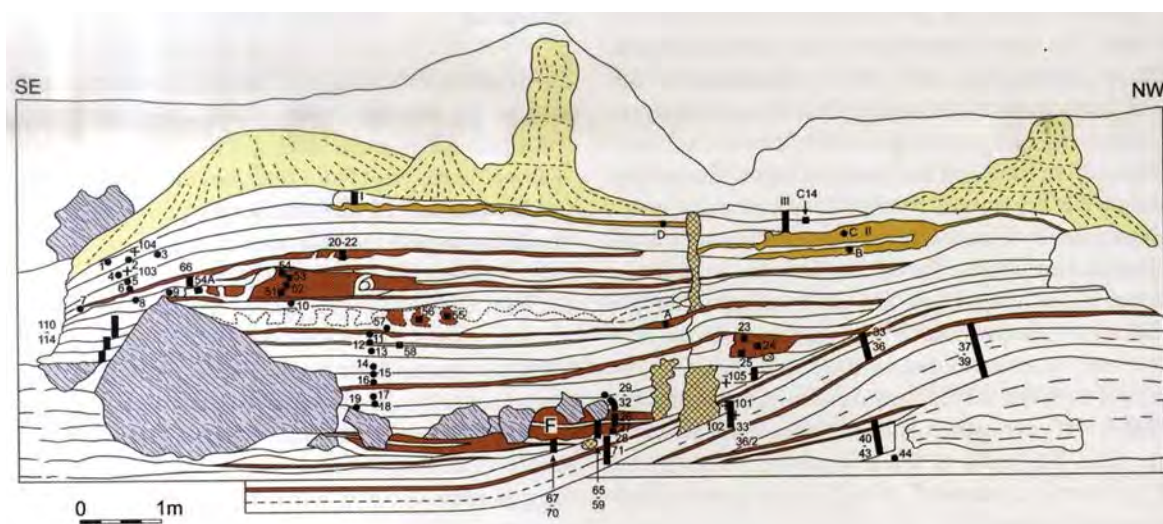


Figure 17: Schematic cross section of the profile in Račiška jama.

Samples from the principal clay accumulations were washed. Fossil remains were found in two layers. The upper (C II on Fig. 17) contained broken bones and teeth of cave bear indicating a Pliocene age (det. I. Horáček). Cave bear bones are also preserved in other parts of the cave. *In cave are preserved also traces of cave bear like polished rocks, claw marks and footprints preserved in a soft clay* (Mihevc 2003).

In the clay layer at the base of the sequence partly covered by collapsed blocks (F on Fig. 17) rodents and remains of probably fresh-water crabs were found. A total of 74 items were obtained. They were mostly very poorly preserved, fragile, and composed particularly of small fragments of teeth enamel (max. 1 - 2 mm in size), corroded and without dentine. Non-mammalian remains (7 pieces) included: cf. *Potamon* (Crustacea), 2 tips of small conical teeth (not identified until now), and 3 pharyngeal pearl teeth of a *Cyprinid* fish, most probably *Barbus* sp. Mammalian remains were 67 in number: *Rodentia* (29 fragments of incisors, 2 fragments of metapodia, 35 fragments of molar enamel of arvicolids): at least 2 spp. (incl. cf. *Borsodia*), 1 M/1 (enamel): *Apodemus* (*Sylvaemus*) sp. – cf. *atavus* Heller 1936.

Owing to the palaeontological data the magnetostratigraphic sequence was satisfactorily correlated with the GPTS. Based on fauna analysis (Quaternary age is excluded), the boundary of N and R polarized magnetozones within the layer with fauna (F) can be identified with the bottom of C2n Olduvai subchron (1.77–1.95 Ma). The short N chron just below the Olduvai base is correlated with the Reunion subchron (C2r.1n; 2.14–2.15 Ma). In the lower part of the profile, the following magnetozones are correlated: the base of Matuyama Chron (2.150–2.581 Ma) and the individual subchrons within the dominantly normal polarized Gauss Chron (2.581–3.58 Ma) = C2An.1n subchron (2.581–3.04 Ma), C2An.1r Keana subchron (3.04–3.11 Ma), C2An.2n subchron (3.11–3.22 Ma), C2An.2r Mammoth subchron (3.22–3.30 Ma) and the upper part of C2An.3n subchron (top at 3.33 Ma). And the bottom flowstone layer at the NW side of the studied profile (Fig. 119) terminates at about 3.4 Ma.

The geometry of the palaeomagnetic subchrons is changed by numerous breaks in deposition, especially within the lower part of the profile. The subchron arrangement can assist estimation of the duration of individual breaks, being about 150–250 ka in the upper parts, and in sequences I to III probably substantially more. This fact can also explain differences in declination values between upper and lower parts, indicating rotations of the tectonic block.

In conclusion it may be emphasised that the roughly three m high profile was growing for more than 3 Ma years and that new speleothems on top of it are still growing. More detailed work on the sediment profile is in progress.

THE CAVE ULICA PEČINA

Ulica Pečina is 120 m long horizontal cave. It is situated in Stržen (645 m); ridge that spreads in direction NW-SE. Cave has two entrances. This fact is very important, because it generates strong air currents which in winter time cool down the cave. The southern entrance is on 587 m above sea level, between the collapse boulders that nearly completely blocked the cave opening. Behind the entrance the 15 m wide and up to 20 m high passage continues toward N. On the floor there are recent patterned ground and traces of cryoturbation and the sediment creeps towards the lowest point of the cave, which is about 20 m below the entrance at elevation of 562 m. From here the passage floor is ascending to the northern entrance. This is 5.5 m high and 10 m wide entrance in the altitude of 484 m.

The flowstone is fractured as a result of freezing in the winter time. But during the warm part of the year the shattered flowstone is cemented back by new calcite deposition. This gives the flowstone characteristic appearance: white color and fractured and ribbed surface.

We have sampled profile of flowstone and some allogenic fluvial sediments for dating, but we have no results yet.

UNROOFED CAVE ULICA

On the Northern side of Ulica pečina entrance we can follow large unroofed cave exposed in the length of about 400 m. Firstly unroofed cave appears as two dolines, since cave ceiling is not yet completely disintegrated. Main part of the unroofed cave is about 200 m oblong trench. The trench of is about 15 m deepening into the surface. It is 20-30 m wide in upper part and about 10 m wide leveled flat bottom. Slopes are steep, on some places vertical. In the bottom and on the slopes there are on several places massive blocks of flowstone, some in primary position. Drilling several m deep on some spots on the bottom showed allogenic quartz sands. On the northern part of the unroofed cave is shallow below the surface narrow, 40 m long horizontal cave. The ceiling of it is 3 m but there is massive flowstone in it. The cave seems to be the remnant of large passage completely filled by sediments.

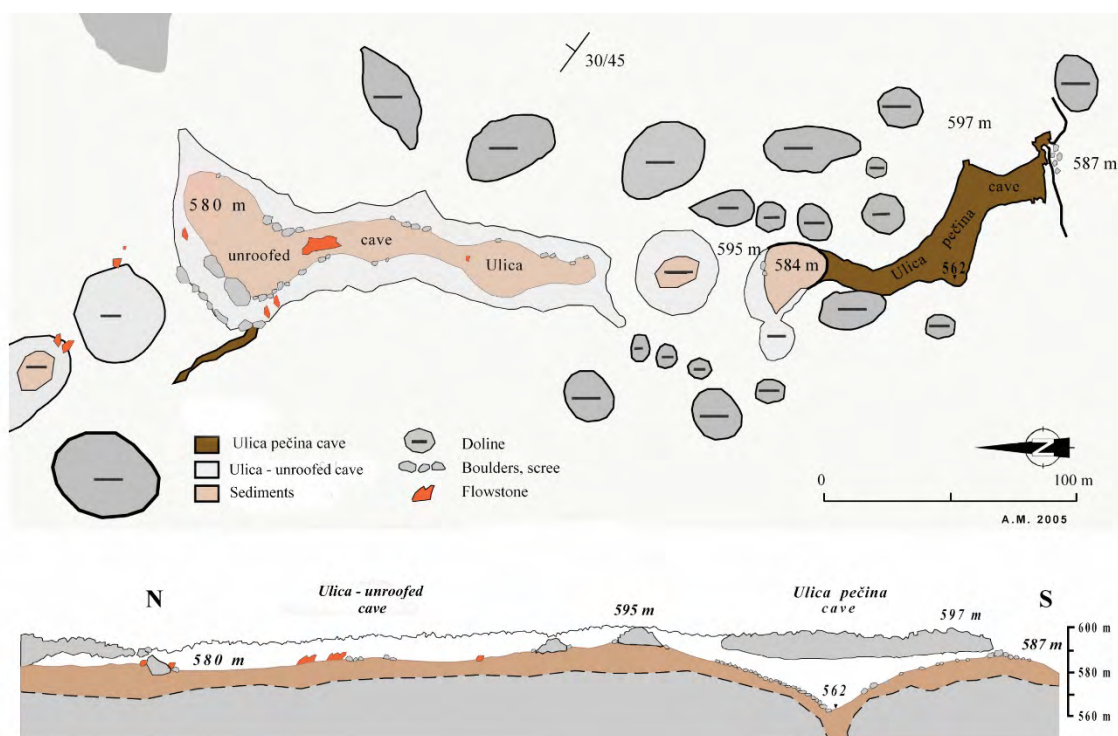


Figure 18: Schematic cross section of cave Ulica and Ulica unroofed cave.

Further north, after the second cave it splits two branches. NW part can be followed as an elongated dolina beyond the shallow part of the cave with massive flowstone and two elongated dolines with flowstone exposed on some places.

The assemblage of the two caves, relief form, massive flowstones and allochthonous sands prove that Ulica is really a remnant of the former cave. As it is located at same elevation as Račiška pečina and only 1 km apart, we can presume that they are remnant of the same cave system.



Figure 19: Northern entrance to Ulica pečina. Photograph was taken from unroofed cave.

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Whole-day field trip (D):
ALPINE CAVE SNEŽNA JAMA
Sunday, 16.9.2018, 8.30–18.00

Andrej Mihevc

Stops:

1 – Snežna jama cave



SNEŽNA JAMA

Snežna jama (46°23'53.71"N, 14°44'31.52"E) is located in the southern slope of Raduha Mountain (2062 m), which belongs to Southern Calcareous Alps, mountain group in N-central part of Slovenia. Mountains consist mostly of Triassic and Jurassic well-karstified limestones and dolomites. The whole mountain group is well karstified; the deepest cave is over 1000 m deep. Prevailing type of caves are vadose pitch-ramp cave systems.

Raduha Mountain (Fig. 20) is on W side separated from the main mountain group by deeply entrenched valley of Savinja river, while on the NE side continues to slightly lower relief of Smrekovec Mountain (1673 m) that is formed of Oligocene volcanic rocks.

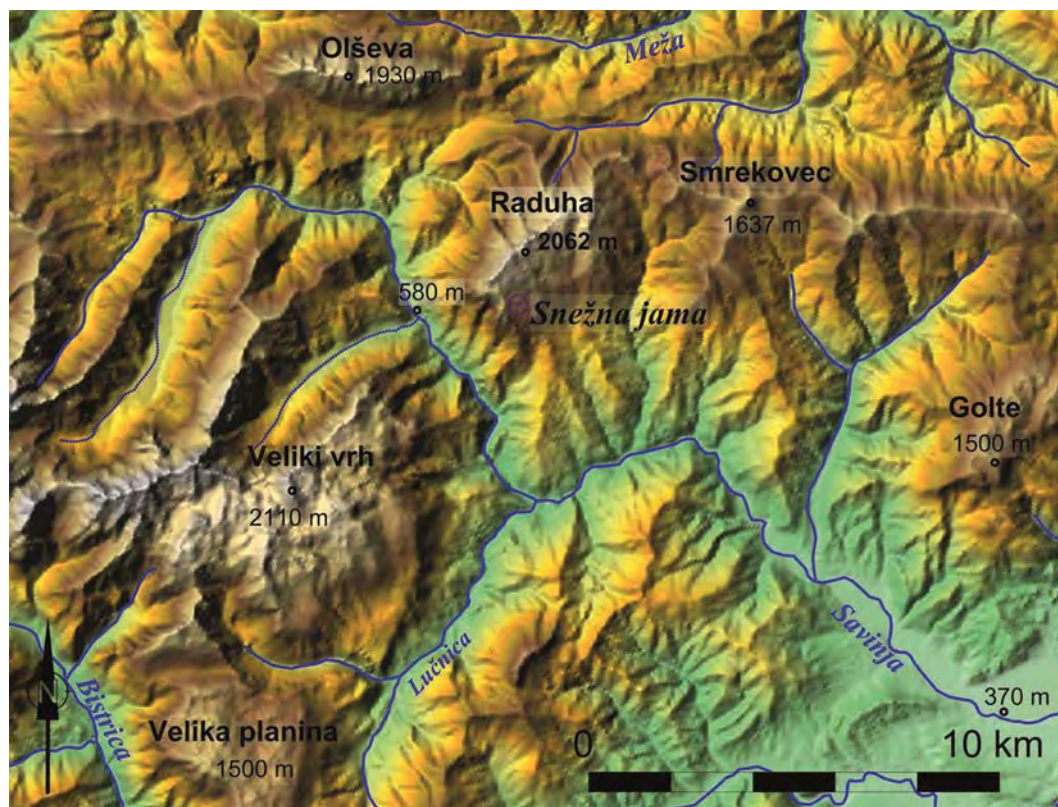


Figure 20: Raduha Mountain and position of cave Snežna jama. (DEM data, Geodetski oddelek ARSO).

In the Raduha mountain are also some deep vadose caves, but more important are fragments of a large horizontal cave system. It is evident, that they were formed by allogenic rivers that originated on volcanic rocks and sink into karst of Raduha mountain. The largest of these caves is 1.600 m long Snežna jama (Fig. 21).

The entrance to cave is on the slope of the mountain at 1514 m a.s.l. in a collapse dolina with permanent snow, which gave the name to the cave. The cave was explored after part of the snow melted in 1980. The main part of the cave consists of a large gallery with diameter more than 10 m and several smaller side passages. A collapse terminates the cave close to the steep or vertical northern slopes of the Mountain ridge

The cave gallery was formed in phreatic and epiphreatic conditions. On the walls are on several places preserved large scallops and wall notches. Through the gallery there are fluvial sediments that filled the cave more than 10 m high. The deposits consist of laminated clays and sands with well-rounded pebbles up to 30 mm in size. Allochthonous pebbles mostly composed of andesite tuffs and tuffites prevail, while poorly-rounded autochthonous limestone pebbles are less frequent. The allochthonous deposits possibly came from Smrekovec mountain east of the Raduha. At the present time, the contact of volcanic and volcanoclastic rocks with limestones lies one km southeast of the cave, but at elevation of 350 m below it. Sedimentation and long horizontal passage indicates that the cave was formed during a long period of stable environment.

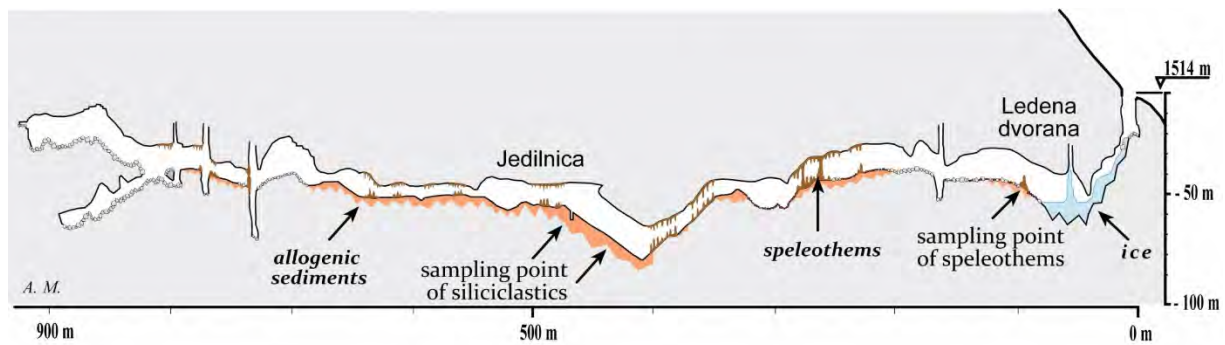


Figure 21: Schematic cross section of Snežna jama. Old nearly horizontal passage is filled with sediments deposited by ancient river in Pliocene. Above them massive speleothems have been deposited, these sediments are marked with brown colour. Ice at the entrance part is coloured blue.

After fluvial deposition stopped massive flowstone was deposited. There is no deposition of flowstone in the present climatic conditions in the cave or in other caves at the same altitude. The flowstone is severely damaged by frost activity in the entrance section of the cave due to the strong and cold airflow from vadose shafts. Speleothems were broken away and displaced by cryoturbation. The influence of frost and cryogenic damage on speleothems and cave walls in the past can be seen throughout the whole cave. In the cave average the annual temperature today is about 4.5 °C. Speleothems are absent in the terminal part of the cave, where the gallery was interrupted by an extensive collapse. A skeleton of *Ursus spelaeus* was found here. The cave bear could not enter the cave through the current entrance, so there had to be another entrance in the terminal part of the cave, which also permitted air movements and cooling of the cave.

Between the entrance and the 150 m distant vadose shaft a strong airflow establishes during winter, which cools down part of the cave, making conditions for perennial ice (Fig. 22). Behind the second chimney temperature is too high for ice formation. At 460 m from the entrance temperature is at about 4.5 °C with yearly oscillations for only one or two degrees.

Snežna jama na Raduhi

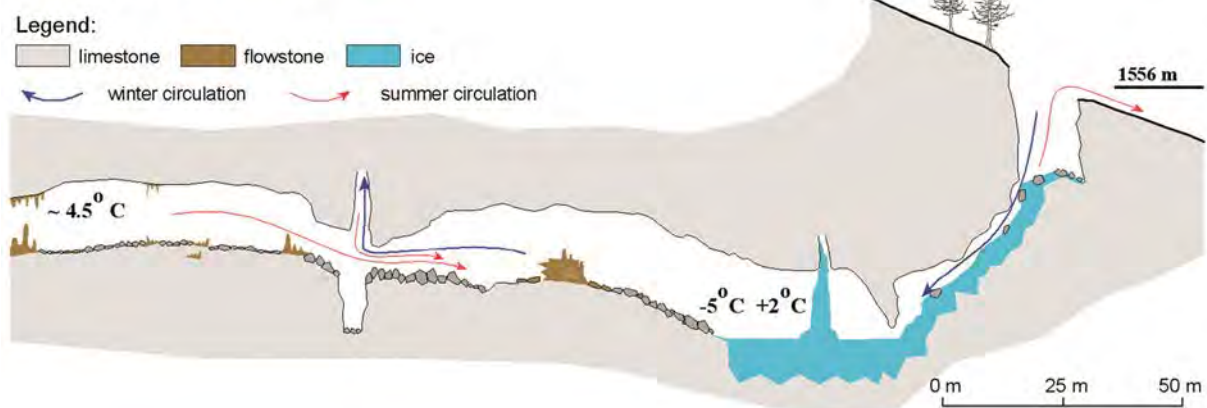


Figure. 22: Schematic cross section of the entrance part of Snežna jama. Extent of ice is marked as well as the summer and winter air circulation in the cave. Freezing and ice formation in the cave occurs only between entrance and the second vadose shaft – chimney, which enables the winter circulation. Inner parts of the cave have stable temperature.

Cave sediments were sampled in two places: from speleothems in Ledena dvorana (Fig. 22) and siliciclastics from natural profile and excavated pit at Jedilnica (Fig. 21).

The speleothem profile is situated in the inner part of **Ledena dvorana**, about 90 m from the entrance to the cave and at a depth of about 45 m. The complex sequence of flowstones contains

numerous hiatuses; there are six principal flowstone layers with a total thickness of 2.4 m. The lower part of the profile contains abundant terrigenous components (most probably clay of terra-rossa type). Stalagmites developed in several of the older periods were completely buried by nearly horizontal younger sequences of younger flowstone. The profile was sampled in 5 separated segments continuously by mostly overlapping trenches cut by circular saw.

Seven N-polarized zones are separated by six R-polarized zones. All samples are older than 350 or 200 ka according to U/Th dating, and the uranium isotopic equilibrium indicates an age above 1.2 Ma (Bosák et al., 2002). It may be supposed that the profile represents a time sequence not younger than the Matuyama chron (1.77 Ma, Olduvai C2n subchron). The profile can be correlated with the Gauss and Gilbert chrons (about 2.6 to 5 Ma; Table 6). The base of the top N1 magnetozone can be identified with 3.04 Ma (C2An.1n subchron; Cande and Kent, 1995) and the top of the N7 with 4.98 Ma (C3n.4n subchron; the base at 5.23 Ma) in the Gauss chron. The growth of speleothems took place over an approximate time span of 1.8 to 2.0 Ma, which gives mean speleothem growth rates of about 1.1 to 1.3 m per 1 Ma.

The speleothem profile in Sněžna jama was the first one where the high-resolution sampling approach was used (Bosák et al., 2002, 2003).

In Jedilnica two profiles were analysed. The excavated pit profile is situated about 460 m from the entrance, where the main cave passage is 8 to 15 m wide and about 15 m high. The present passage bottom is on top of the sedimentary fill. Gravel interbeds occur in the lower part of the slope, while finer siliciclastic sediments prevail in its upper part.

A 4.3 m deep pit, excavated in two steps was dug to facilitate sampling. The sediment profile generally consists of 2 to 4 cm thick layers of rhythmically arranged clays and silts with medium to coarsegrained sandy admixture representing weathered (bentonitized) volcanoclastics. The sediments are laminated to banded, and some laminae/bands are boudined/disturbed; cross-bedded sets occur only above the sequence base. The content of clay component increases in the upper parts of rhythms (flyschoid style) in both sequences. The stratal dip is uniform from 38 - 42°. The clay fraction is composed of 14-Å-minerals (smectite, chlorite), illite, kaolinite, quartz, plagioclase and calcite

Samples for palaeontological analysis were taken in intervals of 30 cm, 20 to 25 kg each. Besides 89 samples for palaeomagnetic analyses were taken.

The surface layer of excavated pit in Jedilnica provided osteological material consisting of ca 25 well preserved fragments, mostly postcranial bones and crania, belonging to 3 individuals of 3 species of bats: *Myotis myotis* (nearly complete rostrum, left mandible), *Pipistrellus cf. pipistrellus* and *Myotis cf. mystacinus*. All three species (Fig. 13) are common elements of the present bat fauna in the region and most probably were distributed there throughout most of the Quaternary period.

In deeper layers, the undeterminable teeth fragments of cartilaginous (Chondrichthyes; at least two distinct taxa) and albulid fish were found, obviously re-deposited fossils from Upper Oligocene source rocks.

However, lower part of the profile more significant remains were found, notably small rodent teeth. Besides small fragments of enamel a well preserved enamel coat of a left third lower molar (m3) belonging to a hypsodont cricetid tentatively attributed to the genus *Baranomys* was found.

The tooth belongs to a young individual; it is unworn with well-preserved details of the initial design of the occlusion enabling us to formulate also some comparative notes. In all these respect it shows the diagnostic characters of microtoid cricetids, the clade parallel to the earliest radiation of arvicolids appearing in the European fossil record from the latest Miocene to early Pliocene. Of course, to establish a reliable species identification based on just a single tooth is virtually impossible, therefore we identify the respective specimens as *Baranomys* sp. (Fig. 23).



Figure 23: A left third lower molar (m_3) of *Baranomys* sp. from excavated Jedilnica section of Snežna jama, sample 11. Occlusal view and buccal views. Scale 1 mm.

In Jedilnica pit, a total of 4 principal N-polarized zones and 3 principal R-polarized zones were interpreted. *Baranomys* fragments in sample No. 11 indicate mammalian MN16a (ca 2.7–3.9 Ma). The location of the sample is within the N-polarized magnetozone it may be supposed that the profile represents a time sequence not younger than the Matuyama chron (1.77 Ma, Olduvai C2n subchron). The base of the top N1 magnetozone represents most probably the base of the Olduvai C2n subchron (1.99 Ma). The profile terminates with a segment with transient polarity, which cannot be older than ca 4.91 Ma according to cosmogenic dating. Therefore the profile correlates with the Matuyama, Gauss and Gilbert chrons.

The smaller profile in Jedilnica at the base of the is composed of mud-supported gravel derived from re-deposited volcanoclastics with individual limestone pebbles. The pebbles are well-rounded and varnished. Quartz pebbles and coarse quartz sand are present in very minor quantities and were taken the lower profile, that is, from the natural outcrop. The calculated burial age for the sample SN yielded an age of 3.57 ± 1.23 Ma (Häuselmann *et al.* 2015).

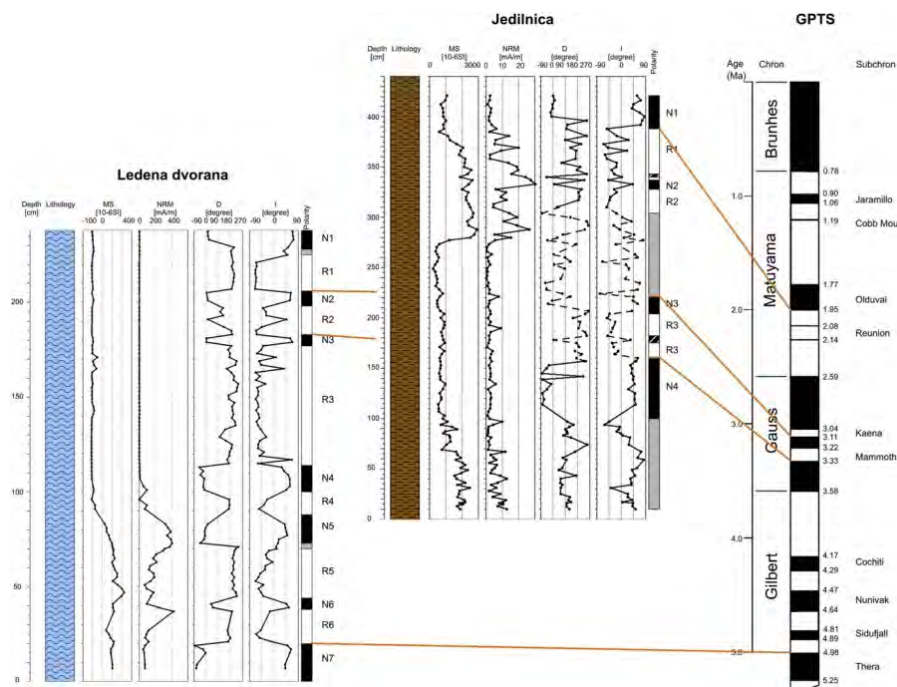


Figure 24: Correlations of magnetostratigraphy interpretation of speleothem profile in Ledena dvorana, siliciclastics in Jedilnica and the GPTS (from Häuselmann *et al.* 2015).

The profile was divided into two distinct parts by the unconformity accompanied by fossil weathering and speleothem precipitation (at 216 cm), which is well-defined both on NRM and MS curves (Häuselmann *et al.* 2015).

The results of subterranean in situ weathering of sedimentary profiles are quite rare not only in Slovenia (Zupan Hajna *et al.*, 2008, 2010), but also elsewhere (Bosák *et al.*, 2003). The weathering crust indicates moist and warmer cave climate than the present one and/or prolonged weathering. According to correlations with the GPTS, it seems that the hiatus lasted for several 100 ka.

Both R and the middle N magnetozone contain one or more short magnetozone of different polarities; they represent short-lived polarity excursions as detected on one sample only. Zones with unclear/ transient polarities correspond to (1) the zone of slumping of unconsolidated sediment below the unconformity surface with open cracks filled with sediments from above the unconformity and the overlying cross-bedded set, and (2) coarse-grained composition of the lower part of the profile.

The distribution of the NRM and especially of total MS indicates a main change of both parameters at 275 cm and at ca. 93 cm. The curve pattern below and above 275 cm is highly similar. Relatively high values in the lower part of the respective segment decrease upwards, which is visible especially on the MS curve. It can indicate the change in composition of clastic material, derived from the catchment area and transported into the cave. This means that eroded bedrock in the catchment had different composition and/or external palaeoenvironmental conditions could differ as well. Higher MS values can indicate more weathered source material in the catchment area, the degree of weathering decreased with continued erosion of source volcanoclastic rocks. The jump in the MS values above 275 cm reflects some climate-change event at the surface, which is expressed also in the cave by in situ chemical weathering of deposits during the hiatus.

The deposition of speleothems in Ledena dvorana and siliciclastics in Jedilnica was contemporaneous for most of the time, which can be indicated also by a thin siliciclastic intercalation in flowstones in Ledena dvorana (at ca. 145 cm). The deposition in Ledena dvorana started between 4.98 and 5.23 Ma and terminated between 3.04 and 2.581 Ma, i.e. earlier than in the Jedilnica (the start not later than 4.91 Ma according to cosmogenic age, and the termination between 1.77 and 1.95 Ma according to the magnetostratigraphic interpretation).

The termination of siliciclastic deposition in Jedilnica also indicates the timing of surface changes in the catchment, possibly due to the abandonment of the cave by the formative stream resulting from more intensive uplift (Fig. 25). The duration of deposition is also remarkable in comparison with other Slovenian caves (cf. Zupan Hajna *et al.* 2008, 2010).

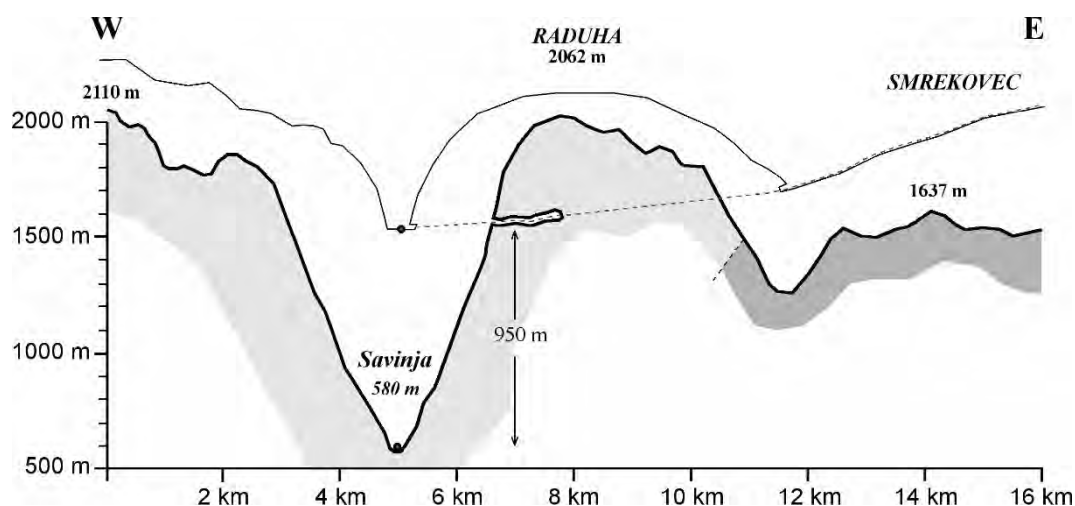


Figure 25: Schematic cross-section showing the position of Snežna jama relative to Savinja river and Smrekovec, the source area of fluvial volcanoclastic sediments. In fine lines, a schematic sketch of the paleolandscapes at the time the cave was active and filled with volcanoclastic sediments

A rough reconstruction of the cave development can be deduced both from the cave morphology and fills and our preliminary results. The main part of the cave was formed as a phreatic/epiphreatic cave containing water table elements with some vadose re-modelling

connected mostly with bypassing and paragenesis. The subterranean flow had an estimated recharge of several cubic meters per second. Both the dimensions and shape of the main cave gallery indicate the stabilization of the karst water level here for a prolonged time period. According to the pebble composition, the catchment area was situated to the southeast of the cave on the Upper Oligocene volcanogenic rocks. The altitude differences of the relief at the time of cave formation can be estimated to 600 m at least, but the hydraulic head in the karst was small.

Fluvial sediments deposited in Snežna jama were covered by thick speleothems, indicating warm, wet climate and a low altitude for the cave. Flowstones, which can be said to have a low altitude circum-Mediterranean appearance, were deposited in different climatic conditions and/or before the main uplift of the mountain. The deposition of speleothems ceased due to climate change caused by the mountain uplift and/or some other general reasons (climate cycles).

Rapid mountain uplift caused surface river entrenchment and cut off the subterranean karst drainage. Fall of the karst water level for about 900 m created conditions favourable for vertical drainage and origin of invasion vadose shafts.

Some vertical shafts simply penetrate the cave, leaving the main passage unchanged, which is comparable with other high mountainous areas, e.g., Julian Alps and Northern Limestone Alps in Austria.

The morphological conditions of the Kamnik–Savinja Alps are comparable with another part of the Alpine chain – the Northern Calcareous Alps. In the upper Pleistocene, the denudation of the slopes reached the cave and probably created two entrances. Cave bears could enter the cave through a yet unknown one on the north-western side of the ridge. Cold Pleistocene climate or simply two entrances with strong air circulation caused freezing throughout the entire cave. Recently these processes have been limited to the entrance part only, where there is a subterranean glacier. The frost processes displaced or destroyed thick layers of speleothems.

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Whole-day field trip (E):
SEDIMENTARY ENVIRONMENTS OF LJUBLJANA BASIN
 Sunday, 16.9.2018, 8.30–18.00

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Stops:

- 1** – Udin Boršt terrace and Arneževa luknja
- 2** – Tržiška Bistrica terraces
- 3** – Vrata valley



UDIN BORŠT TERRACE

Udin Boršt is a remnant of large alluvial fan that was deposited by river Tržiška Bistrica. The source area of the river is in the Alps, where it formed deep valleys with high gradient. When it enters into Ljubljana Basin where gradient is much smaller, the river has deposited a large alluvial fan. It consists mostly of limestone and dolomite pebbles and sands with admixture of siliciclastic rocks. The alluvial fan later underwent several modifications, central part was eroded and replaced with younger sediments, the old sediments and the original surface are preserved on both edges only. Only a rough chronological framework of the terraces has been provided in the past by combining morphostratigraphic relationship (Penck and Brueckner, 1909; Šifrer, 1969; Žlebnik, 1971) and application of ¹⁰Be and paleomagnetic dating (Pavich and Vidic, 1993; Vidic and Lobnik, 1997, Vidic, 1998).

Simplified, the terrace system can be divided into four dominant surfaces, named traditionally (Žlebnik, 1971) (Fig. 26) as the Older Conglomerate Infill (4), Middle Conglomerate Infill (3), Younger Conglomerate Infill (2), and finally a system of Younger gravel terraces (1).

Largest part of the old alluvial fan surface is about 8 km long and 2.5 km wide terrace Udin boršt. The elevation of the terrace is about 560 m a.s.l. on the N and 410 m a.s.l. on the S, where it is

covered with younger fluvio-glacial gravels of the Sava river. The terrace has steep erosional scarps formed by Tržiška Bistrica in the west and Parovnica river on the east.

The sediments of the alluvial fan sit directly on the erosional surface formed on dark grey Eggerian (Oligocene – Miocene) mudstone. These rocks are exposed by erosion on both sides of the Udin boršt and also in some fluvial valleys that cut through the terrace (Fig. 27). The thickness of the conglomerates that form the terrace is up to 50 m.

The conglomerate of Udin Boršt is well karstified; the surface is dissected by numerous several meters deep dolines. All the precipitations drain into the conglomerate and there are several vertical caves on the terrace and horizontal caves on the edges.

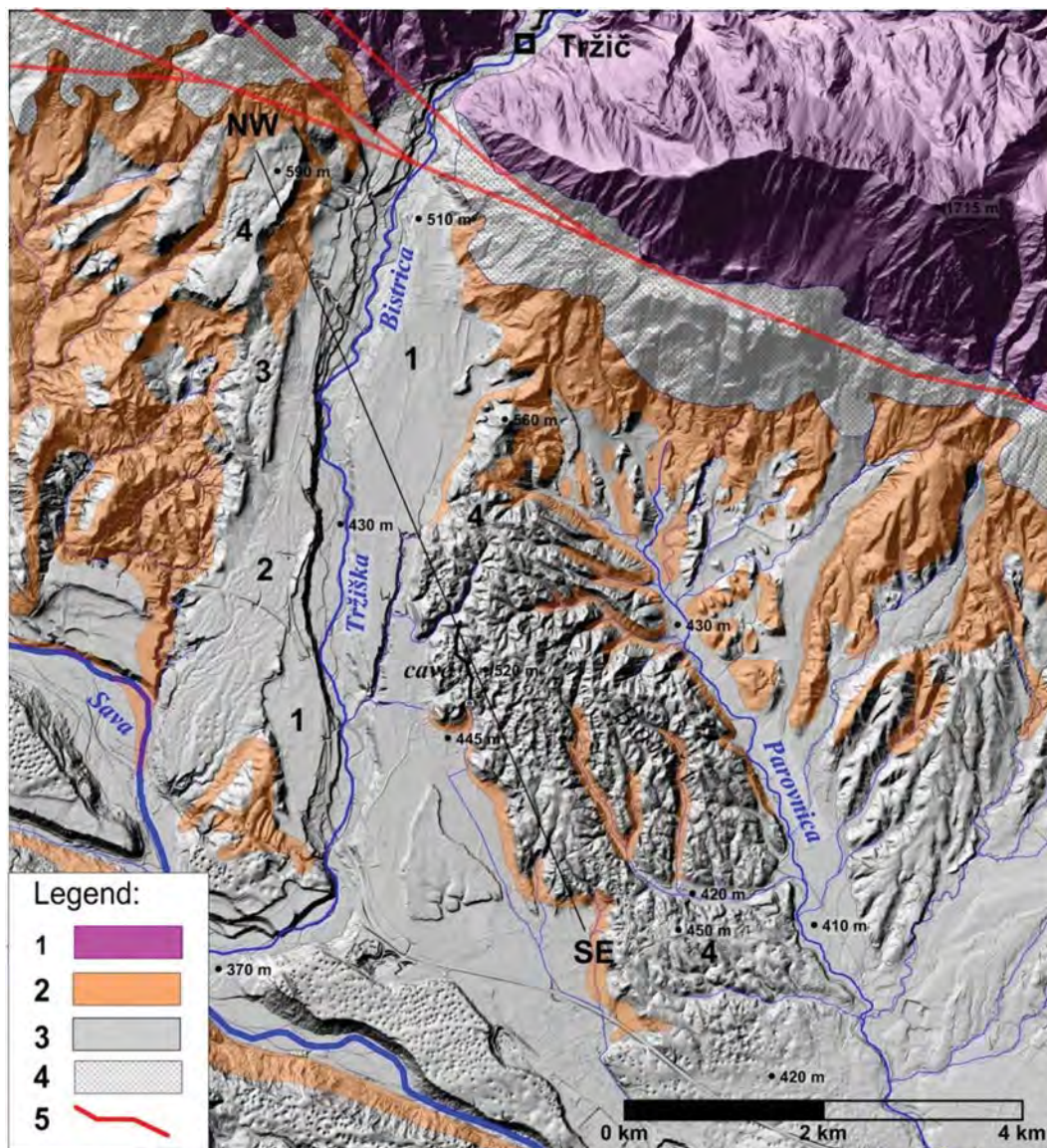


Figure 26: DEM and simplified geologic map of the Udin boršt and surroundings. Legend: 1. Mesozoic, mostly carbonate rocks of Karavanke; 2. Upper Oligocene mudstones; 3. Pleistocene and Holocene fluvial and fluvio-glacial sediments; 4. Holocene slope gravels, scree material; 5. Sava Fault. Line marked NW-SE show the position of the profile (Figs. 2). Numbers 1 – 4 on the map are chronological estimations of the terraces after Žlebnik. Modified from Mihevc, 2015.

A similar, but smaller part of the conglomerate terrace is preserved also on the W side of Tržiška Bistrica, at an elevation of about 590 m (Fig. 27). The thick soils developed on the terrace were dated by Pavich and Vidic (1993).

On the W side of Udin Boršt, four spring caves formed on the contact of conglomerate and the underlying impermeable basement, which is also seen in the entrance parts of the caves. Caves are all dipping from N to S following the dip of the basement rocks. The total length of their passages is over 2 km.

ARNEŠEVA LUKNJA

The longest cave of the area is Arneševa luknja (815 m long). It is a spring cave with a discharge of about 1 l/s. The cave is formed in conglomerate just above (2-3 m at the entrance) the grey mudstone and is nearly horizontal. Passages are low and narrow, only on few places to several m high or wide. They were formed by precipitation water that percolates through the conglomerate. No allogenic input to terrace is known. The entrance to the cave is 470 m a.s.l. Above the cave the surface is at an elevation of 510-540 m, so the cave has more than 40 m of conglomerate cover.

A sample of quartzite pebbles was collected from the walls and ceiling of the entrance part of the cave for cosmogenic dating. The method involves the measurement of two isotopes (^{26}Al and ^{10}Be) that are produced by cosmic radiation in quartz pebbles prior to burial.

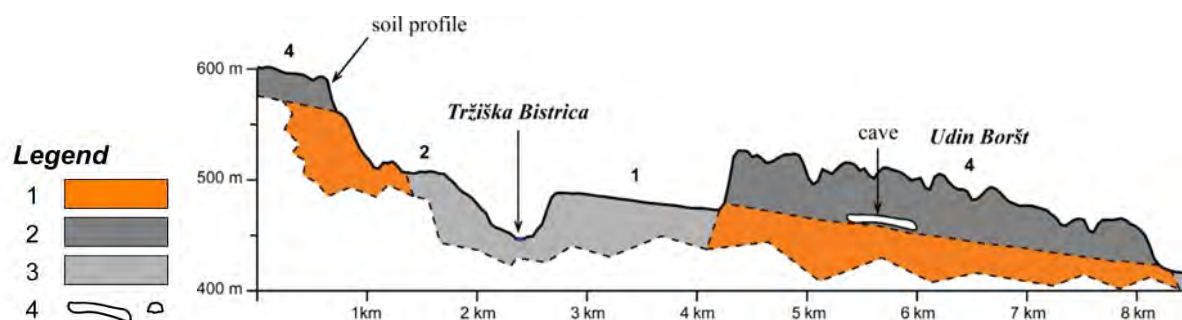


Figure 27: Longitudinal NW-SE cross-section showing the remnants of conglomerate terrace (4) and younger glaciofluvial sediments (terraces 2 and 1) of Tržiška Bistrica. The arrow shows the sampling position of quartz pebbles in Arneševa luknja and the position where a soil profile was studied by Pavich and Vidic (1993) on terrace 4. Legend 1: upper Oligocene mudstones, 2: Conglomerate, 3: younger Pleistocene and Holocene fluvial and fluvio-glacial sediments, 4: outline of the cave Arneševa Luknja.

The deposition age of buried pebbles in the cave is 1.86 ± 0.19 Ma. This age indicates the end of erosion of the Oligocene grey mudstones and the onset of gravel sedimentation. This clear change is most likely the result of tectonic activity connected with the Sava fault (Jamšek Rupnik et al., 2012), i.e. uplift of the mountains N of the fault and subsidence of the basin S of the fault.

Several phases of erosion of the alluvial fan, repeated sedimentation and formation of terraces 3, 2 and 1 are most likely to be attributed to climatic changes, mostly glacial cycles in the Quaternary.

The age of the Udin Boršt karst and caves is significantly younger than 1.86 ± 0.19 Ma. They could of form only after first incision of the Tržiška Bistrica into the alluvial fan.

LJUBLJANA BASIN QUATERNARY DEPOSITS

The Ljubljana Basin is an intramontane basin located between the Southern Alps and the Dinarides with a general southward slope and altitude ranging from 300 to 600 m a.s.l. Quaternary deposits cover the bedrock between Jesenice and Ljubljana, with thicker Quaternary infill between Kranj and Vodice reaching 270 m southeast of Kranj (Grad and Ferjančič, 1974; Premru, 1983; Car, 1991). The most recent deposits in the Ljubljana Basin are fluvial deposits transported by the Sava River and its tributaries. The Sava River originates from the Julian Alps, where it drains largely

glaciated valleys during the LGM (Bavec and Verbič, 2011). It then enters into the basin on its northwestern side, flows southeastward and is fed by moderate-size rivers grading down from the Karavanke Mountains in the N. Most of deposits in the basin are mapped as Pleistocene age (Šifrer, 1961, 1969; Žlebnik, 1971; Meze, 1974; Kuščer, 1990; Pavic and Vidic, 1993; Vidic and Lobnik, 1997) and are mainly made of large coalescent fans that merge together to form a broad southward sloping apron.

The most used relative dating technique in the basin in the past was morphostratigraphic dating of Quaternary surfaces, which was based on comparison of relative elevation of the surfaces, the induration of conglomerates, and a degree of surface degradation in terms of erosion and karstification and soil thickness (e.g. Šifrer, 1961, 1969; Žlebnik, 1971; Meze, 1974). Four major morphostratigraphic units were traditionally distinguished in the Ljubljana Basin: the Older conglomerate fill of supposedly Günz age, the Middle conglomerate fill of supposedly Mindel age, the Younger conglomerate fill of supposedly Riss age, and Gravel fill of supposedly Würm age (Šifrer, 1961, 1969; Žlebnik, 1971; Meze, 1974; Kuščer, 1990). Würm was further divided into Würm I, Würm II and Würm III.

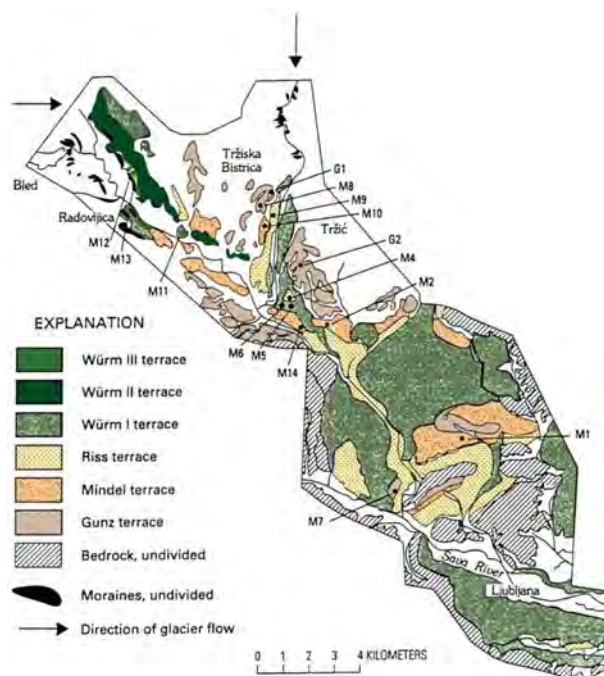


Figure 28: Quaternary morphostratigraphic units of the Ljubljana Basin with sampling sites (Pavic and Vidic, 1993).

The absolute ages of Tržiška Bistrica Terraces (one of the Sava River tributaries) and Sava Terraces were first estimated with paleomagnetic analysis and isotopic ^{10}Be dating (Pavic and Vidic, 1993; Vidic and Lobnik, 1997). Using morphostratigraphic correlation, those ages were extrapolated to other Quaternary terraces and alluvial fans in the area (Fig. 28, Table 1).

Table 1: Inferred ages of morphostratigraphic units in the Ljubljana Basin (Pavic and Vidic, 1993; Vidic and Lobnik, 1997).

Morphostratigraphic unit	Terrace No. by Šifrer (1969)	Estimated age (ka)	Uncertainty intervals (ka)	Dating methods
	IX	5	0–10	Topographic position
	VIII	10	0–10	Topographic position
Würm III	IV	32	20–35	¹⁰ Be
Würm II	III	44	40–50	¹⁰ Be
Würm I	II	62	50–70	¹⁰ Be
Riss	I	450	435–515	¹⁰ Be
Mindel II	IAa	960	> 780	Paleomagnetic analysis
Mindel I	IA	980	780–1000	¹⁰ Be, paleomagnetic analysis
Günz	IB	1800	780–1800	Paleomagnetic analysis
Günz	IB	1800	> 1000	¹⁰ Be

LJUBLJANA BASIN TECTONIC FORMATION REVEALED FROM QUATERNARY DEPOSITS

The Ljubljana Basin tectonic evolution has been studied recently with tectonic geomorphic analyses of Quaternary surfaces and by integrating various data on Quaternary deposits from geological mapping, geophysical, borehole and age dating data as well as seismological and geodetic data (Jamšek Rupnik, 2013, and references therein).

The basin is located in the northeastern section of the Adria-Europe convergent margin and is bounded by two NW-SE-striking dextral faults, the Sava Fault to the north and the Žužemberk Fault to the south (Fig. 27), both interpreted as master faults that controlled the subsidence of Ljubljana Basin in a releasing stepover between them (Vrabec and Fodor, 2006). The subsidence of the Ljubljana Basin probably started in Pliocene, with the onset of transpressional shortening in the Sava Folds area east of Ljubljana Basin, which blocked the eastward continuation of the Sava Fault (Vrabec and Fodor, 2006). This change is synchronous with commencement of the widespread regional inversion in the Alpine-Carpathian-Pannonian system (e.g. Peresson and Decker, 1997). However, because Pliocene sediments are lacking in the Ljubljana Basin, the exact timing of the basin formation cannot be constrained more precisely.

The sequence of deposition and geometry of Quaternary strata in the Ljubljana Basin suggests Quaternary folding (Žlebnič, 1971; Kuščer, 1990). Thus, the westward propagation of N-S directed shortening and folding typical of the Sava Folds probably affected the Ljubljana Basin after the basin formation, which implies a major change in the deformational regime in the basin, from transtensional subsidence to transpression (Jamšek Rupnik, 2013). Progressive uplift of Quaternary terraces in the northern part of the basin (northwest of Kranj) indicate continuous uplift in this part through the last ~ 2 Myr (Jamšek Rupnik, 2013; Mihevc et al., 2015), whereas sediments southeast of the Kranj indicate subsidence of the Kranj-Sora Polje through the Quaternary (Žlebnič, 1971; Kuščer, 1990) which is associated to the synclinal folding. The onset of reverse faulting along the Vodice Fault in the southern part of the Kranj-Sora Polje has been estimated to occur about 2.5 Myr ago (Jamšek Rupnik, 2013). Thus, the major kinematic inversion from transtensional to transpressional tectonics in the Ljubljana Basin occurred in the Early Pleistocene (Jamšek Rupnik, 2013). Geological and geomorphological observations, earthquake focal mechanisms, and geodetic measurements suggest that the NW-SE-striking dextral faults and ~E-W-striking reverse faults are active in the current regional stress regime with ~N-S oriented axis of maximum horizontal compression (e.g. Poljak et al., 2000; Vrabec and Fodor, 2006; Verbič, 2006; Bavec et al., 2012; Jamšek Rupnik et al., 2012, 2013).

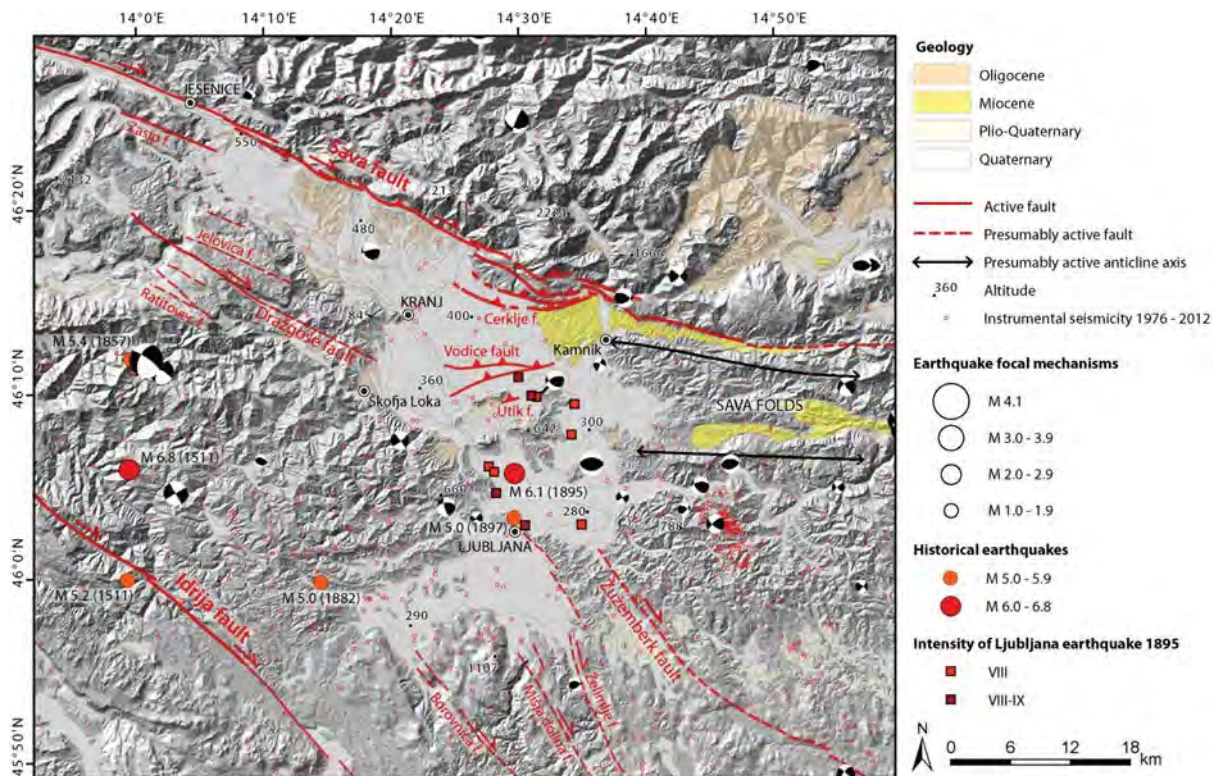


Figure 29: Seismotectonic map of the Ljubljana Basin (Jamšek Rupnik, 2013, and references therein).

TRŽIŠKA BISTRICA TERRACES AND THE SAVA FAULT ACTIVITY

Tržiška Bistrica River is a northern tributary to the Sava River with a source in the Karavanke Mountains at the altitude of 1460 m. It carved its about 1 km deep valley through Carboniferous – Triassic bedrock before crossings the Sava Fault and entering in the Ljubljana Basin. There it flows southwards in the 200-400 m wide valley, incising into fluvial Quaternary deposits, meandering for about 10 km before it outfalls into the Sava River at 370 m a.s.l.

The Tržiška Bistrica River watershed was shaped with glacial and periglacial geomorphic processes (Šifrer, 1969). South of the Sava Fault the Tržiška Bistrica River formed a system of glaciofluvial and fluvial terraces (Fig. 29). Altogether eight generations of terraces were mapped (Jamšek Rupnik, 2013). All are sloping towards S to SW. The highest among the terraces is T4, which is well preserved about 120 m above the present river. Terrace ages increase with elevation above the present river, which is also evident from high degradation of the highest surfaces and good preservation of the lowest surfaces. Patches of T4 are most probably residuals of a larger surface that previously extended from the mouth of the valley southward and was later degraded by erosion of Tržiška Bistrica and side streams. Some of the terraces were dated with paleomagnetic analysis, isotopic ^{10}Be dating and $^{26}\text{Al}/^{10}\text{Be}$ burial age dating (Pavic and Vidic, 1993; Vidic and Lobnik, 1997; Mihevc et al., 2015) (Fig. 28).

There are more terraces on the W bank then on the E one which indicates that the river migrated eastwards. This migration was governed by the Sava Fault right-lateral activity by which the N block, i.e. valley mouth from the mountains, was displaced eastwards and S block, i.e. terraces, went westward, resulting in abandonment of the terraces on the W bank, migration of the river eastwards and erosion of surfaces on W bank S of the Sava Fault. The displacement along fault required to restore the continuity of terrace T4 south of the fault and the actual Tržiška Bistrica valley N of the fault is roughly 1 km. Given the age of the T4 terrace was constrained to 1.8-2.0 Myr (Pavich and Vidic, 1993; Vidic and Lobnik, 1997; Mihevc et al., 2015) the slip-rate of the Sava Fault at this location was estimated to 0.5-0.6 mm/yr (Jamšek Rupnik, 2013). The Quaternary slip-rate of the Sava

Fault estimated from displaced geomorphic markers on other locations and from GPS data is between 0.5 – 1.5 mm/yr (Jamšek Rupnik et al., 2012).

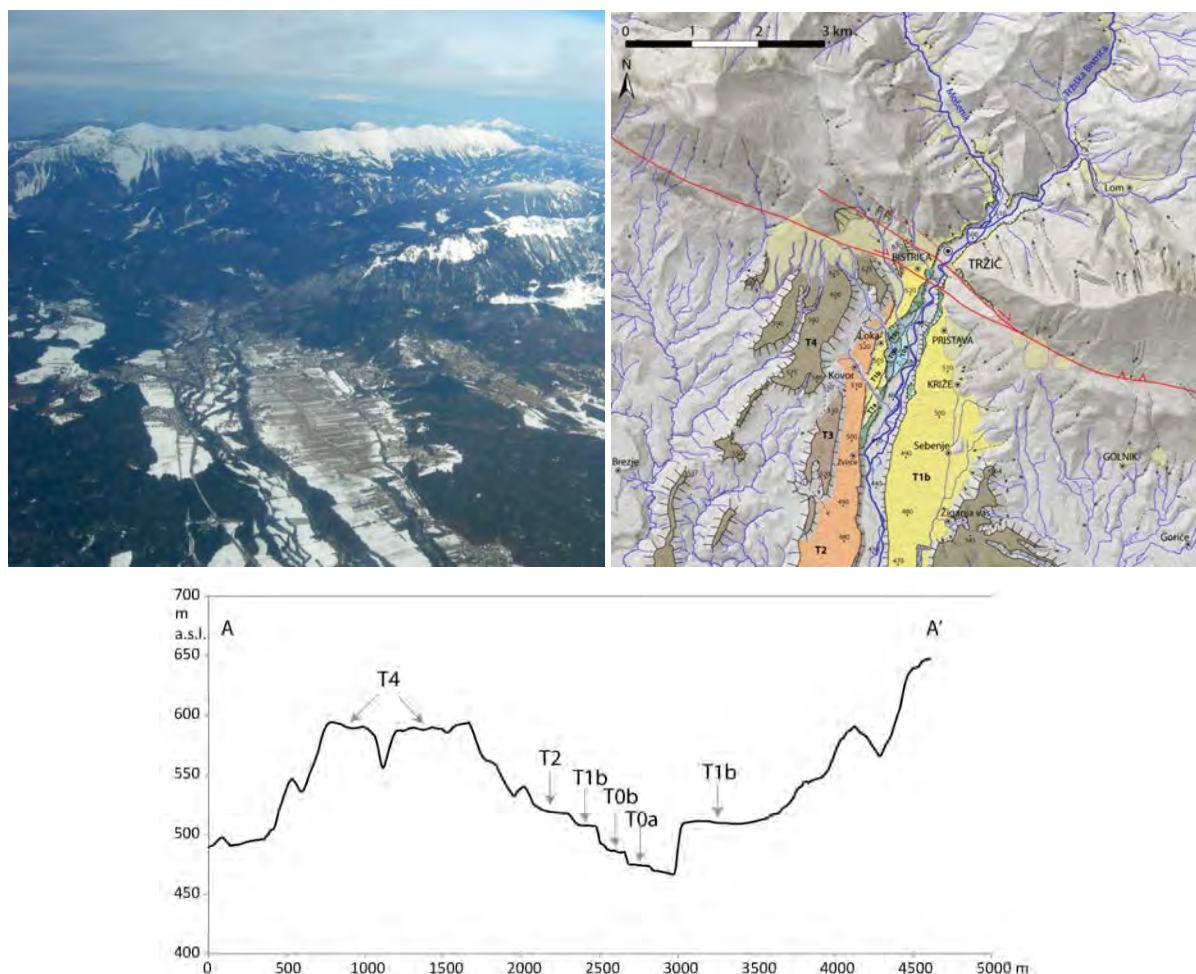


Figure 30: Upper left image – aerial view on the surfaces formed by glaciofluvial and fluvial deposition by the Tržiška Bistrica River during the Pleistocene (photo taken by Irena Mrak); upper right image – geomorphic map of the Tržiška Bistrica Terraces (Jamšek Rupnik, 2013); lower image – topographic profile across the Tržiška Bistrica Terraces derived from 5 m resolution DEM.

SAVA DOLINKA RIVER VALLEYS

Northern part of Ljubljana basin was glaciated by the valley glaciers following the two main branches of Sava River. Confluence of the glaciers was in the area of Radovljica and Bled. There are some remnants of terminal moraines above the younger Holocene sedimentary terrace of Sava. Western branch of Sava cut deep canyon and separated two karst plateaus. The canyon was modified by the glacial and the glacial partly moved across the plateaus. Northern branch of Sava river valley follows the Sava fault line towards NW. River collects waters from surface streams from deeply incised valleys. One of them is the valley Vrata, that leads towards W right into the centre of Julian Alps and ends in altitude 780 m, just below the N wall of Triglav, 2864, the highest mountain in Slovenia. There is in altitude 2500 m last remnants of the Triglav glacier. The remnants of the glacier less than one hectare are situated on the karst plateau and its melted water is discharged into the karst. On the edge of glacier there is a 375 m deep cave Triglavsko brezno. In this cave and several others in lower positions, to elevation about 700 m, perennial ice exists and forms a special type of patchy permafrost.

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