

8th RMQG

“Early Quaternary Archives”

Book Of Abstracts
and Field Trip Guidebook

4–6 November 2026

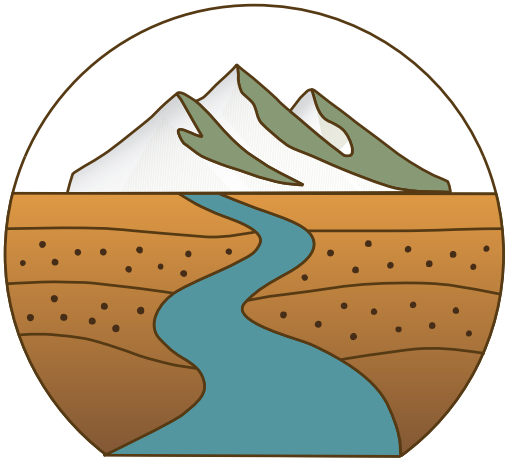
Čatež ob Savi, Slovenia

BOOK OF ABSTRACTS AND FIELD TRIP GUIDEBOOK

8th Regional Scientific Meeting on Quaternary Geology: Early Quaternary Archives

4-6 November 2026

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Early Quaternary Archives

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Book of abstracts and field trip guidebook

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CONTENTS

KEYNOTE **8**

Naki Akçar

DECKENSCHOTTER SAGA: BEYOND THE MYTH OF LAYER-CAKE STRATIGRAPHY 9

Eva Mencin Gale, Petra Jamšek Rupnik, Jure Atanackov, Miloš Bavec, Michael Logan Cline, Stephanie Neuhuber, Christopher Lüthgens, Gustav Firla, Markus Fiebig, Naki Akçar, Marcus Christl, Christof Vockenhuber

ADVANCES AND CHALLENGES IN RECONSTRUCTIG PLIOCENE-EARLY PLEISTOCENE FLUVIAL ARCHIVES IN SLOVENIA 11

Giovanni Monegato

PLEISTOCENE EVOLUTION OF THE SOUTH-EASTERN ALPS: TECTONICS VS GLACIATIONS 13

Stephanie Neuhuber, Zsofia Ruszkiczay-Rüdiger, Clemens Schmalfuss, Sandra Braumann, Philipp Strauss, Gustav Firla, Christopher Lüthgens, Markus Fiebig, Bernhard Salcher

PLIOCENE AND PLEISTOCENE FLUVIAL RECORDS IN THE VIENNA BASIN AREA 14

Zsófia Ruszkiczay-Rüdiger, László Fodor

UPLIFT RATES OF THE WESTERN PANNONIAN BASIN AND ITS SURROUNDINGS QUANTIFIED USING COSMOGENIC NUCLIDE GEOCHRONOLOGY 15

ABSTRACTS **16**

İrem Salman, Jules Bredon, Fien de Doncker, Naki Akçar, Frédéric Herman, Georgina King, Guillaume Jouvet, Susan Ivy-Ochs, Giovanni Monegato, Christoph Schmidt, Giancarlo Scardia, David Mair, Tancrède Leger, Franco Gianotti, Marcus Christl, Christof Vockenhuber, Philip Gautschi, Zheng-Tian Lu

SOUTHICE: DECIPHERING THE MIDDLE PLEISTOCENE GLACIAL HISTORY OF THE EUROPEAN SOUTHERN ALPINE FORELAND 17

Andrej Anžel, Marko Vrabec, Lovro Rupar, Petra Jamšek Rupnik

STRUCTURE AND QUATERNARY ACTIVITY OF THE SAVA FAULT NEAR THE VILLAGE OF GOZD (SLOVENIA) 19

Koraljka Bakrač, Nikolina Ilijanić, Ozren Hasan, Slobodan Miko

THE IMPORTANCE OF NON-POLLEN PALYNOMORPHS (NPPS) IN PALAEOENVIRONMENTAL RECONSTRUCTION: EVIDENCE FROM HOLOCENE LAKES OF THE EASTERN ADRIATIC 21

Veronica Chiarini, Alessandro Fontana

AN EARLY-HOLOCENE CATASTROPHIC ALLUVIAL PHASE OF TORRE RIVER (NE ITALY) 22

Čedomir Benac, Neven Bočić, Mladen Juračić,

PALEOPOLJES AND PALEOLAKES IN THE KVARNER AREA DURING LATE PLEISTOCENE (NE ADRIATIC SEA) 23

Neven Bočić

KARST GEOMORPHOLOGY OF THE CENTRAL PART OF THE PAPUK NATURE PARK (CROATIA) 24

Rok Brajkovič

STATISTICAL LEARNING AS AN EMERGING TOOL FOR PROVENANCE DETERMINATION 25

Sanja Faivre, Jadranka Barešić, Davor Horvatić, Marin Mićunović, Iva Veverec Ines Krajcar Bronić, Russell N. Drysdale

GEOCHRONOLGY AND FRESHWATER RESERVOIR EFFECT OF TUFA BARRIERS IN ZRMANJA RIVER VALLEY 26

Alessandro Fontana, Giovanni Monegato, Paolo Mozzi, Sandro Rossato, Veronica Chiarini

PLEISTOCENE MARINE HIGHSTANDS IN THE NORTHERN ADRIATIC SEA 28

David Gerčar, Jure Atanackov, Andrej Lapanje, Nina Rman, Blaž Milanič, Dušan Rajver, Mitja Janža

QUATERNARY-FILL BASEMENT MODELS OF THE LJUBLJANA BASIN 29

David Gerčar, Ana Novak, Simona Adrinek, Eva Mencin Gale, Maša Mušič, Matevž Novak, Luka Serianz, Nina Rman, Andrej Lapanje

GEOLOGICAL MODELLING OF QUATERNARY BASINS IN SLOVENIA 31

Petra Gostinčar, Lovro Rupar, Petra Jamšek Rupnik, Eva Mencin Gale, Manja Žebre

INVESTIGATING GLACIGENIC DEPOSITS AT MOST NA SOČI (NW SLOVENIA): PRELIMINARY RESULTS FROM ERT AND BOREHOLE DATA 33

Klara Grošanić, Neven Bočić

MORPHOLOGY AND SPELEOGENESIS OF THE OSTROVICA CAVE (GOSPIĆ, CROATIA) 34

Ozren Hasan, Filip Šegović, Dea Brunović, Slobodan Miko, Ivona Ivkić Filipović, Nikolina Ilijanić, Natalia Smrkulj, Ivan Razum, Martina Šparica Miko

RECONSTRUCTION OF SUBMERGED ARCHIVES OF THE CETINA PALAEORIVER AND LAKE SYSTEM IN THE EASTERN ADRIATIC COAST DURING THE LAST GLACIAL MAXIMUM 35

Jan Hinkelman, Nikolina Ilijanić, Slobodan Miko, Ozren Hasan, Stefan Engels, Oliver Heiri, Martina Jambrović, Koraljka Bakrač

ENCOUNTERING CHIRONOMIDS ON POLLEN SLIDES: A CASE FROM A KARST LAKE OF CROATIA 37

Nikolina Ilijanić, Slobodan Miko, Ozren Hasan, Dea Brunović, Ivona Ivkić Filipović, Martina Šparica Miko Natalia Smrkulj, Filip Šegović
LATE PLEISTOCENE (MIS 5) SEDIMENTARY RECORD OF LAKE VISOVAC (DALMATIA, CROATIA) 39

Petra Jamšek Rupnik, Andrej Novak, Eva Mencin Gale, Manja Žebre, Andrej Anžel, Petra Gostinčar, Edmundo Placencia-Gómez, Anže Markelj, Martin Gaberšek, Mateja Gosar
RECONSTRUCTING EXTREME WEATHER EVENTS FROM ALLUVIAL FAN ARCHIVES IN THE UPPER SAVA VALLEY (SOUTHERN ALPS): FIRST RESULTS FROM RATEČE AND PODKOREN 40

Dora Janković, Ankica Oros Sršen
THE HOLOCENE AVIFAUNA OF ŽUKOVICA CAVE AS AN INDICATOR OF PALEOECOLOGICAL CONDITIONS ON KORČULA ISLAND 41

Kristina Krklec, David Domínguez-Villar
FACIES AND DEPOSITIONAL ENVIRONMENTS OF PLEISTOCENE TUFA DEPOSITS AT ROŠKI SLAP, KRKA RIVER (CROATIA) 42

Jurij Kunaver
RELATIONSHIPS BETWEEN THE INTENSITY OF GLACIAL EROSION AND THE KARST PHENOMENA IN THE CASE OF THE VELIKA VRATA GLACIOKARST (1924 M, GORENJA KOMNA, JULIAN ALPS). THE USEFULNESS OF DRONE VIDEO AERIAL RECORDINGS 44

Nina Lončar Baričević
PALEOGEOGRAPHIC RECONSTRUCTION OF THE ENVIRONMENT: LAKES AND WETLANDS OF THE RAVNI KOTARI REGION (PALRES) 45

Neal Mathes, Naki Akçar, Ainhoa Val, Susan Ivy-Ochs, Marcus Christl, Christof Vockenhuber, Philip Gautschi, Marc Luetscher
CAVE SEDIMENTS AS AN ARCHIVE OF MIDDLE PLEISTOCENE ALPINE GLACIATIONS IN THE JURA MOUNTAINS 46

Marin Mićunović, Sanja Faivre
EMBAYMENT GEOMETRY AS A CONTROL FACTOR OF POCKET BEACHES WAVE EXPOSURE: ISLAND OF HVAR, CROATIA 47

Ana Novak, Branko Čermelj, Boštjan Rožič, Luca Baradello, Martina Busetti, Emiliano Gordini, Petra Žvab Rožič
NEW LATE QUATERNARY FINDINGS FROM THE SLOVENIAN PART OF THE GULF OF TRIESTE (NORTHERN ADRIATIC SEA) 49

Ana Novak, Ozren Hasan, Petra Gostinčar, Dea Brunović, Slobodan Miko, the EMODnet Geology network
QUATERNARY MARINE GEOLOGY CONTRIBUTIONS TO THE EMODNET GEOLOGY PORTAL FROM THE EASTERN ADRIATIC SEA 50

Andrej Novak, David Gerčar
QUATERNARY DEPOSITS BETWEEN KRANJSKA GORA AND PODKOREN (UPPER SAVA VALLEY, NW SLOVENIA) 51

Andrej Novak, Marko Vrabec, Andrej Šmuc
SEVEN YEARS IN PLANICA: UAV MONITORING OF SEDIMENTARY PROCESSES ON ALLUVIAL FANS (JULIAN ALPS, NW SLOVENIA) .. 52

Iva Palatinuš, Petra Bajo, Maja Briški, Vlatko Brčić, Christoph Spötl, Regina Mertz-Kraus
INVESTIGATING PROXY-CLIMATE RELATIONSHIP USING INSTRUMENTAL DATA: MODERN STALAGMITE RECORD FROM NOVA GRGOSOVA CAVE, CROATIA 53

Małgorzata Pisarska-Jamroży, Albertas Bitinas, Andreas Börner, Małgorzata Bronikowska, Aldona Damušytė, Tiit Hang, Heiko Hüneke, Asta Jusienė, Michael Kenzler, Māris Krievans, Kristaps Lamsters, Māris Nartišs, Karsten Obst, Niko Putkinen, Alar Rosentau, Henrik Rother, Anna Salwowska, Holger Steffen, Rebekka Steffen, Raimo Sutinen, Sylwia Świątek, Szymon Belzyt, Tom Van Loon, Barbara Woronko, Piotr Paweł Woźniak
SEDIMENTARY ARCHIVES OF GLACIALLY TRIGGERED EARTHQUAKES IN THE SOUTHERN BALTIC REGION 54

Dora Rebić, Ankica Oros Sršen, Preston T. Miracle
BIRDS FROM THE HOLOCENE DEPOSITS OF THE CAVE VELA PEĆ IN ISTRIA 55

Leonello Serva, Andrea Berlusconi, Livio Bonadeo, Fabio Iacuone
A HUGE CHANGE IN THE DRAINAGE PATTERN OCCURRED IN THE LOWER QUATERNARY IN CENTRAL APENNINES: TECTONIC AND EROSIONAL ROLE 56

Sašo Stefanovski, Mateja Ferk, Timotej Verbovšek, Matej Dolenec, Uroš Stepišnik
SEDIMENTOLOGICAL CHARACTERISTICS OF DOLINE INFILLS IN THE DINARIC KARST OF SLOVENIA 57

Petar Stejić, Eleonora Kostić, Mihajlo Pandurov, Rodoljub Gajić, Vesna Tahov
CONTINENTAL QUATERNARY SEDIMENTS IN SERBIAN PART OF PANNONIAN PLAIN 59

Maša Surić, Ozren Hasan, Robert Lončarić, Tvrtko Dražina, Krešimir Žganec, Filip Šapina
PRELIMINARY RESULTS OF THE PROJECT MOKRO - ENVIRONMENTAL CHANGE OF THE LITTORAL KARST DURING THE LATE QUATERNARY 60

Maša Surić, Tomislav Kurečić, Petra Bajo, Lara Wacha, Robert Lončarić, Neven Bočić, Nadja Zupan Hajna
COMPLEMENTARITY OF THE CAVE SEDIMENTS IN QUATERNARY ENVIRONMENTAL RECONSTRUCTION 61

Filip Šegović, Ozren Hasan, Dea Brunović, Natalia Smrkulj, Slobodan Miko, Nikolina Ilijanić, Ivan Razum, Martina Šparica Miko
TRACING THE JADRO PALAEORIVER FROM THE KAŠTELA BAY TO THE MID-ADRIATIC DEEP: EVIDENCE FROM HIGH-RESOLUTION GEOPHYSICAL DATA 62

Marko Špelić, Josipa Maslač Soldo, Tomislav Kurečić, Matija Vukovski, Krešimir Petrinjak, Nikola Belić, Marko Budić, Branko Kordić, Michal Šujan, Petra Jamšek Rupnik, Eva Mencin Gale, Lara Wacha

QUATERNARY FLUVIAL FEATURES AS MORPHOTECTONIC MARKERS ABOVE A BURIED INVERSION FAULT ZONE AT THE NORTHERN SAVA BASIN MARGIN, CENTRAL CROATIA 64

Astrid Švara, Nadja Zupan Hajna, Šimon Kdýr, Petr Pruner, Paula Sierpień, Helena Hercman, John Hellstrom, Ivan Horáček, Pavel Bosák

RECONSTRUCTING PLIOCENE–PLEISTOCENE CHANGES OF CAVE SEDIMENTATION USING TECTONIC UPLIFT PHASES (POSTOJNA CONTACT KARST, W SLOVENIA) 66

Tea Trčak, Ankica Oros Sršen, Preston T. Miracle

BIRDS FROM THE QUATERNARY DEPOSITS OF THE CAVE PUPIĆINA PEĆ IN ISTRIA 67

Lara Wacha, Dea Brunović, Marko Budić, Tvrtko Korbar

CONSTRAINING TECTONIC MOVEMENTS USING QUATERNARY DEPOSITS PRESERVED ON THE CENTRAL ADRIATIC OFFSHORE ISLANDS 68

Lara Wacha, Tomislav Kurečić, Filip Šarc, Marijan Kovačić, Neven Bočić, Petra Bajo, Šimon Kdýr, Pavel Bosák, Nadja Zupan Hajna, Hrvoje Cvitanović

ALLOGENIC DEPOSITS OF BARAĆ AND CEROVAC CAVES: DESCRIPTION, SAMPLING AND FIRST RESULTS 69

Manja Žebre, Petra Gostinčar, Eva Mencin Gale, Petra Jamšek Rupnik, David Gerčar, Lovro Rupar, Andrej Novak, Miloš Bavec

FIRST RESULTS FROM THE GEOFRAME-BOVEC PROJECT 70

Eva Mencin Gale, Petra Jamšek Rupnik, Jure Atanackov, Miloš Bavec, Rok Brajkovič, Josipa Maslač Soldo

Pliocene-Quaternary evolution of the Krško Basin: field trip guide 71

Introduction 72

Stop 1: Globoko 77

Stop 2: Artiče - Dečno selo 78

Stop 3: Prilipe 80

Stop 4: Drnovo 81

PRESENTATION PROGRAMME

8th RMQG programme (4 - 6 November 2026, Čatež ob Savi, Slovenia)

WEDNESDAY - 4 NOVEMBER 2026

8:30–9:00	Registration
09:00–09:15	Opening ceremony *dr. Eva Mencin Gale, dr. Manja Žebre, dr. Petra Gostinčar (meeting opening)* *dr. Petra Jamšek Rupnik (president of SINQUA)* *dr. Miloš Bavec (director of Geological Survey of Slovenia)*
Session 1: Landscape evolution, geomorphology and extreme events	
09:15–10:00	KEYNOTE **Mencin Gale et al.:** Pliocene-Pleistocene fluvial sedimentary dynamics and chronology in Southeastern Alpine Foreland (Eastern Slovenia)
10:00–10:15	**Gerčar et al.:** Geological modelling of Quaternary basins in Slovenia
10:15–10:30	**Anžel et al.:** Structure and Quaternary activity of the Sava Fault near the village of Gozd (Slovenia)
10:30–11:00	**Coffee break**
11:00–11:45	KEYNOTE **Monegato:** Pleistocene evolution of the South-Eastern Alps: tectonics vs. glaciations
11:45–12:00	**Chiarini and Fontana:** An early-Holocene catastrophic alluvial phase of Torre River (NE Italy)
12:00–12:15	**Jamšek Rupnik et al.:** Reconstructing extreme weather events from alluvial fan archives in the Upper Sava Valley (Southern Alps): First results from Rateče and Podkoren
12:15–12:30	**Novak et al.:** Quaternary deposits between Kranjska Gora and Podkoren (Upper Sava Valley, NW Slovenia)
12:30–12:45	**Pisarska-Jamroży et al.:** Sedimentary archives of glacially triggered earthquakes in the southern Baltic region
12:45–14:15	**Lunch break**
Session 2: Karst environments	
14:15–14:30	**Švara et al:** Reconstructing Pliocene-Pleistocene changes of cave sedimentation using tectonic uplift phases (Postojna contact karst, W Slovenia)
14:30–14:45	**Bočić:** Karst geomorphology of the central part of the Papuk nature park (Croatia)
14:45–15:00	**Stefanovski et al.:** Sedimentological characteristics of doline infills in the Dinaric Karst of Slovenia
15:00–15:15	**Palatinuš et al.:** Investigating proxy-climate relationship using instrumental data: Modern stalagmite record from Grgosoav Cave, Croatia
15:15–15:30	**Janković and Oros Sršen**: The Holocene avifauna of Žukovica Cave as an indicator of paleoecological conditions on Korčula Island
15:30–15:45	**Trčak et al.:** Birds from the Quaternary deposits of the Cave Pupićina Peć in Istria
15:45–16:15	**Coffee break**
16:15–17:30	**Poster session**
19:00–21:00	Social dinner (hotel Terme restaurant)
21:00–	Gathering in Bar Cabana

THURSDAY - 5 NOVEMBER 2026

Session 3: Geomorphology and paleoenvironmental archives in marine and continental settings	
09:00–09:45	KEYNOTE **Neuhuber et al.:** Pliocene and Pleistocene fluvial records in the Vienna Basin area
09:45–10:30	KEYNOTE **Ruszkiczay-Rüdiger and Fodor:** Uplift rates of the Western Pannonian Basin and its surroundings quantified using cosmogenic nuclide geochronology
10:30–11:00	**Coffee break**
11:00–11:15	**Fontana et al.:** Pleistocene marine highstands in the Northern Adriatic Sea
11:15–11:30	**Novak et al.:** New late Quaternary findings from the Slovenian part of the Gulf of Trieste (Northern Adriatic Sea)
11:30–11:45	**Hasan et al.:** Reconstruction of submerged archives of the Cetina paleoriver and lake system in the Eastern Adriatic coast during the Last Glacial Maximum
11:45–12:00	**Šegović et al.**: Tracing the Jadro palaeoriver from the Kaštela Bay to the Mid-Adriatic Deep: evidence from high-resolution geophysical data
12:00–12:15	**Ilijanić et al.:** Late Pleistocene (MIS 5) sedimentary record of Lake Visovac (Dalmatia, Croatia)
12:15–12:30	**Faivre et al.:** Geochronology and freshwater reservoir effect of tufa barriers in Zrmanja River Valley
12:30–14:00	**Lunch break**
14:00–14:45	KEYNOTE **Akçar:** Deckenschotter saga: Beyond the myth of layer-cake stratigraphy
14:45–15:00	**Brajkovič:** Statistical learning as an emerging tool for provenance determimation
15:00–15:15	**Hinkelman et al.:** Encountering chironomids on pollen slides: a case from a karst lake of Croatia
15:15–15:30	**Serva et al.:** A huge change in the drainage pattern occurred in the lower Quaternary in Central Apennines: tectonic and erosional role
15:30–15:45	Excursion introduction and closing remarks, invitation to the next 9thRMQG meeting
15:45–16:15	**Coffee break**
16:15–17:30	**Poster session**

FRIDAY - 6 NOVEMBER 2026

EXCURSION: Pliocene-Quaternary evolution of the Krško Basin	
08:30	Start: parking of Hotel Terme
08:30–10:00	Stop 1: Globoko (Introduction to Krško Basin and Early Quaternary section)
10:00–11:00	Stop 2: Dečno selo (Subsurface and paleoseismological investigations in Krško Basin)
11:00–12:30	Stop 3: Prilipe (Geomorphological features and fluvial and colluvial Early Quaternary succession)
12:30–14:30	Lunch at Reset Brewery (Brežice)
14:30–16:30	Stop 4: Drnovo (Late Pleistocene surfaces and Holocene floodplain, archaeological site Neviodunum)
17:00	End: parking of Hotel Terme

KEYNOTES

DECKENSCHOTTER SAGA: BEYOND THE MYTH OF LAYER-CAKE STRATIGRAPHY

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The Swiss Deckenschotter constitute one of the most important terrestrial archives of Early Pleistocene glaciation and landscape evolution in the northern Alpine foreland. Traditionally, these glaciofluvial gravels were organized into a morphostratigraphic "layer-cake" model, in which elevation, lithology, and apparently continuous fine-grained horizons were used to correlate successive depositional units across the landscape (Graf, 2009). At Irchel, the fossil-bearing Hasli Formation provided a particularly important biostratigraphic anchor for this framework (Thew et al., 2024). However, the absence of independent numerical ages left the chronostratigraphic validity of these correlations largely untested.

This keynote synthesizes almost two decades of research combining geomorphological mapping, sedimentary facies analysis, clast petrography, morphometry and fabric, palaeopedology, trenching, borehole coring, geophysics, and cosmogenic ^{10}Be-^{26}Al burial dating. The resulting chronology places Deckenschotter accumulation within the broader history of Early Pleistocene Alpine glaciations (cf. Ivy-Ochs et al., 2022; Monegato et al., 2023). Cosmogenic nuclide studies have provided direct constraints on the timing of gravel accumulation, major Alpine glaciations, and changes in foreland landscape evolution (Claude et al., 2019; Knudsen et al., 2020; Dieleman et al., 2022; Bros et al., 2025). These studies also demonstrate the importance of accounting explicitly for inherited nuclide inventories and post-burial production when interpreting old terrestrial deposits. Recent work reveals complex Early Pleistocene drainage patterns across the Swiss Alpine foreland (Bros et al., 2025), while investigations of terminal overdeepenings document repeated phases of glacial erosion and sedimentary infilling in northern Switzerland (Buechi et al., 2024).

The results obtained over the past two decades demonstrate that the Deckenschotter do not form laterally continuous, chronologically ordered layers. Instead, they record repeated erosion, channel migration, aggradation, and channel reoccupation within highly dynamic, glacier-fed braided-river systems. At Irchel, gravel bodies previously interpreted as regionally continuous units form a complex cut-and-fill architecture, while fine-grained deposits attributed to the Hasli Formation occur discontinuously and at different stratigraphic positions (Claude et al., 2019; Dieleman et al., 2022). Lithologically similar gravels may therefore differ substantially in age, whereas younger channel fills may occur adjacent to, or locally beneath, older deposits.

These findings also transform our understanding of long-term landscape evolution. Incision and relief generation accelerated markedly during and after the Mid-Pleistocene Transition, reflecting a fundamental reorganization of glacial erosion and foreland drainage systems (Claude et al., 2019; Dieleman et al., 2026). The Deckenschotter saga therefore offers a broader methodological lesson: in terrestrial sedimentary systems, lithostratigraphic continuity does not necessarily imply chronostratigraphic continuity. Reconstructing such archives requires an integrated four-dimensional approach in which sedimentary processes, subsurface architecture, and independent geochronology are evaluated together.

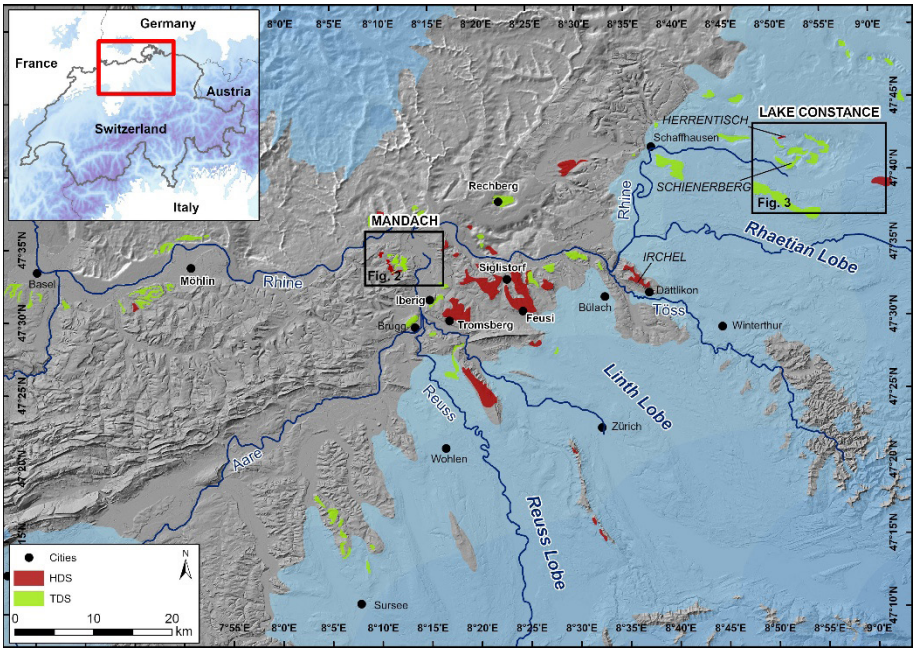


Figure 1: Extent of the Reuss, Linth, and Rhaetian lobes in the northern Swiss Alpine Foreland during the Last Glacial Maximum, and distribution of the Upper (HDS; Höhere Deckenschotter) and Lower Cover Gravels (TDS; Tiefere Deckenschotter) (from Dieleman et al., 2026).

REFERENCES

Buechi, M.W., Landgraf, A., Madritsch, H., Mueller, D., Knipping, M., Nyffenegger, F., Preusser, F., Schaller, S., Schnellmann, M., Deplazes, G., 2024. Terminal glacial overdeepenings: Patterns of erosion, infilling and new constraints on the glaciation history of Northern Switzerland. Quaternary Science Reviews 344.

Bros, E., Ivy-Ochs, S., Pollhammer, T., Kober, F., Grischott, R., Salcher, B., Norgaard, J., Knudsen, M.F., Vockenhuber, C., Christl, M., Gautschi, P., Maden, C., Ylä-Mella, L., Jansen, J.D., Landgraf, A., Synal, H.A., 2025. Comprehensive temporal and spatial analysis of Early Pleistocene drainage patterns on the Swiss Alpine foreland. Earth Surface Processes and Landforms 50.

Claude A., Akçar N., Ivy-Ochs S., Schlunegger F., Kubik P.W., Christl M., Vockenhuber C., Kuhlemann J., Rahn M., Schlüchter C., 2019. Changes in landscape evolution patterns in the northern Alpine Foreland during the Mid-Pleistocene Revolution. GSA Bulletin, 131, 2056-2078.

Dieleman C, Christl M, Vockenhuber C, Gautschi P, Schlunegger F, Akçar N (2026) Relief increase in the Swiss northern Alpine Foreland after the Mid-Pleistocene Transition. Geomorphology 492: 110060. https://doi.org/10.1016/ j.geomorph.2025.110060.

Dieleman, C., Christl, M., Vockenhuber, C., Gautschi, P., Akçar, N., 2022. Early Pleistocene complex cut-and-fill sequences in the Alps. Swiss Journal of Geosciences 115, 11.

Graf, H.R., 2009. Stratigraphie von Mittel- und Spätpleistozän in der Nordschweiz. Swiss Federal Office of Topography, swisstopo.

Ivy-Ochs, S., Monegato, G., Reitner, J.M., 2022. Chapter 39 - The Alps: glacial landforms prior to the Last Glacial Maximum, in: Palacios, D., Hughes, P.D., García-Ruiz, J.M., Andrés, N. (Eds.), European Glacial Landscapes. Elsevier, pp. 283-294.

Knudsen, M.F., Nørgaard, J., Grischott, R., Kober, F., Egholm, D.L., Hansen, T.M., Jansen, J.D., 2020. New cosmogenic nuclide burial-dating model indicates onset of major glaciations in the Alps during Middle Pleistocene Transition. Earth and Planetary Science Letters 549, 116491.

Monegato, G., Gianotti, F., Ivy-Ochs, S., Reitner, J. M., Scardia, G., Akçar, N., 2023. The Early and Middle Pleistocene glaciations in the Alps. Alpine and Mediterranean Quaternary 36, 127-148.

Thew, N., Kälin, D., Cuenca-Bescós, G., Buechi, M. W., Penkman, K., Scheidt, S., et al. (2024). The Hasli Formation of the Irchel Plateau – A key record for older Early Pleistocene interglacial sediments in northern Switzerland. Quaternary Science Reviews, 332(December 2023). https://doi.org/10.1016/j.quascirev.2024.108550

ADVANCES AND CHALLENGES IN RECONSTRUCTIG PLIOCENE-EARLY PLEISTOCENE FLUVIAL ARCHIVES IN SLOVENIA

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The Pliocene and Pleistocene periods in the European Alps and their forelands were strongly influenced by an interplay of glacial-interglacial cycles and tectonic processes. Pliocene-Pleistocene fluvial sediments in Slovenia were deposited in several intramontane basins: the Slovenj Gradec, Nazarje, Celje, Drava-Ptuj, Velenje, and Krško Basins (Mencin Gale, 2021; Mencin Gale et al., 2019a, 2019b, 2024). The oldest part of the Pliocene–Pleistocene fluvial succession is represented by a Pliocene–early Pleistocene unit, which is either preserved in terraces located at the highest landscape position or buried deeply in the basins and can be accessed via drillings. The main challenges of establishing a Pliocene-Pleistocene stratigraphic chronology are severely degraded terraces, limited number of outcrops, intense

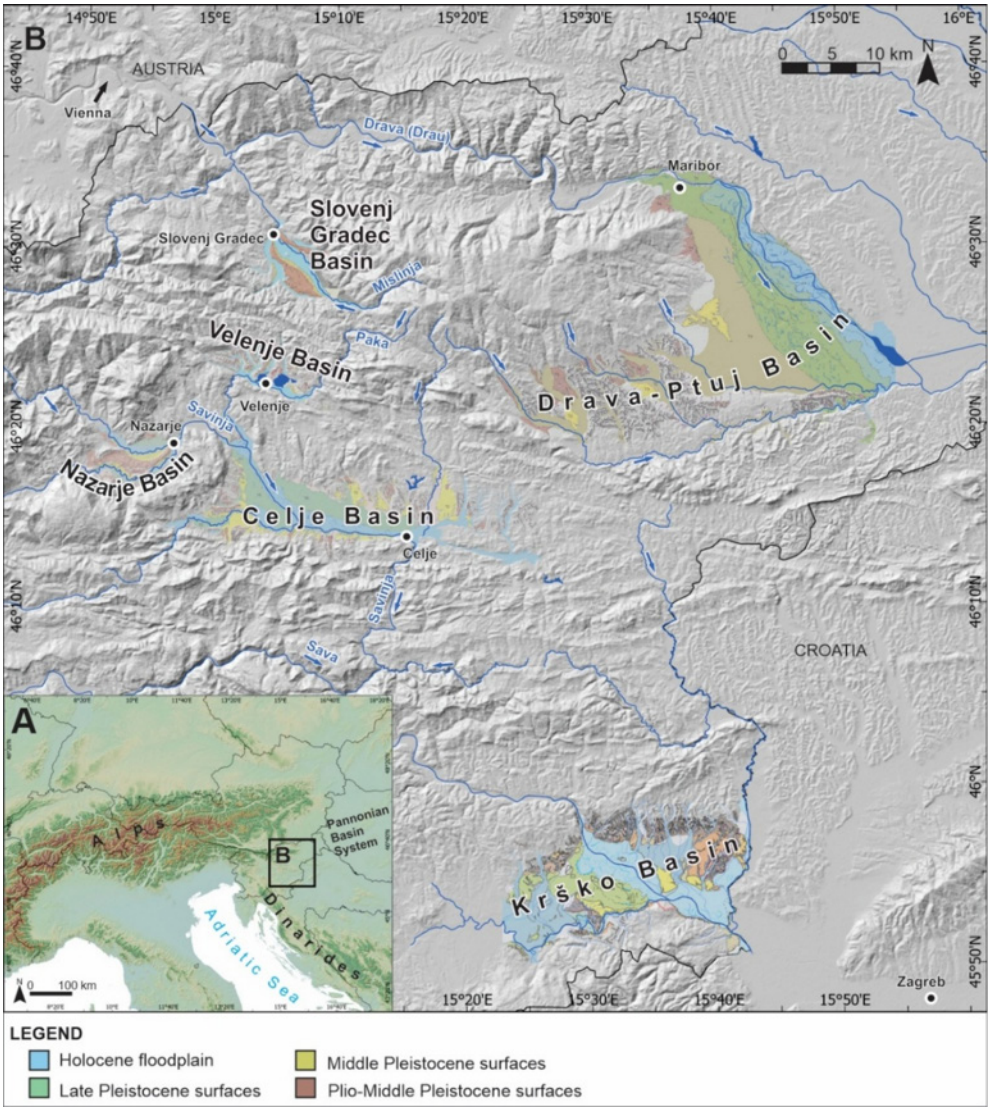


Figure 1: Geomorphological maps of the Slovenj Gradec, Nazarje, Celje, Drava-Ptuj, Velenje, and Krško Basins (Mencin Gale 2021; Mencin Gale et al., 2019a, 2019b, 2024).

weathering, and where sediments are deeply buried, low radionuclide concentrations. Despite these limitations several numerical ages were obtained in the Krško and Velenje Basins using cosmogenic radionuclide dating. In the Krško Basin, Pliocene to early Pleistocene unit indicates ages from approximately 1.3-2.0 Ma for near surface sediments and 1.1 - 2.8 Ma for the buried deposits. Additionally, parts of previously interpreted early Pleistocene deposits were dated to early-middle Pleistocene, yielding ages from 550-840 ka. In the Velenje Basin, an isohron age for the Pliocene-early Pleistocene terrace returned an age of approximately 2.7 Ma. The chronology is further expanded to middle and Lower Pleistocene units in Krško and Drava-Ptuj Basins. In the Krško Basin the middle and late Pleistocene near surface sediment ages span from 95-152 ka and 13-20 ka, respectively. In the Drava-Ptuj Basin the middle Pleistocene buried units ages span from 130-170 ka and the late Pleistocene near surface sediments span 19-20 ka. The ages of different terrace levels within Krško, Velenje and Drava-Ptuj Basins are well aligned, indicating synchronous landscape evolution and sedimentary dynamics of Pliocene-Pleistocene basins in Slovenia.

REFERENCES

Mencin Gale, E., 2021. Pliocene to Quaternary sedimentary evolution of intramountain basins at the junction of Alps, Dinarides and Pannonian Basin Faculty for Natural Sciences and Engineering. PhD thesis. Univerza v Ljubljani, Ljubljana, p. 187. https://repozitorij.uni-lj.si/IzpisGradiva.php?id=127012&lang=eng

Mencin Gale, E., Jamšek Rupnik, P., Trajanova, M. et al., 2019a. Morphostratigraphy and provenance of Plio-Pleistocene terraces in the south-eastern Alpine foreland: the Mislinja and Upper Savinja valleys, northern Slovenia. Journal of Quaternary Science 34, 633-649. https://doi.org/10.1002/jqs.3156

Mencin Gale, E., Jamšek Rupnik, P., Trajanova, M. et al., 2019b. Provenance and morphostratigraphy of the Pliocene-Quaternary sediments in the Celje and Drava-Ptuj Basins (eastern Slovenia). Geologija 62, 189-218. https://doi.org/10.5474/geologija.2019.009

Mencin Gale, E., Jamšek Rupnik, P., Trajanova, M. et al., 2024. The onset of Pliocene–Early Pleistocene fluvial aggradation in the Southeastern Alpine Foreland (Velenje Basin, Slovenia) and its paleoenvironmental implicationsa. Journal of Quaternary Science 34, 1-19. https://doi.org/10.1002/jqs.3623Digital Object Identifier (DOI)

PLEISTOCENE EVOLUTION OF THE SOUTH-EASTERN ALPS: TECTONICS VS GLACIATIONS

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In the framework of the Alpine Glaciations, the south-eastern European Alps represent a key area. This sector provides a unique archive in terms of chronology and sedimentary evolution thanks to the mountain-to-sea correlations, through available long cores in the foreland, and significant outcrop areas located in the piedmont plain and within the mountain valleys.

The evolution of the major catchments (namely: Astico, Brenta, Piave, Cellina, Meduna, Arzino, Tagliamento, Torre, Natisone/Nadiža and Isonzo/Soča) has been strongly influenced by Alpine glaciations and by the ongoing compressive to transpressive deformation of the thrust systems at the front of the eastern Southern Alps, which is the Alpine sector with the highest deformation rates.

The reconstruction of Pleistocene Glaciations indicates that the last two glacial maxima (i.e. MIS 6 and LGM) shaped the present-day landscape configuration and left their deposits in the end-moraine systems. However, traces of older glacial advances are scattered along the valleys and in the foothills. These deposits are normally cemented, weathered and located at higher elevations in respect to the more recent glacial advances pointing to uplift phases that lead to their preservations, especially in the Carnian and Julian prealps.

The study of the evolution of the south-eastern Alpine foreland revealed that each cold phase had a different configuration of the glaciers' network, producing a diverse pattern of the glaciofluvial megafans. The distribution of the main accumulation areas has changed from a glaciation to the other because of the ongoing uplift and the transfluence saddles were not always active. In particular, provenance lithological markers show that old Middle Pleistocene glacier networks were fed also by the inner sector of the Eastern Alps, whereas during the last two glacial maxima saw the maximum development of the local glaciers.

PLIOCENE AND PLEISTOCENE FLUVIAL RECORDS IN THE VIENNA BASIN AREA

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The objective of this talk is to give an overview of the current state of research on Pliocene and Quaternary deposits in the Vienna Basin located at the transition between the Eastern Alps and Western Carpathians. This basin formed by extension and subsidence since the Early Miocene and records a regression from marine and brackish environments of the Paratethys into a fluvially dominated environment that coincides with a regional uplift and a decrease in tectonic subsidence. The geological subsurface of the basin is exceptionally well documented during its marine and lacustrine phase, however the shift to a fluvially dominated environment from the Late Miocene/Early Pliocene onward causes a prominent gap in the sedimentary records. During the Pleistocene, fluvial sediment deposition was influenced by the growth and shrinking of the Alpine Ice sheets resulting in vastly changing hydraulic forces in glacials/interglacials. The area of the Vienna Basin is shaped by local and regional tectonics and climatically driven variations in sediment supply.

Research in the last years targeted fluvial deposits of the Danube on different fault blocks within the basin and at its eastern and western margins. Those fluvial deposits are preserved either in the form of sediments forming terrace staircases or within small local sub-basins. Dating efforts focus mainly on burial age determination using the cosmogenic radionuclide (CRN) pair of Aluminium-26 and Beryllium-10 because their temporal resolution is suitable for the expected time frame between 0.1 and 5 million years. Burial age of younger deposits was determined using luminescence dating on Feldspar.

Following a transect though the Central Vienna Basin, we present depositional ages from sediments on different fault blocks as well as from regions just outside the basin and infer uplift/incision rates relative to the base level of the Danube ranging between tens and a few hundred meters per million years. The talk will also briefly address the potential of cosmogenic radionuclide concentrations in older sediments to reconstruct landscape evolution where the geological record is incomplete. This approach could provide new insights into the timing and extent of erosion and sediment accumulation in the Vienna Basin and contribute to broader studies on Quaternary landscape development.

UPLIFT RATES OF THE WESTERN PANNONIAN BASIN AND ITS SURROUNDINGS QUANTIFIED USING COSMOGENIC NUCLIDE GEOCHRONOLOGY

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Formation of the Pannonian Basin started ~20 Ma ago, by the eastward retreat of the subducting slab beneath the Carpathian arc resulting in back-arc extension and extrusion of lithospheric blocks from the Alps and Dinarides. During Late Miocene and Pliocene, the isolated brackish Lake Pannon was gradually filled up by the deltaic then alluvial sediments. By the end of the Miocene a regional basin-scale inversion started and led to differential vertical deformation of the basin interior: the intra-basinal ranges started to uplift while the sub-basins show a record of continuous subsidence.

The timing and rate of vertical movements were addressed using the cosmogenic radionuclide (CRN) geochronology toolbox and at some locations it was combined with other geochronological and geomorphological data. Exposure and burial ages of fluvial terraces of the Danube River (Vienna Basin, Transdanubian Range), burial ages of cave sediments (Eastern Alps, Mecsek Mts), wind-shaped landforms (Transdanubian Range), CRN denudation rates (Mecsek) were used to infer data relevant to quantify the local uplift rates. These data were combined and compared with literature data to obtain a regional picture on the pattern and magnitude of Pliocene to Quaternary vertical deformation rates in and around the Western Pannonian Basin. The lowest uplift rates were estimated in the Mecsek Mountains with values remaining below ~30 m/Ma. The long-term uplift rates in the axial zone of Transdanubian Range and intra-basinal hills in the Vienna Basin are usually below or around ~50 m/Ma and mostly remain below 100 m/Ma. In the Eastern Alps the uplift rates show an increasing trend starting with values of ~100 m/Ma at the Basin margin to ~300 m/Ma in the more distant inner ranges (Figure 1).

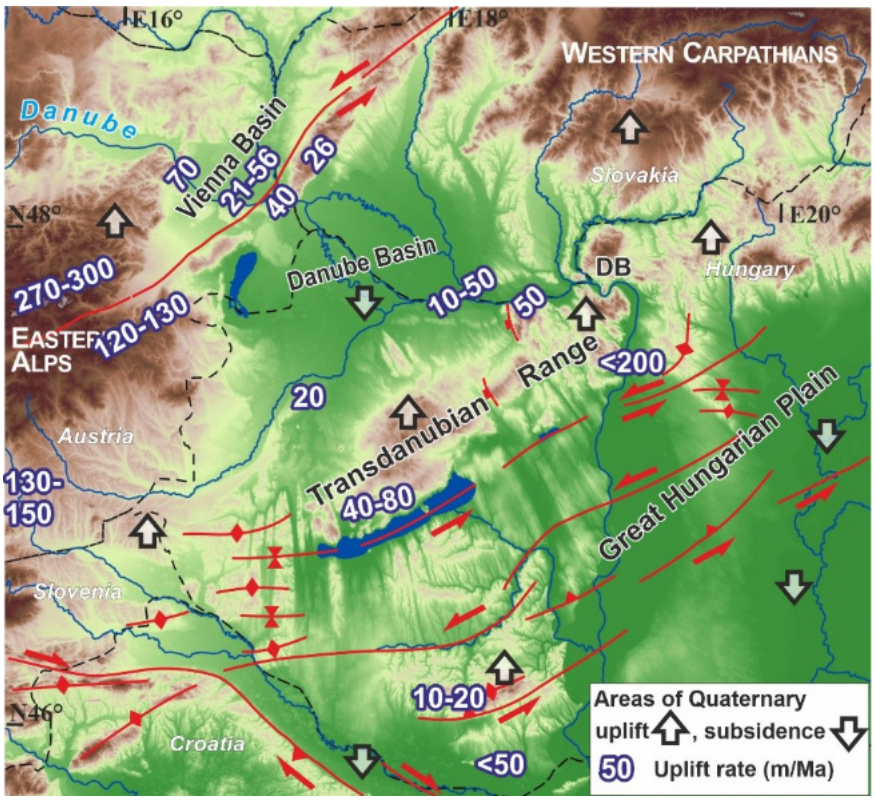


Figure 1: Quaternary uplift rates (without uncertainties) in and around the Western Pannonian Basin.

ABSTRACTS

SOUTHICE: DECIPHERING THE MIDDLE PLEISTOCENE GLACIAL HISTORY OF THE EUROPEAN SOUTHERN ALPINE FORELAND

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Despite detailed mapping of extensive glacial landforms and deposits, the timing of pre-Last Glacial Maximum (LGM) glaciations in the southern Alpine foreland remains largely unresolved. Previous research relied primarily on geomorphological and sedimentological interpretations of these archives, with little to no numerical dating (Preusser et al., 2011; Schlüchter et al., 2020; Ivy-Ochs et al., 2022; Monegato et al., 2023). In contrast, the Swiss Alpine foreland in the north has a well-established pre-Last Glacial Maximum chronostratigraphy, documenting 13 glacier advances during the Early and Middle Pleistocene. Among these, only two Middle Pleistocene glaciations exceeded the extent of the LGM (Figure 1) in the Swiss Alpine foreland. These are the Möhlin glaciation, which marks the most extensive glaciation, and the Beringen glaciation (penultimate), which is attributed to Marine Isotope Stage 6 (MIS; Lisiecki and Raymo, 2005) (Dieleman et al., 2026 and references therein).

SouthIce will establish the first numerical glacial chronology for the most extensive and penultimate glaciations (and other Middle Pleistocene glaciations) in the southern Alpine foreland, focusing on the Ivrea and Verbano morainic amphitheaters (Figure 1), where well preserved sedimentary archives suggest up to seven pre-LGM glacier advances (Zuccoli 2000; Gianotti et al., 2008; 2015; Bini et al., 2014). SouthIce will apply cosmogenic nuclide dating ($^{10}Be/^{26}Al$, $^{41}Ca/^{36}Cl$, and $^{41}Ca/^{10}Be$), complemented by luminescence dating and paleomagnetic analysis, to build the first high-resolution temporal framework for the southern Alps. In addition, the project will pioneer ^{41}Ca-based burial dating us-

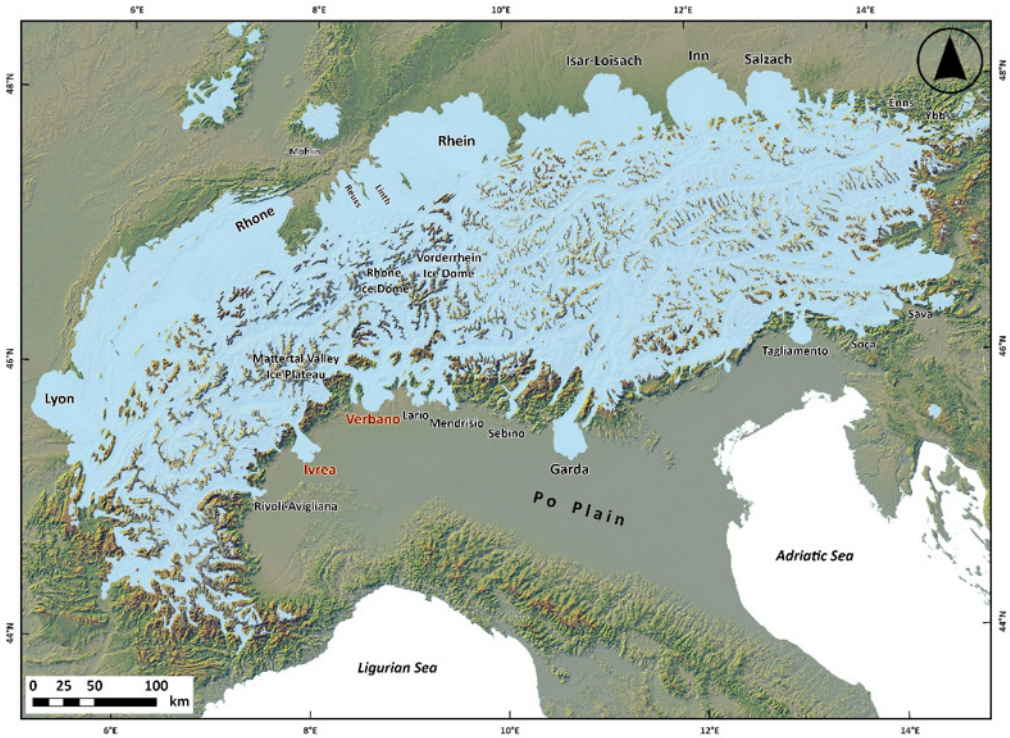


Figure 1: The maximum extent of Alpine glaciation during the LGM (updated after Ehlers et al. 2011). The research sites are the Ivrea and Verbano amphitheaters.

ing Atom-Trap Trace Analysis (ATTA), offering a potential breakthrough for <300 ka chronologies. Taken together, these advances will for the first time enable a robust, multi-method reconstruction of Middle Pleistocene glacier advances in the southern Alps. The new chronological framework will then be integrated with glacier modelling to assess the evolution of glacier dynamics under different climate forcings and different Alpine topographies.

REFERENCES

Bini, A., Sciunnach, D., Bersezio, R., Scardia, G., Tomasi, F., 2014. Carta Geologica d'Italia alla scala 1:50.000. Foglio 096 - Seregno. Istituto Superiore per la Protezione e la Ricerca Ambientale, Servizio Geologico d'Italia, Organo Cartografico dello Stato.

Dieleman C, Christl M, Vockenhuber C, Gautschi P, Schlunegger F, Akçar N (2026) Relief increase in the Swiss northern Alpine Foreland after the Mid-Pleistocene Transition. Geomorphology 492: 110060. https://doi.org/10.1016/ j.geomorph.2025.110060.

Ehlers, J., Gibbard, P.L., Hughes, P.D., 2011. Quaternary Glaciations - Extent and Chronology, in: Ehlers, J., Gibbard, P.L., Hughes, P.D. (Eds.), Developments in Quaternary Sciences. Elsevier.

Gianotti, F., Forno, M. G., Ivy-Ochs, S., Monegato, G., Pini, R., Ravazzi, C., 2015. Stratigraphy of the Ivrea morainic Amphitheatre (NW Italy): an updated synthesis. Alpine and Mediterranean Quaternary 28, 29-58.

Gianotti, F., Forno, M.G., Ivy-Ochs, S., Kubik, P.W., 2008. New chronological and stratigraphical data on the Ivrea amphitheatre (Piedmont, NW Italy). Quaternary International 190, 123-135.

Ivy-Ochs, S., Monegato, G., Reitner, J.M., 2022. Chapter 39 - The Alps: glacial landforms prior to the Last Glacial Maximum, in: Palacios, D., Hughes, P.D., García-Ruiz, J.M., Andrés, N. (Eds.), European Glacial Landscapes. Elsevier, pp. 283-294.

Lisiecki, L.E., Raymo, M.E., 2005. A Pliocene-Pleistocene stack of 57 globally distributed benthic delta O-18 records (vol 20, art no PA1003, 2005). Paleoceanography 20.

Monegato, G., Gianotti, F., Ivy-Ochs, S., Reitner, J. M., Scardia, G., Akçar, N., 2023. The Early and Middle Pleistocene glaciations in the Alps. Alpine and Mediterranean Quaternary 36, 127-148.

Preusser, F., Graf, H.R., Keller, O., Krayss, E., Schlüchter, C., 2011. Quaternary glaciation history of northern Switzerland. Quaternary Science Journal (Eiszeitalter und Gegenwart) 60, 282-305.

Schlüchter, C., Akçar, N., Ivy-Ochs, S., 2020. The Quaternary Period in Switzerland, in: Reynard, E. (Ed.), Landscapes and Landforms of Switzerland. Springer International Publishing, Cham, pp. 47-69.

Zuccoli, L., 2000. Geologia dei Pianalti di Castelseprio e Tradate (Provincia di Varese). Il Quaternario (Italian Journal of Quaternary Sciences) 13, 57-80.

STRUCTURE AND QUATERNARY ACTIVITY OF THE SAVA FAULT NEAR THE VILLAGE OF GOZD (SLOVENIA)

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Sava Fault is a major NW–SE striking fault of the Periadriatic Fault System in the south-eastern Alps, active since at least the last 6 Ma (Vrabec, 2001; Jamšek Rupnik, 2013; Jamšek Rupnik et al., 2024). Despite its significant seismogenic potential, its Quaternary activity and seismic history remain poorly constrained. This study investigates the structure and Quaternary evolution of the Sava Fault near the village of Gozd above Golnik, Slovenia, and evaluates the suitability of the site for future palaeoseismological investigations.

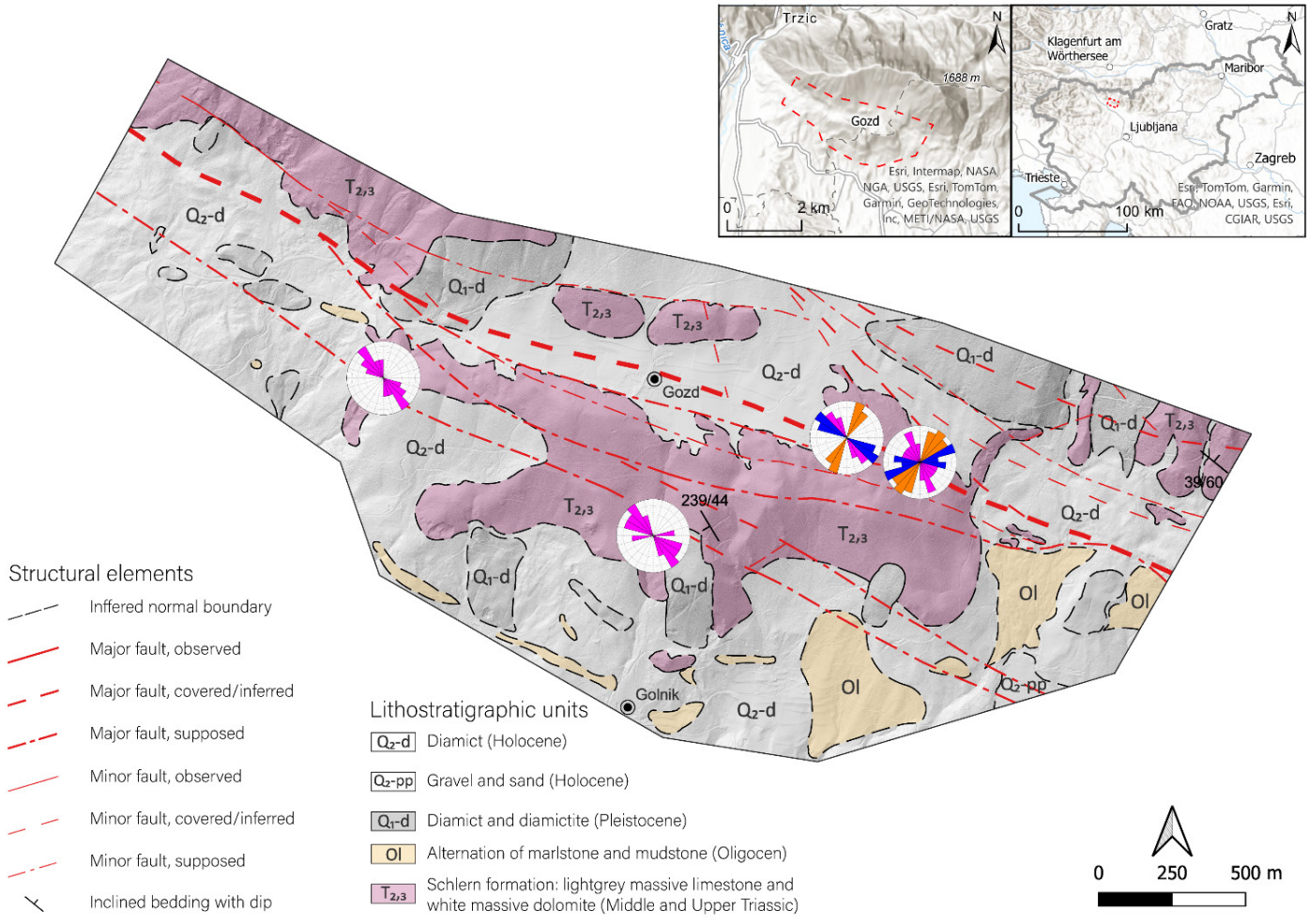


Figure 1: Structural-geological map of the Gozd village area with rose diagram representations. The base layer used is a LiDAR-derived DEM (ARSO, 2014), inset map with location of the study area using ESRI World Terrain Base.

Detailed structural-geological mapping, geomorphic analysis of high-resolution photogrammetric and LiDAR digital elevation models, electrical resistivity tomography, sedimentological logging, and radiocarbon dating were applied to characterize the fault zone and associated Quaternary deposits. The mapped units include Triassic carbonates, Oligocene clastic and volcaniclastic rocks, Pleistocene diamictons and diamictites, and Holocene alluvial and colluvial sediments. Geomorphic analysis of various digital elevation model visualisations shows that the village of Gozd lies on a levelled surface covered by Quaternary sediments deposited as alluvial fans. Electrical resistivity tomography revealed

the fault as a subvertical low resistivity anomaly and indicated deformation of Quaternary sediments, demonstrating its Quaternary activity. Sedimentary units exposed in the excavation pit and radiocarbon dating of charcoal (~4–42 ka) indicate predominantly slow accumulation of fine-grained colluvium interrupted by a single high-energy debris-flow event in the distal part of the fan. Synthesis of the data implies that the village of Gozd lies on a large structural landslide, likely triggered in the Early to Middle Pleistocene (about 1 Ma to 500 ka) and since then offset for 200-500 m along the fault.

The results provide new insights into the interaction between tectonic and gravitational processes along the Sava Fault and establish a basis for future palaeoseismological research in the area.

REFERENCES

Jamšek Rupnik, P., 2013. Geomorphological evidence of active tectonics in the Ljubljana Basin. PhD Thesis, University of Ljubljana, Ljubljana, Slovenia, pp. 1-214.

Jamšek Rupnik, P., Atanackov, J., Horn, B., Mušič, B., Zajc, M., Grützner, C., Ustaszewski, K., Tsukamoto, S., Novak, M., Milanič, B., Markelj, A., Ivančič, K., Novak, A., Jež, J., Žebre, M., Bavec, M., Vrabec, M., 2024. Revealing subtle active tectonic deformation: integrating lidar, photogrammetry, field mapping, and geophysical surveys to assess the Late Quaternary activity of the Sava Fault (Southern Alps, Slovenia). Remote sensing 16, 1490. https://doi.org/10.3390/rs16091490

Vrabec, M., 2001. Strukturna analiza cone Savskega preloma med Trstenikom in Stahovico. PhD Thesis, University of Ljubljana, Ljubljana, Slovenia, pp. 1-94.

THE IMPORTANCE OF NON-POLLEN PALYNOMORPHS (NPPS) IN PALAEOENVIRONMENTAL RECONSTRUCTION: EVIDENCE FROM HOLOCENE LAKES OF THE EASTERN ADRIATIC

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Non-pollen palynomorphs (NPPs) are increasingly recognized as valuable proxies in palaeoenvironmental research because they provide information that complements traditional pollen-based reconstructions. By recording changes in aquatic ecosystems, hydrological conditions, and environmental disturbances, NPPs allow for a more comprehensive understanding of past environmental dynamics. Their integration into multiproxy studies has significantly improved the resolution of palaeoecological reconstructions, particularly in lacustrine settings.

Our research focuses on the analysis of NPPs from Holocene lake sediments of the eastern Adriatic karst region, with particular emphasis on Cyanobacteria, Chlorophyta, and Dinoflagellata. These aquatic microfossils provide direct evidence of past limnological conditions and environmental changes within lake ecosystems. Cyanobacterial remains are useful indicators of nutrient availability, water-column stability, and eutrophication processes, while Chlorophyta, including various green algae, reflect changes in lake productivity, water levels, and ecological status. Dinoflagellate cysts contribute additional information on hydrological variability, salinity fluctuations, and aquatic ecosystem dynamics. The present study combines evidence from Lake Vrana, where NPPs contributed to the interpretation of sapropel S1 formation and changing limnological conditions (Bakrač et al., 2018). In the Bokanjačko blato karst polje, NPPs complemented pollen analyses by providing additional evidence for shallow karst lake (Ilijanić et al., 2018). In the Baćina Lakes, detailed NPP and palynofacies analyses provide new insights into Holocene environmental change (Bakrač et al., under review). These signals often reveal environmental changes that are not clearly visible in pollen records alone, highlighting the importance of NPPs as valuable palaeoenvironmental indicators.

Overall, the results from Holocene lake records, including Lake Vrana near Biograd na Moru, Bokanjačko blato and the Baćina Lakes demonstrate the importance of NPPs in palaeoecological investigations in the eastern Adriatic. The integration of NPPs with pollen and other palaeoenvironmental indicators strengthens multiproxy reconstructions, enabling a more detailed and reliable interpretation of Holocene environmental change.

This work was supported by the Croatian Science Foundation under the project number HRZZ-IP-2024-05-1687 (Non-pollen palynomorphs and palynofacies in paleoenvironmental reconstruction, Non-Poll).

REFERENCES

Bakrač, K., Ilijanić, N., Miko, S., Hasan, O., 2018. Evidence of sapropel S1 formation from Holocene lacustrine sequences in Lake Vrana in Dalmatia (Croatia). Quaternary International 494, 5-18. https://doi.org/10.1016/j.quaint.2018.06.010

Bakrač, K., Hinkelman, J., Ilijanić, N., Hasan, O., Šparica-Miko, M., Miko, S., 2026, Non-Pollen Palynomorphs (NPPs) and palynofacies of lake sediments from the Baćina Lakes (Croatia) as indicators of Holocene paleoenvironmental changes, Review of palaeobotany and palynology, under review

Ilijanić, N., Miko, S., Hasan, O., Bakrač, K., 2018. Holocene environmental record from lake sediments in the Bokanjačko blato karst polje (Dalmatia, Croatia). Quaternary International, 494, 66-79. https://doi.org/10.1016/j.quaint.2018.01.037

AN EARLY-HOLOCENE CATASTROPHIC ALLUVIAL PHASE OF TORRE RIVER (NE ITALY)

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Torre River is currently a major tributary of Isonzo (Soča) and its catchment extends for 925 km^2 in the Julian Prealps but, during the LGM (ca. 29-19 ka cal. BP), it was an outwash stream directly fed by the front of the Tagliamento glacier, forming its own alluvial megafan (Fontana et al., 2008). A typical braided pattern characterizes the apical portion of the LGM megafan, but in this sector, west of the present Torre River, the analyses of aerial photos, satellite images and LiDAR-derived DEM allowed to recognize a swarm of shallow and small palaeochannels (10 to 30 m wide). They discontinuously cover the older braided traces between Udine and Palmanova and show a rather straight direction, even if they often end in multiple small channels with a kind of crevasse-splay geometry (Fontana et al., 2024).

These channel traces correspond to fine gravels that laterally are associated with yellowish silt deposits, discontinuously mantling the LGM surface with a maximum thickness of 1 to 2 m.

Based on radiocarbon dates and to the distribution of prehistoric archaeological sites (Pessina et al., 2019), this sedimentary phase occurred after 8 ka BCE but before 5.5 ka BCE, and it is likely related to a single and catastrophic Torre River flood, or to a few extreme events. Although the causes and duration of this phase are still under investigation, it might reflect the local response of the Torre River catchment to a meteorological/climate-related event.

REFERENCES

Fontana, A., Mozzi, P., Bondesan A., 2008. Alluvial megafans in the Venetian-Friulian Plain (north-eastern Italy): Evidence of sedimentary and erosive phases during Late Pleistocene and Holocene. Quaternary International 189, 71-90.

Fontana A., Monegato G., Chiarini V., Poli M.E., 2024. L'alta Pianura Friulana centrale. In Fontana A. (Ed.), La pianura del Friuli Venezia Giulia. Geomorfologia e Geologia del Quaternario. Trieste, Regione Autonoma Friuli Venezia Giulia - Servizio Geologico, pp. 69-97.

Pessina, A., Fiappo, G.C., Rottoli, M., 2019. Il sito Neolitico di Pavia di Udine: una sintesi delle ricerche. Gortania, 41, 61-91.

PALEOPOLJES AND PALEOLAKES IN THE KVARNER AREA DURING LATE PLEISTOCENE (NE ADRIATIC SEA)

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The Kvarner area is located in the north-western part of the Adriatic Sea. Present-day relief, in terms of the present-day islands and marine basins, has generally changed slightly since the Miocene. Sea level oscillations in the Adriatic Sea during the Late Pleistocene and Holocene caused considerable paleogeographic changes on a highly rugged karst relief. The transition from a marine environment (similar to today's conditions) to a terrestrial/freshwater/lacustrine environment caused dramatic changes in the Kvarner area. The bottoms of the Rijeka Bay, the Vinodol-Velebit Channel in the northwest, and the central and south-eastern part of the Velebit Channel gradually dried up, while sea level oscillated between -50 m and -80 m (70 - 30 ka B.P.).

The complete regression of the sea from Rijeka Bay and the Vinodol-Velebit Channel occurred during the Last Glacial Maximum (30-20 ka B.P.) when the sea level fluctuated between -100 and -120 m. The elevations of today's Cres-Lošinj-Premuda-Ist island chain prevented sediment transport and the filling of depressions in the Kvarner area from the paleo-Po flood plain. As a result, today's Kvarnerić basin is significantly deeper than the open Adriatic Sea to the west. During the Last Glacial Maximum, considerable amounts of surface and groundwater flowed into the Rijeka Bay and Vinodol-Velebit Channel. The water could only flow from these depressions into the deeper Kvarnerić basin. The paleolake was formed in the deeper north-western part, around which the largest polje extended, similar to other poljes in the Dinarides. There is a possibility that water from the paleolake flowed through sinkholes along the eastern coast of Cres Island, or between Ilovik and Premuda islands, or also through a deep, partly submerged canyon between Škarda and Ist islands.

During the rapid sea level rise between 19 and 7 ka B.P., the sea flooded the deep depression in the Kvarner area and then invaded the marginal basins. Since the stagnation of the sea level at 7 ka B.P., considerable sedimentation occurred in limited areas in front of the river and torrent mouths in Kvarner, Rijeka Bay, and the Vinodol-Velebit Channel. In contrast, the relief of the bottom of the present-day Kvarnerić remained slightly altered during the Late Pleistocene and Holocene, due to scarce input of particulate material. Therefore, this area and parts of other basins in Kvarner are a fine example of a drowned karst relief. Kvarnerić is the largest paleopolje in the Dinarides, with an area of approximately 880 km². The entire Kvarner area, and the Kvarnerić paleopolje in particular, are promising sites for submarine archaeology from the Middle and Upper Paleolithic periods.

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REFERENCES

Benac, Č., Bočić, N., Juračić, M. 2022. Geomorphologic changes of the Velebit Channel during Late Pleistocene and Holocene (NE Adriatic). Geografia Física e Dinâmica Quaternária, 45, 41-54. DOI 10.4461/ GFDQ.2022.45.3

Benac, Č., Bočić, N., Juračić, M. 2026. Late Pleistocene-Holocene geomorphologic evolution of the Kvarner area (northern Adriatic, Croatia), Quaternary International, 771(110296), 1-17. https://doi.org/10.1016/j.quaint.2026.110296

KARST GEOMORPHOLOGY OF THE CENTRAL PART OF THE PAPUK NATURE PARK (CROATIA)

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Karst covers approximately 50% of Croatia's territory, with most of this area forming part of the extensive Dinaric Karst belt. However, significant karst areas also occur outside this region, including Mt. Papuk, one of the Slavonian mountains in the Pannonian part of Croatia. Papuk is protected as a Nature Park and UNESCO Global Geopark. Its central, highest part is composed of Triassic carbonate rocks and exhibits well-developed karst features.

This study investigates the geomorphology of the central karst area of Papuk, focusing on landforms, geomorphic processes, and their spatial and relative temporal relationships to improve understanding of the evolution of this isolated karst landscape.

The research was primarily based on a high-resolution (1 × 1 m) digital elevation model (DEM) derived from airborne LiDAR surveys conducted across Croatia and provided by the State Geodetic Administration. The study comprised several stages. First, a general morphometric analysis of the terrain was performed. Second, a doline inventory was produced using two complementary methods: the DEM filling approach (Fill-DEM) and visual identification and interpretation (VII) based on multiple DEM derivatives. Third, the (palaeo)hydrographic network, including active, dry, and relict valleys, was mapped using the VII method.

The spatial and morphometric analyses provided new insights into the characteristics, morphometry, spatial distribution, and typology of dolines, as well as the distribution and characteristics of active, dry, and relict components of the hydrographic network. Analysis of the spatial relationships between dolines and the hydrographic network revealed the relative importance of karst and fluvial processes in shaping the landscape.

The results enabled the reconstruction of the main phases of karst landscape evolution in central Papuk, providing a valuable framework for future geochronological research. Furthermore, the findings contribute to the assessment of Papuk's geodiversity and geoheritage, particularly its geomorphological component, supporting future conservation and management efforts.

REFERENCES

Jamičić, D., 1995. The Role of Sinistral Strike-Slip Faults in the Formation of the Structural Fabric of the Slavonian Mts. (Eastern Croatia). Geologia Croatica 48/2, 155-160

Pamić, J., Radonić, G., Pavić, G., 2003. Geological guide through Papuk Nature Park. [in Croatian]. JU PP Papuk, Velika, pp. 1-67.

Stroj, A., Kuhta, M., 2007. Hydrogeological explorations of Mt. Papuk karst aquifer, NE Croatia. 15th International Karstological school "Classical Karst" – Management of transboundary karst aquifers, Postojna, Slovenia, 18.-22. 06. 2007., Karst Research Institute ZRC SAZU, Collection of short scientific papers, Postojna.

STATISTICAL LEARNING AS AN EMERGING TOOL FOR PROVENANCE DETERMINATION

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This study demonstrates how statistical learning (Hastie et al., 2017) can enhance provenance determination by exploiting multivariate geochemical and isotopic datasets, supported by traditional petrological methods. While the approach was initially developed for determining the provenance of historical stone artefacts (Brajkovič and Koselj, 2025), advanced statistical learning methods offer wide applicability for tracing provenance in complex sedimentary systems. The study focuses on evaluating the performance of multiple statistical learning methods—linear discriminant analysis (LDA), decision trees (DTs), random forests (RFs), and support vector machines (SVMs)—in determining provenance.

Rather than relying on a single-method classification, an integrated workflow leveraging bootstrap aggregation (bagging) principles across diverse statistical methods was realized. The results show that higher consensus among these aggregated estimators corresponds to more reliable provenance assignments. Integrating bagged consensus outputs with petrographic and paleontological evidence further strengthens provenance interpretations. The highest predictive performance was achieved by the radial-basis SVMs optimised on principal components, which achieved a classification accuracy of 87%.

By combining geological expertise with statistical learning, this approach enhances reproducibility, quantifies uncertainty, and improves the resolution of provenance signals in heterogeneous depositional systems. The proposed interdisciplinary workflow provides a transferable framework for provenance studies also in Quaternary archives.

REFERENCES

Brajkovič, R., & Koselj, K. (2025). Statistical learning improves classification of limestone provenance. *Heritage*, *8*(11), Article 464. https://doi.org/10.3390/heritage8110464

Hastie, T.; Tibshirani, R.; Friedman, J. The Elements of Statistical Learning: Data Mining, Inference, and Prediction, 2nd ed.; Springer: New York, NY, USA, 2017; Available online: https://hastie.su.domains/ElemStatLearn (accessed on 14 August 2025).

GEOCHRONOLGY AND FRESHWATER RESERVOIR EFFECT OF TUFA BARRIERS IN ZRMANJA RIVER VALLEY

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Tufa deposits in the Dinarides have attracted increasing scientific attention in recent years (Veverec et al., 2018; Marić et al., 2020; Hasan, 2017; Hasan et al., 2020; Barešić et al., 2021; Smrkulj et al., 2024). The Zrmanja river is a typical fluviokarstic river characterized by abundant tufa deposits, whose geomorphological evolution and chronology have remained largely unexplored.

Although reservoir effects are well documented in marine environments (Reimer and McCormac, 2002; Faivre et al., 2015, 2019), they also occur in freshwater systems. In such settings, they are commonly associated with hard waters enriched in dissolved ancient carbonates, which may produce anomalously old radiocarbon ages. Consequently, ^{14}C ages in tufa deposits are subject to the freshwater reservoir effect (FRE), representing the main source of uncertainty in radiocarbon dating of tufa carbonates (Srdoč et al., 1980). Accurate interpretation therefore requires consideration of tufa-specific carbon dynamics.

In this study, fossil tufa was sampled from a well-preserved Gazin kuk barrier, and downstream valley side tufa fragments related to Potok barrier located in the middle reaches of Zrmanja river. High-resolution radiocarbon dating and stable isotope analyses ($\delta^{13}C$ and $\delta^{18}O$) were used to reconstruct the timing and environmental controls of tufa deposition.

The results indicate that the 12 m high Gazin kuk barrier developed during the Middle and Late Holocene, between ~5500 and ~1300 cal BP. The obtained chronology reveals alternating phases of tufa accumulation and erosion. Periods of enhanced tufa deposition and barrier growth correspond to prolonged warm climatic conditions, whereas erosion phases are associated with rapid transitions from warm to cooler and wetter conditions. Given the scarcity of long, well-dated tufa records in the region, the Gazin kuk sequence represents a unique Middle–Late Holocene palaeoenvironmental archive for the Outer Dinarides providing valuable insights into the interactions between climate variability, river dynamics, and tufa development.



Figure 1: Gazin kuk tufa barrier.

REFERENCES

Barešić, J., Faivre, S., Sironić, A., Borković, D., Lovrenčić Mikelić, I., Drysdale, R.N., Krajcar Bronić, I., 2021. The Potential of Tufa as a Tool for Paleoenvironmental Research—A Study of Tufa from the Zrmanja River Canyon, Croatia. Geosciences 11, 376.

Faivre, S., Bakran-Petricioli, T., Barešić, J., Horvatinčić, N., 2015: New data on the marine radiocarbon reservoir effect in the Eastern Adriatic based on pre-bomb marine organisms from the intertidal zone and shallow sea. Radiocarbon, Vol 57, 4, 527–538.

Faivre, S., Bakran-Petricioli, T., Barešić, J., Morhange, C., Borković, D., 2019a. Marine radiocarbon reservoir age of the coralline intertidal alga Lithophyllum byssoides in the Mediterranean, Quaternary Geochronology, 51, 15–23; doi.org/10.1016/j.quageo.2018.12.002

Hasan, O., 2017. Paleookolišna rekonstrukcija slivova Karinskoga mora, Novigradskoga mora i Velebitskoga kanala tijekom holocena, (Holocene palaeo-environmental reconstruction of the Karin sea, Novigrad sea and Velebit channel catchments), PhD thesis, University of Zagreb, pp. 564

Hasan, O., Miko, S., Brunović, D., Papatheodorou, G., Christodolou, D., Ilijanić, N., Geraga, M., 2020. Geomorphology of Canyon Outlets in Zrmanja River Estuary and Its Effect on the Holocene Flooding of Semi-enclosed Basins (the Novigrad and Karin Seas, Eastern Adriatic). Water 12, 2807. https://doi.org/10.3390/w12102807.

Marić, I., Šiljeg, A., Cukrov, N., Roland, V., Domazetović, F., 2020. How fast does tufa grow? Very high-resolution measurement of the tufa growth rate on artificial substrates by the development of a contactless image-based modelling device. Earth Surface Processes and Landforms, 45 (10), 2331–2349. DOI: 10.1002/esp.4883

Reimer, P.J., Mc Cormac, F.G., 2002. Marine radiocarbon reservoir corrections for the Mediterranean and Aegean seas. Radiocarbon 44 (1), 159–166.

Smrkulj, N., Hasan, O., Brunović, D., Miko, S., Ilijanić, N., 2024. Holocene palaeoenvironmental development of Prokljan Lake (Krka River, Croatia): Evolution from a calcareous tufa barrier system to a karst estuary. Mar. Geol. 476, 107370. https://doi.org/10.1016/j.margeo.2024.107370.

Srdoč, D., Obelić, B., Horvatinčić, N., Sliepčević, A., 1980. Radiocarbon dating of calcereous tufa: How reliable data can we expect. Radiocarbon, 22, 858–862.

Veverec, I., Faivre, S., Barešić, J., Buzjak, N., Horvatinčić, N., 2018. Evolucija fosilne sedrene barijere Gazin kuk u rijeci Zrmanji (Hrvatska). In: Zbornik Sažetaka Završne Radionice; projekt HRZZ-IP-2013-11-1623 Reconstruction of the Quaternary environment in Croatia using isotopemethods—REQUENCRIM, 2014–2018; Institut Ruđer Bošković, Zagreb, Croatia, 2018; p. 33. (In Croatian)

PLEISTOCENE MARINE HIGHSTANDS IN THE NORTHERN ADRIATIC SEA

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The deposits of the marine transgressions occurred during the Pleistocene represent some of the major markers for chrono-stratigraphic correlations along the Adriatic. In particular, the sediments related to the marine highstand of the Last Interglacial (i.e. MIS 5.5, 132-116 ka), when sea level arrived few meters above the present Mean Sea Level (MSL), have been recognized as key features for reconstructing the palaeoenvironmental evolution but also the geodynamic trend (e.g. Cerrone et al., 2021; Novellino et al., 2024). Several new long stratigraphic cores were recently carried out along the coast between the Venice Lagoon and Istria, allowing to identify also the coastal deposits of the MIS 7, between -70 and -100 m MSL. Moreover, the new investigations highlight the occurrence of lagoon sediments above the coastal unit formerly attributed to MIS 5.5. The detailed facies analysis rather indicates that these upper lagoon deposits, found at an elevation between -32 and -60 m MSL, may refer to the MIS 5.3 (105-98 ka), when the available global sea-level curves hypothesize a maximum highstand around ca. -20 m MSL (e.g. Lisiecky and Stern, 2016). The new discoveries rise several issues about the reliability of global reconstructions over large sectors of northern Mediterranean.

REFERENCES

Cerrone, C., Vacchi, M., Fontana, A., Rovere, A., 2021. Last Interglacial sea-level proxies in the western Mediterranean, Earth System Science Data, 13, 4485–4527. https://doi.org/10.5194/essd-13-4485-2021

Lisiecki, L.E., Stern, J.V., 2016. Regional and global benthic d18O stacks for the last glacial cycle. Paleoceanography 31, 1-27. http://dx.doi.org/10.1002/2016PA003002

Novellino, M.D., Fontana, A., Bertuletti, P., Furlanetto, G., Pini, R., Felja, I., Juračić, M., Ravazzi, C., 2025. Vegetation and climate history during the Last Interglacial on the Istrian coast (Northern Adriatic Sea), Palaeogeography, Palaeoclimatology, Palaeoecology, 659, 112671. https://doi.org/10.1016/j.palaeo.2024.112671

QUATERNARY-FILL BASEMENT MODELS OF THE LJUBLJANA BASIN

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Geological models of the Quaternary-fill basements of the wider Ljubljana Basin were originally developed through several research projects for hydrogeological and geothermal studies of urban and suburban environments. Updates to existing geological models are usually prompted either by increasing uncertainties in legacy numerical models or by extensive drilling campaigns that provide new datasets.

The Ljubljana Basin is an Alpine intramontane basin located on the junction of the Southern Alps and External Dinarides with a complex palaeogeographic and geotectonic evolution reflecting the intricate history of the Alpine orogenic cycle. In addition to several extensional phases clearly preserved in Mesozoic units, the area underwent several compressional phases in the Cenozoic. Neotectonic conditions and Quaternary sedimentary fill clearly illustrate a complex interplay between evolving regional stress fields and pre-existing palaeogeographic and geotectonic elements.

As well as consideration of basic stratigraphic and structural constraints, such as the law of superposition and law of lateral continuity, understanding the regional tectono-stratigraphic evolution is often critical for geological modelling of Quaternary-fill basins, whether for hydrogeological and geothermal research or general exploitation. Such knowledge and regional geological conceptualization can become especially important when the input datasets have an unfavourable spatial distribution and unquantified uncertainties.

Beyond direct application for hydrogeological and geothermal exploration, simple geological models are becoming an increasingly important step in planning basic geological studies, as they often clearly indicate areas of increased geological uncertainty and discrepancies in existing interpretations. Spatial analysis and 3D visualizations of modelled horizons and digital elevation models can be performed in high detail using QGIS 3D Map View or various EGDI solutions.

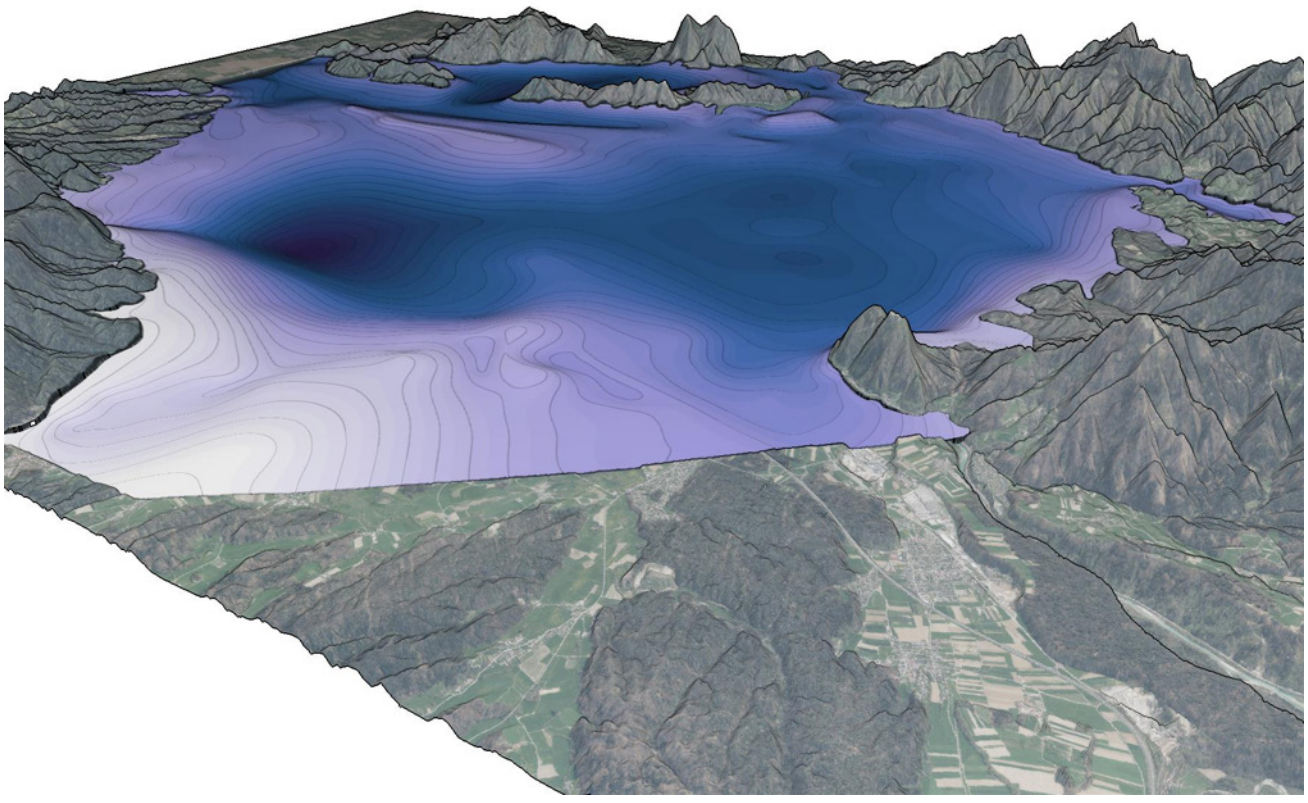


Figure 1: Model of the Quaternary-fill basement at the Kranj-Sora field (looking southeast, triple vertical exaggeration).

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REFERENCES

Jamšek Rupnik, P., Atanackov, J., Horn, B., Mušič, Br., Zajc, M., Grützner, C., Ustaszewski, K., Tsukamoto, S., Novak, M., Milanič, B., Markelj, A., Ivančič, K., Novak, A., Jež, J., Žebre, M., Bavec, M., Vrabec, M. 2024. Revealing subtle active tectonic deformation: integrating lidar, photogrammetry, field mapping, and geophysical surveys to assess the Late Quaternary activity of the Sava Fault (Southern Alps, Slovenia). Remote sensing, 16/9: 33 p. https://doi.org/10.3390/rs16091490

Janža, M., Lapanje, A., Šram, D., Rajver, D., Novak, M. 2017. Research of the geological and geothermal conditions for the assessment of the shallow geothermal potential in the area of Ljubljana, Slovenia = Raziskave geoloških in geotermalnih razmer za oceno potenciala plitve geotermalne energije na območju Ljubljane, Slovenija. Geologija. 60/ 2, p. 309–327. https://doi.org/10.5474/geologija.2017.022

GEOLOGICAL MODELLING OF QUATERNARY BASINS IN SLOVENIA

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Geological modelling of Quaternary basins in Slovenia is an ongoing and continuously evolving task, primarily associated with the management of groundwater and geothermal resources. Quaternary fills represent a crucial and, in a hydrogeological sense, the most reliable source of drinking water. However, these groundwater resources are highly dependent on climatic conditions and are vulnerable to over-exploitation and nitrate pollution. In the era of climate change and increasing environmental pressure, a robust management and protection system is of utmost importance. An additional challenge is posed by the rapidly expanding need for heat extraction and Underground Thermal Energy Storage in shallow geothermal plays.

Successful management of these natural resources requires an integrated approach. In most cases, the results of groundwater storage, groundwater flow, and pollutant migration studies are based on generalised conceptual hydrogeological models. Groundwater head, aquifer depth, permeability, geothermal parameters, and boundary conditions are determined by the sedimentological and structural properties of the Quaternary basin infill.

Establishing discrete 2.5D models of selected stratigraphic horizons, with a focus on Quaternary fill basement, is the primary step in geological modelling of Quaternary basins and their aquifers. Due to sedimentological complexity, vertical and horizontal heterogeneities are complex, and often nearly impossible to determine explicitly. Therefore, we are making extensive efforts to produce a reliable digital Geological Database that will enable systematic and objective quantification of parameters and uncertainties of modelled hydrostratigraphic horizons. These efforts are based on semi-automated and AI-based digitisation of historic borehole stratigraphic columns, as well as the development of geological ontologies.

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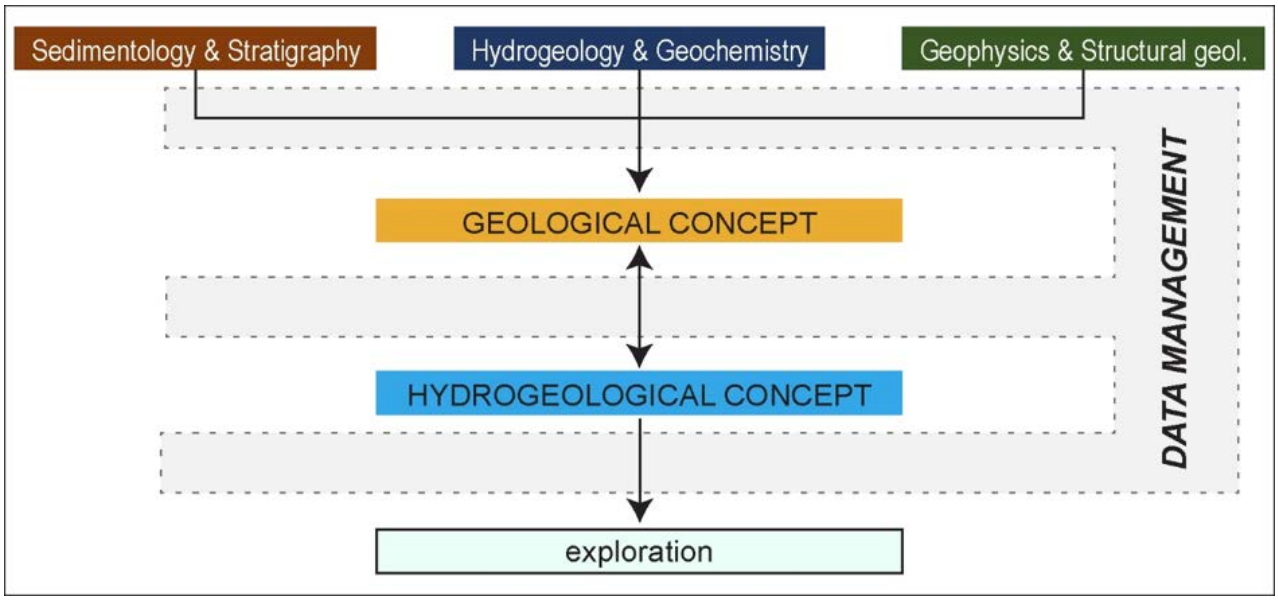


Figure 1: Workflow scheme for research and exploration of natural resources in Quaternary basins.

REFERENCES

Adrinek, S., Janža, M., Singh, R. M. 2024. Influence of geology, hydrogeology, and climate on ground source heat pump distribution in Slovenia and selected European countries. Resources 13/3, 17 p. https://doi.org/10.3390/resources13030039

Šram, D., Brenčič, M., Lapanje, A., Janža, M. 2012. Perched aquifers spatial model: a case study for Ljubljansko polje (central Slovenia). Geologija 55/1, 107–116. https://doi.org/10.5474/geologija.2012.008

INVESTIGATING GLACIGENIC DEPOSITS AT MOST NA SOČI (NW SLOVENIA): PRELIMINARY RESULTS FROM ERT AND BOREHOLE DATA

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The Soča glacier, located in the Julian Alps (NW Slovenia), reached its maximum extent during the Last Glacial Maximum (LGM), with its southernmost preserved margin at Most na Soči. Glacial deposits in this area mark the largest advance of the Soča glacier and provide key evidence of Alpine glaciation at its southern limit. The proximity of the Idrija Fault Zone adds further geological significance to the site, underlining the importance of understanding the interaction between glacial processes and tectonic activity in shaping the Quaternary landscape of the Soča Valley.

Previous investigations included geomorphological mapping, geochronological analyses (radiocarbon dating), and sedimentological analyses of hand-drilled samples.

We conducted non-invasive geophysical investigations to further characterise subsurface structures. An electrical resistivity tomography (ERT) survey was carried out in a grid configuration, enabling multidirectional data acquisition and the construction of a pseudo 3D subsurface resistivity model.

The geophysical survey was complemented by recently drilled boreholes, which are currently being digitised and integrated into the interpretation workflow. Preliminary borehole data reveal a complex succession comprising glaciofluvial deposits, glaciolacustrine deposits, and subglacial till.

The ERT model identifies a laterally extensive low-resistivity unit enclosed within more resistive deposits. Correlation with borehole lithology suggests that the resistive domains correspond predominantly to coarse glaciofluvial sediments, whereas the low-resistivity unit corresponds to fine-grained glaciolacustrine sediments with intercalated subglacial till. The low-resistivity body displays systematic variations in thickness and geometry across the study area, indicating complex glacier-margin deposition and subsequent deformation. Several ERT profiles further reveal inclined sedimentary packages within the moraine complex, suggesting glaciotectonic disturbance associated with glacier advance. These results provide valuable information for 3D subsurface modelling and enhance our understanding of glacial dynamics at the southern Alpine margin.

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MORPHOLOGY AND SPELEOGENESIS OF THE OSTROVICA CAVE (GOSPIĆ, CROATIA)

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The Ostrovica Cave is located in the central part of the Croatian Dinaric karst. Its entrance lies at the northeastern margin of Ličko polje, one of the largest karst poljes in the Dinaric karst. The cave is 39 meters deep and consists of a spacious main passage, 130 meters in length, with several shorter passages branching away from it. The cave was formed in Palaeogene carbonate breccia, commonly referred to as the Jelar Formation. The entrance is located at 660 meters above sea level. The value of this cave was recognised early on – in the year 1970, it was put under protection as a geomorphological natural monument. Since then, no further exploration or geospeleological investigations have been carried out. Therefore, the aim of this study was to determine the basic morphological characteristics of the cave and to define phases of its speleogenesis. The research was conducted in several steps: 1) a new cave survey was carried out, 2) morphometric, as well as macro- and mesomorphological characteristics were determined, 3) detailed geospeleological mapping was performed, including mapping of structural elements (faults and fractures), speleogens and other denudational features, water bodies and sediments. Based on the collected data, the main conditions and phases of speleogenesis were defined: (1) passage enlargement in the phreatic zone; (2) clastic sediment fills the passages in the epiphreatic phase; (3) speleothem deposition in the vadose zone; (4) functional reactivation of a part of the cave, accompanied by erosion of a part of the sediment infill; (5) collapse of part of the sediment infill; (6) opening of the entrance due to surface denudation.

In addition to carbonate lithology and fracture porosity, the position of Ličko polje relative to the cave appears to have played an important role in controlling its speleogenetic processes. Today, the polje floor lies 70 meters below the main passage of the cave.

RECONSTRUCTION OF SUBMERGED ARCHIVES OF THE CETINA PALAEORIVER AND LAKE SYSTEM IN THE EASTERN ADRIATIC COAST DURING THE LAST GLACIAL MAXIMUM

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During the Last Glacial Maximum (LGM), karst rivers incised their channels into the now submerged part of the eastern Adriatic shelf (Juračić and Prohić, 1991), due to the sea level being at a depth of -120 and -134 meters below the present level (Lambeck et al., 2014; Maselli and Trincardi, 2013). However, the currently available studies in the area (e.g., Fritz and Bahun, 1997; Crmarić et al., 1998, Sikora et al., 2014) do not indicate the flow path, morphology, or sediment infill of the submerged systems.

This study aims to define submerged Quaternary landscapes surrounding the karst river Cetina located in central Dalmatia, with a particular focus on the precise recognition of the submerged fluvial and lacustrine archives. To achieve these objectives, we employed state-of-the-art instruments and methodologies. The field techniques included high-resolution acoustic surveys using a sub-bottom profiler (SBP) and multibeam echosounder (MBES), as well as coring in two locations. A collection of more than 780 km of SBP and MBES data was used to interpret the processes that lead to the formation of submerged environments. An evolution of the well-defined fluvial channel can be tracked for the Cetina River from its present-day river mouth, while in continuation there is evidence of the formation of a lacustrine environment between the islands of Brač and Hvar. The research continues with detailed sediment core analyses.

The findings of this study will enhance our understanding of Quaternary sea-level dynamics and sea-level-related landscape changes in the study area, which are pivotal for estimating future climate, sea-level variability, and the response of coastal systems to such changes.

The presented research was conducted in the scope of the internal research project „Rivers Into MAD" at the Croatian Geological Survey, funded by the National Recovery and Resilience Plan 2021–2026 of the European Union – NextGenerationEU, and monitored by the Ministry of Science and Education of the Republic of Croatia.

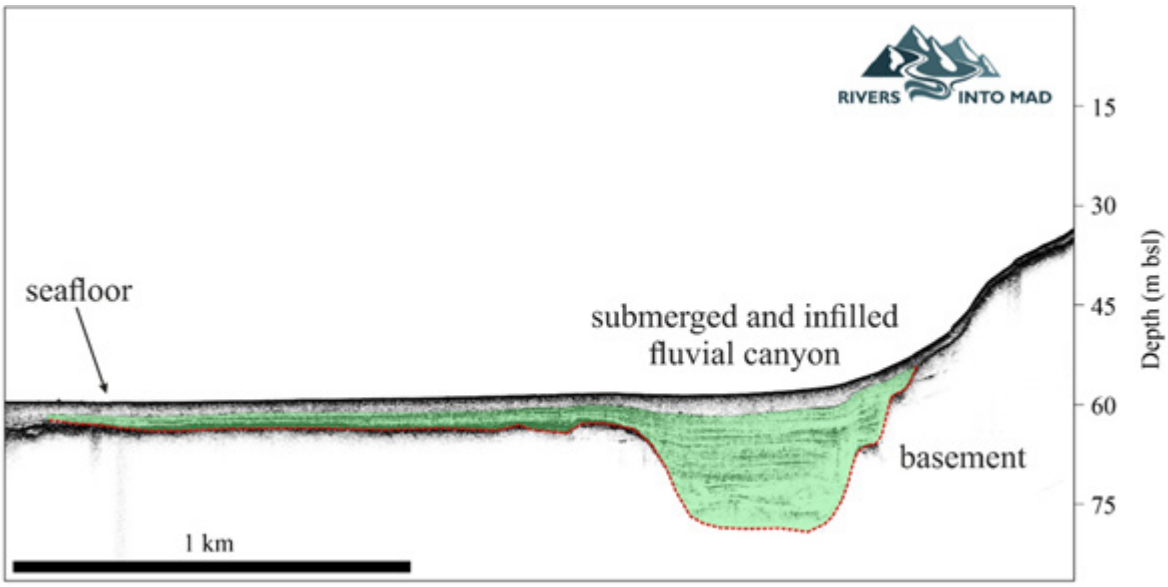


Figure 1: An example of a Cetina River submerged fluvial channel sub-bottom profile located near the present-day river mouth.

REFERENCES

Crmarić, R., Bogner, D., & Juračić, M., 1998. Holocenski sedimenti i sedimentacija u Kaštelanskom zaljevu. In M. Hodžić (Ed.), Znanstveno-stručni kulturološki skup, Kaštela, Zbornik radova, pp. 178-182.

Fritz, F., Bahun, S., 1997. The morphogenesis of submarine springs in the Bay of Kastela, Croatia. Geol. Croat. 50, pp. 105–110. https://doi.org/10.4154/GC.1997.10

Juračić, M. and Prohić, E., 1991. Mineralogy, sources of particles and sedimentation in the Krka River estuary (Croatia). Geološki Vjesn. 44, pp. 195–200.

Lambeck, K., Rouby, H., Purcell, A., Sun, Y., Sambridge, M., 2014. Sea level and global ice volumes from the Last Glacial Maximum to the Holocene. Proc. Natl. Acad. Sci. U. S. A. 111, pp. 15296–15303. https://doi.org/10.1073/pnas.1411762111

Maselli, V., Trincardi, F., 2013. Large-scale single incised valley from a small catchment basin on the western Adriatic margin (central Mediterranean Sea). Glob. Planet. Change 100, pp. 245–262. https://doi.org/10.1016/j.gloplacha.2012.10.008

Sikora, M., Mihanović, H., Vilibić, I., 2014. Paleo-coastline of the Central Eastern Adriatic Sea, and Paleo-Channels of the Cetina and Neretva rivers during the last glacial maximum. Acta Adriat. 55, pp. 3–18.

ENCOUNTERING CHIRONOMIDS ON POLLEN SLIDES: A CASE FROM A KARST LAKE OF CROATIA

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Chironomidae are a diverse and species-rich insect family within the order Diptera. They are holometabolous with a life cycle consisting of four stages: egg, larva, pupa and imago/adult. Their larvae are important components of freshwater ecosystems, commonly used as bioindicators in paleolimnological research due to their sensitivity to temperature, oxygen, trophic status and habitat conditions (Zheng et al., 2019; Antczak-Orlewska et al., 2021; Engels et al., 2025; Jambrović et al., 2025). Although subfossil chironomids are usually studied as separate bioindicators, their remains also occur on palynological slides, mostly as fragments of their chitinous exoskeleton. These were first described and assigned a non-pollen palynomorph (NPP) type name by Bas Van Geel (1989). Since then, several other chironomid-related NPP types were identified, representing mouthparts and head capsules.

Here, we show diverse chironomid NPP remains on pollen slides prepared from Holocene lake sediments collected from the Baćina lakes in southern Dalmatia, Croatia (Ilijanić, 2014). The lake system comprises six interconnected lakes formed at the end of Pleistocene (Ivičić et al., 1996; Ilijanić, 2014) and is characterised by a Mediterranean climate with warm, dry summers and mild, wet winters. Numerous chironomid remains were identified, including mandibles, ligula, menta, and parapodial claws. Some remains showed varying degrees of degradation. Unlike head capsules extracted using standard chironomid methods, remains on pollen slides originate from different sediment fractions and sample volumes, limiting direct comparison (Engels et al. 2026). Nevertheless, taxa with narrow ecological preferences can be useful when studied together with other NPP paleoecological indicators (freshwater algae, aquatic macrophyte, Cladocera, testate amoeba etc.).

Chironomid remains on pollen slides provide information on depositional environments, past trophic levels, and ecological conditions if identified to high taxonomic resolution and in sufficient abundance (Engels et al. 2026).

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REFERENCES

Antczak-Orlewska, O., Płóciennik, M., Sobczyk, R., Okupny, D., Stachowicz-Rybka, R., Rzodkiewicz, M., Siciński, J., Mroczkowska, A., Krąpiec, M., Słowiński, M., Kittel, P., 2021. Chironomidae Morphological Types and Functional Feeding Groups as a Habitat Complexity Vestige. Frontiers in Ecology and Evolution 8, 583831. https://doi.org/10.3389/fevo.2020.583831

Engels, S., Lane, C.S., Wilkinson-Rowe, E., 2025. How long is longterm? Comparing decadal and centennialscale insect diversity dynamics. Hydrobiologia 852, 4231–4250. https://doi.org/10.1007/s10750-025-05862-w

Engels, S., Heiri, O., Hinkelman, J., Jambrović, M., 2026. Palaeoecological potential of chironomid (non-biting midge) remains encountered on pollen slides. Review of Palaeobotany and Palynology 352, 105632. https://doi.org/10.1016/j.revpalbo.2026.105632

Ilijanić, N., 2014. Clay Minerals in Lake Sediments along the Eastern Adriatic Coast as Proxies of Environmental Changes during Late Pleistocene and Holocene. Ph.D. Thesis,. Faculty of Science, University of Zagreb, Zagreb, Croatia.

Ivičić, D., Pavičić, A., Buljan, R., Prelogović, E., 1996. Hidrogeološki istražni radovi za prijedlog zona sanitarne zaštite za izvore Klokun i Modro oko. Institut za geološka istraživanja, arhiv. br. 62/96, Zagreb.

Jambrović, M., Hamerlík, L., Szarłowicz, K., Hrdý, T., Milovský, R., Čerba, D., Jędrzejek, F., Pipík, R., Chamutiová, T., Bitušík, P., 2025. Subfossil chironomid assemblage shifts indicate Little Ice Age termination, deforestation, and human impact in a subalpine lake catchment. Aquatic Sciences 87, 81. https://doi.org/10.1007/s00027-025-01208-9

Van Geel, B., Coope, G.R., van der Hammen, T., 1989. Palaeoecology and stratigraphy of the Lateglacial type section at Usselo (the Netherlands). Review of Palaeobotany and Palynology 60, 25–129. https://doi.org/10.1016/0034-6667(89)90072-9

Zheng, W. Wang, R., Zhang, E., Chang, J., 2019. Complex relationship between the diversity and stability of chironomid assemblages in the recent sediments of two large alpine lakes in SW China. Science of the Total Environment 684, 705–714. https://doi.org/10.1016/j.scitotenv.2019.05.321

LATE PLEISTOCENE (MIS 5) SEDIMENTARY RECORD OF LAKE VISOVAC (DALMATIA, CROATIA)

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Lake sediments from various sites in Lake Visovac (central Dalmatia, Croatia) were studied using radiocarbon and OSL dating. The chronology provides a framework to define the timing of lake evolution during Late Pleistocene and Holocene in this region. Lake Visovac is one of the tufa barrier lakes of the Krka River, situated between Roški Slap (60 m asl) and Skradinski Buk (46 m asl). Its formation is linked to the development of tufa barriers and waterfalls along the Krka River before it enters Prokljan Lake and forms an estuary near Skradin, eastern Adriatic. Lake sediment cores from Lake Visovac (Site A) were recovered from the central part near Visovac Island, and from the southern part near the exposed Kalički Kuk tufa barrier, at an elevation of approximately 46 m asl. Geomorphological investigations on the margins of the karst polje Polje, on the road towards the village of Rupe revealed lake deposits exposed in outcrops (Site B) in horizontal distance of around 1 km, and at elevations between 55 and 65 m asl, up to ~20 m above the present lake level, indicating that Lake Visovac was considerably larger in the past. The maximum thickness of lake sediments reaches approximately 40 m in the southern part of the lake. Radiocarbon dating of an 8 m lake sediment core indicates Holocene sedimentation, whereas OSL dating of exposed lake deposits yielded an age of 97 ± 8 ka, corresponding to the marine isotope stage (MIS) 5c. These results demonstrate that Lake Visovac already existed during MIS 5c and reached a water level approximately 20 m higher than at present, indicating a substantially more extensive lake during this warm interstadial of the Late Pleistocene. The obtained chronology provides new insights into the long-term evolution of the River Krka tufa barrier system and demonstrates the potential of exposed lake deposits as valuable archives of Late Pleistocene environmental change in the eastern Adriatic.



Figure 1: Lake deposits exposed in outcrops (A, B) approximately 1 km along the margins of the karst polje near the village of Rupe, on the shores of Lake Visovac. The sediment profile sampled for OSL dating is shown in (C).

RECONSTRUCTING EXTREME WEATHER EVENTS FROM ALLUVIAL FAN ARCHIVES IN THE UPPER SAVA VALLEY (SOUTHERN ALPS): FIRST RESULTS FROM RATEČE AND PODKOREN

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Alluvial fans in alpine environments are key sedimentary archives of past geomorphic processes, commonly triggered by extreme hydroclimatic events. This study investigates Late Pleistocene to Holocene alluvial fan development in the Upper Sava Valley (Southern Alps) to reconstruct the frequency and magnitude of past extreme weather-driven sedimentation. High-resolution geomorphological mapping based on lidar data shows that alluvial fans dominate the valley floor, fluvial terraces occur along the Sava River, and extensive moraines are preserved upslope. The spatial relationships among these landforms suggest that moraine-derived material has substantially contributed to fan aggradation. Additionally, several generations of alluvial fans can be distinguished, locally separated by erosional features, indicating episodic phases of activity.

Work carried out so far has focused on the largest and most socially relevant fans at Rateče and Podkoren. Their internal architecture was examined through detailed sedimentological observations in two excavation pits per site, each reaching depths of approximately 4 m. Detailed sedimentological logging enabled identification of depositional processes associated with debris flows and flood events, along with systematic sampling for radiocarbon dating and granulometric, geochemical, mineralogical, and laboratory geophysical analyses. Electrical resistivity tomography was used to help delineate the geometry and extent of depositional processes beyond the pits. Chronological data indicate that the upper 4 m of sediment at Rateče span approximately the last 6 ka to recent centuries, whereas deposits at Podkoren reach back to the Late Glacial Maximum (31–20 ka). Both locations record multiple phases of mass-movement and flood activity, indicating repeated pulses of enhanced sediment flux. Ongoing work will expand investigations to additional large fans along the valley to establish a more comprehensive reconstruction of spatiotemporal patterns of extreme-event sedimentation on alluvial fans.

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THE HOLOCENE AVIFAUNA OF ŽUKOVICA CAVE AS AN INDICATOR OF PALEOECOLOGICAL CONDITIONS ON KORČULA ISLAND

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Bird remains represent an important source of information for reconstructing past environments, as their ecological requirements closely reflect changes in vegetation, climate, water availability, and human impact. This study presents the analysis of avian remains recovered from the Holocene deposits of Žukovica Cave on Korčula Island, Croatia, spanning the Mesolithic and Neolithic periods (Early to Middle Holocene; Janković, 2026). The assemblage was examined using taxonomic identification, osteometric analysis, and taphonomic methods to reconstruct paleoenvironmental conditions and assess the processes responsible for bone accumulation.

Taxonomic analysis identified representatives of nine avian orders: Galliformes, Anseriformes, Columbiformes, Pelecaniformes, Charadriiformes, Strigiformes, Accipitriformes, Falconiformes, and Passeriformes. Taphonomic evidence suggests that humans were the primary accumulators of bird remains, while animal predators played a secondary role.

Paleoecological interpretation indicates that woodland habitats were the dominant landscape element throughout the studied period, consistent with previous paleoenvironmental reconstructions for Korčula. Mesolithic deposits contain a higher proportion of taxa associated with aquatic habitats, suggesting the presence of nearby freshwater or brackish environments, possibly related to seasonal wetlands and flooded karst poljes documented elsewhere on the island (Dean et al., 2020). In contrast, Neolithic assemblages show an increased representation of taxa associated with open habitats, although this pattern may partly reflect selective human exploitation of particular bird species.

Overall, the avifaunal assemblage from Žukovica Cave indicates a heterogeneous Holocene landscape composed of forested areas, open habitats, and local wetland environments. The results demonstrate the value of bird remains as paleoecological proxies and contribute to a better understanding of environmental development and human–environment interactions on Korčula Island during the Holocene.

REFERENCES

Dean, S., Pappalardo. M, Boschian. G., Spada, G., Forenbaher, S., Juračić, M., Felja, I., Radić, D., Miracle, P. T., 2020.Human adaptation to changing coastal landscapes in the Eastern Adriatic: Evidence from Vela Spila cave, Croatia. Quaternary Science Reviews, 244. 1-15. https://doi.org/10.1016/j.quascirev.2020.106503.

Janković, D., 2026. Birds from the holocene deposits of the Žukovica cave on the island of Korčula. Master thesis, University of Zagreb, Faculty of Science, pp. 1-82

FACIES AND DEPOSITIONAL ENVIRONMENTS OF PLEISTOCENE TUFA DEPOSITS AT ROŠKI SLAP, KRKA RIVER (CROATIA)

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Tufa deposits are freshwater carbonates precipitated under cool or near-ambient temperatures. They form in a wide range of geomorphological and hydrological contexts (e.g., spring, fluvial, lacustrine and paludal settings) and display a variety of morphologies and sedimentary features. Tufa environments are highly dynamic, often characterized by episodes of erosion, allogenous sediment deposition and subsequent cementation. Consequently, due to their rapid response to changes in environmental and climatic conditions at the time of their creation, tufas are considered excellent paleoenvironmental indicators.

The Krka River in Croatia is a karstic river that has entrenched its canyon into the North Dalmatian Plain. Here, tufa is the main constructive element; along the river course, it precipitates at seven currently active tufa barriers, forming a cascade facies (tufa barrier - lake system). Apart from these actively growing tufa barriers, a fragments of older barrage deposits can be found on the canyon walls at the Roški Slap location. A sedimentological and petrographic analysis of these deposits allowed the reconstruction of past depositional conditions and environments. The results showed that due to environmental changes, there was a long-term increase in erosion in the Krka River basin, which resulted in the deposition of detritus in the upstream formed lake, its filling, and ultimately the erosion of the barrier.



Figure 1: Different Pleistocene tufa facies at Roški slap

REFERENCES

Domínguez-Villar, D., Vázquez-Navarro, J.A., Cheng, H., Edwards, R.L., 2011. Freshwater tufa record from Spain supports evidence for the past interglacial being wetter than the Holocene in the Mediterranean region. Global and Planetary Change 77, 129-141.

Domínguez-Villar, D., Vázquez-Navarro, J.A., Carrasco, R.M., 2012. Mid-Holocene erosive episodes in tufa deposits from Trabaque Canyon, central Spain, as a result of abrupt arid climate transitions. Geomorphology 161-162, 15-25.

Domínguez-Villar, D., Vázquez-Navarro, J.A., Krklec, K., Lojen, S., Fairchild, I.J., 2017. Laminated tufa sediments formed from overflow karst springs: Controls on their deposition and carbon-oxygen isotope records. Sedimentology 64, 1274-1288.

Domínguez-Villar, D., Vázquez-Navarro, J.A., Krklec, K., 2017. The role of gypsum and/or dolomite dissolution in tufa precipitation: lessons from the hydrochemistry of a carbonate-sulphate karst system. Earth surface processes and landforms 42/2, 245-258.

RELATIONSHIPS BETWEEN THE INTENSITY OF GLACIAL EROSION AND THE KARST PHENOMENA IN THE CASE OF THE VELIKA VRATA GLACIOKARST (1924 M, GORENJA KOMNA, JULIAN ALPS). THE USEFULNESS OF DRONE VIDEO AERIAL RECORDINGS

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The high density, diversity and abundance of corrosion forms of all types and sizes, as well as traces of other morphogenetic factors and their seemingly random distribution over the surface are the basic characteristics of most known glaciokarst areas, first of all in high-mountain areas. Due to the difficult transparency, they pose a special challenge and problem for researchers. Drone video aerial recordings have proven to be a highly useful tool in this regard, because they enable viewing a larger area from one location and from multiple angles. On the high-mountain glaciokarst surface in the vicinity of Velika Vrata (1924 m) on Gorenja Komna, we have used it to identify some previously unknown local patterns in the distribution of preserved traces of glacial transformation, and in this connection, the dependence of the distribution of recent corrosion forms. More extensive glacial erosion was only where the moving ice encountered obstacles and vice versa, which is still visible today. We conclude that this is a consequence of a thinner glacial cover, because any thicker glacial cover, even in high-mountain karst areas, can completely remove the thicker upper layer of limestone during glaciation. A thinner glacial cover, such as that at Velika Vrata, was not able to do this. Additional evidence for the above are the remains of eroded karren. A special indicator for the specific conditions at Velika Vrata is also a high number of the karst tables. Comparisons are possible with the lower parts of Komna with its glacially transformed surfaces along the Valley of the Triglav Lakes and with the Kanin Mts.



REFERENCES

Erhartič, B., 2012. Geomorfološka dediščina v Dolini Triglavskih jezer. Geografija Slovenije 23. ZRC-SAZU. Ljubljana.

Kunaver, J., 1988. Kraške mize pri nas in na tujem. Proteus : ilustriran časopis za poljudno prirodoznanstvo. 1988, letn. 50, št. 7, str. 263-268.

Kunaver, J., 2009. Corrosion terraces, a Megaausgleichsfläche or a specific landform of bare glaciokarst. V: Gines, Ángel (ur.), et al. Karst rock features : karren sculpturing. Ljubljana: Založba ZRC: = ZRC Publishing, 2009. Str. 161-168, ilustr. Carsologica, 9.

McIlroy de la Rosa, J., 2016. The Burren: a glacial, karstic and biokarstic expression of a limestone plateau in western Ireland. Earth Surface Processes and Landforms 41(11).

PALEOGEOGRAPHIC RECONSTRUCTION OF THE ENVIRONMENT: LAKES AND WETLANDS OF THE RAVNI KOTARI REGION (PALRES)

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The Vrana Lake basin in northern Dalmatia is a coastal karst landscape in which water, carbonate deposition and human settlement have been closely connected throughout the Holocene. Its development cannot be reduced to a simple transition from natural to anthropogenic conditions, but reflects successive hydrological thresholds shaped by inherited geological structure, Holocene sea-level and groundwater changes, wetland dynamics and historically specific human interventions. Tufa deposits are sensitive archives of carbonate-rich freshwater environments and can provide spatially precise evidence of former hydrological conditions.

This contribution presents the conceptual framework and preliminary mapping results of the PALRES project (IP-UNIZD2025-28020), supported by the European Union through NextGenerationEU, focusing on tufa deposits in the wider Vrana area as field indicators of past hydrological conditions. Within PALRES, tufa is examined not only as a carbonate deposit, but as a spatial archive at the intersection of spring activity, palaeochannels, wetland margins and human use of local resources. The research aims to reconstruct former watercourses and palaeoflow directions, clarify connectivity between springs, wetlands and settlement zones, and evaluate how water availability and tufa influenced the organization of the cultural landscape. Specific objectives include systematic mapping of tufa occurrences, documentation of their geomorphological and archaeological context, radiocarbon dating, and palaeoenvironmental interpretation supported by stable isotope analyses.

Field observations show that tufa occurs in localized profiles and archaeological contexts. Some deposits are related to former or present drainage lines, while others occur within or near historically significant structures. This spatial pattern suggests that tufa formation was linked to earlier phases of carbonate-rich freshwater circulation and that the deposits were later reused, modified or exposed through human activity. Although preliminary, the results point to tufa as a valuable additional archive for reconstructing Holocene palaeohydrology in the Vrana basin, complementing lake-sediment and archaeological records.

REFERENCES

Fritz, F., 1984. Postanak i starost Vranskog jezera kod Biograda na Moru. Geološki vjesnik 37, 231–234.

Ilijanić, N., Miko, S., Marković, T., Hasan, O., 2018. Geological, structural-tectonic and hydrogeological characteristics of the Pakoštane area and Lake Vrana, in: Radić Rossi, I., Boetto, G. (Eds.), Pakoštane Veli Školj: The Late Roman Shipwreck in its Geological-Geographic and Cultural-Historical Context. University of Zadar, Zadar, pp. 161–177.

Lončar, N., Domazetović, F., 2018. Paleogeographic and modern geographic characteristics of the Municipality of Pakoštane, in: Radić Rossi, I., Boetto, G. (Eds.), Pakoštane Veli Školj: The Late Roman Shipwreck in its Geological-Geographic and Cultural-Historical Context. University of Zadar, Zadar, pp. 179–198.

Lončar, N., Faivre, S., Šućur, J., Gusar, K., Barešić, J., 2020. Rekonstrukcija hidroloških uvjeta na širem području PP Vransko jezero temeljem određivanja starosti sedrenih naslaga. Unpublished report, University of Zadar, Zadar.

Radić Rossi, I., Antonioli, F., Spada, G., Zubčić, K., Meštrov, M., 2018. Sea level and shoreline changes in the Pakoštane area over the past six millennia, in: Radić Rossi, I., Boetto, G. (Eds.), Pakoštane Veli Školj: The Late Roman Shipwreck in its Geological-Geographic and Cultural-Historical Context. University of Zadar, Zadar, pp. 229–248.

CAVE SEDIMENTS AS AN ARCHIVE OF MIDDLE PLEISTOCENE ALPINE GLACIATIONS IN THE JURA MOUNTAINS

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With thousands of caves and countless sinkholes, the karstic features of the Jura Mountains provide a valuable sedimentary archive. Recent research has highlighted how these sediments can be used to reconstruct the Middle Pleistocene glacial history of the region (Vivier et al., 2025; Mathes et al., 2026). During this time, the Alpine Rhone glacier advanced repeatedly across the Molasse Basin and into the Jura Mountains, contributing to the formation of the External Moraine Complex. However, the age of this complex remains poorly constrained. Through the ongoing CaveSeds project, five caves have been targeted for sediment sampling and analysis. These caves are located across the Jura and all contain sediments originating from the Alps. These sediments have been dated using the cosmogenic nuclides ^{10}Be and ^{26}Al. Ages have been calculated using both isochron-burial dating and P-PINI age modelling methods. Results suggest Alpine sediment deposition occurred within the cave systems during both MIS 12 and MIS 6. In addition to burial dating, clast lithology analyses are improving our understanding of the source area of the Alpine ice that entered the Jura during the most extensive glaciations. Our results build towards a multi-stage chronology of Alpine Icefield advance along the southwestern front of the Jura Mountains and highlight how much the karst record has to offer for reconstructing the region's glacial past.

REFERENCES

Vivier, M., Jaillet, S., Husson, E., Pons-Branchu, E., & Charlier, J. B., 2025. New evidence of mid-Pleistocene glaciations in the French Jura Mountains using debris flow deposits and U/Th dating of speleothems (Verneau karst network). International Journal of Speleology, 54(2). https://doi.org/10.5038/1827-806X.ijs2558

Mathes, N., Luetscher, M., Ivy-Ochs, S., Dieleman, C., Christl, M., Vockenhuber, C. and Akçar, N., 2026. An extensive MIS 12 Alpine glaciation in the Jura Mountains: insights from cave sediments and burial dating. Quaternary Science Reviews, 376, 109818. https://doi.org/10.1016/j.quascirev.2026.109818

EMBAYMENT GEOMETRY AS A CONTROL FACTOR OF POCKET BEACHES WAVE EXPOSURE: ISLAND OF HVAR, CROATIA

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Pocket beaches enclosed by rocky headlands are a characteristic landform of the rocky Mediterranean, including Adriatic coasts. Embayment geometry is a primary control on wave exposure, sediment transport, and beach dynamics (Bowman et al., 2009; Loureiro et al., 2012), yet systematic morphometric characterisation of eastern Adriatic pocket beaches remains scarce. This study presents a morphometric analysis of 47 embayed beaches on Hvar Island, with embayment morphology incorporated as a component of a multi-parameter beach vulnerability assessment. Seven parameters (Fig.1) were measured in ArcGIS Pro: shoreline length (S1), beach length (S2), headland-to-headland width (Ro), indentation depth (a), and beach and headland-line orientations (S3°, Ro°). Three indices followed Bowman et al. (2009; 2013): the indentation index (a/Ro), embaymentisation index (S1/Ro), and angular offset (|Ro° − S3°|). The mean indentation index of 0.98 places the average Hvar embayment in the moderately indented category, ranging from 0.28 to 2.02. Strong linear relationships between beach and headland-line orientation ($r^2 = 0.98$) and between indentation depth and shoreline length ($r^2 = 0.97$) confirm uniform wave energy distribution across most embayments. The indentation and embaymentisation indices co-vary strongly ($r^2 = 0.88$), reflecting that more indented embayments consistently achieve static equilibrium, restricting sediment transport beyond the embayment. Beaches with low angular offset between headland-line and beach orientation indicate equilibrium conditions and minimal sediment loss, while those with greater angular offset show the largest shoreline changes, exceeding 70% area reduction. Shallowly indented embayments remain exposed to oblique wave attack, sediment loss across headlands, and heightened erosion during storms (Fellowes et al., 2019). Embayment morphometric indices show a clear correspondence with observed long-term beach area changes (Mićunović and Faivre, 2024), confirming their value as indicators of beach stability and vulnerability and their potential contribution to sustainable coastal management.

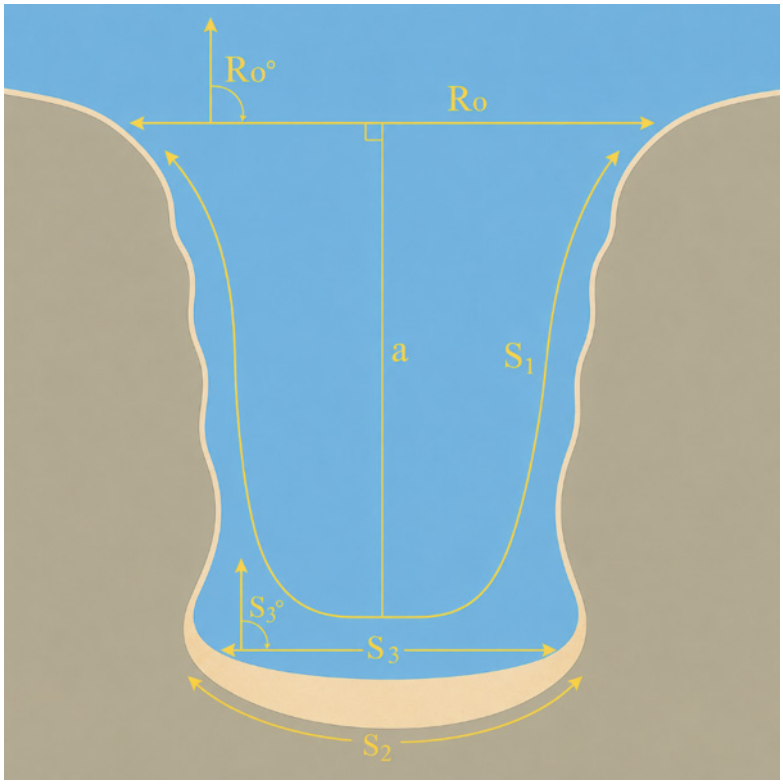


Figure 1: Bay morphology parameters.

REFERENCES

Bowman, D., Guillén, J., López, L., Pellegrino, V., 2009. Planview geometry and morphological characteristics of pocket beaches on the Catalan coast (Spain). Geomorphology 108, 191–199.

Bowman, D., Ferri, S., Pranzini, E., 2013. Pocket beach indentation index. Annals of Geomorphology 57, 35–50.

Fellowes, T.E., Vila-Concejo, A., Gallop, S.L., 2019. Morphometric classification of swell-dominated embayed beaches. Marine Geology 411, 78–87.

Loureiro, C., Ferreira, Ó., Cooper, J.A.G., 2012. Geologically constrained morphological variability and boundary effects on embayed beaches. Marine Geology 329–331, 1–15.

Mićunović, M., Faivre, S., 2024. Evolution of Hvar island pocket beaches during the last 200 years (eastern Adriatic coast, Croatia). Geomorphology, 447, p.109023.

NEW LATE QUATERNARY FINDINGS FROM THE SLOVENIAN PART OF THE GULF OF TRIESTE (NORTHERN ADRIATIC SEA)

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Despite a good understanding of the Quaternary evolution of the Gulf of Trieste (GoT), new insights are arising from continuous research of the seabed. In this study we present new Late Quaternary findings which emerged during the investigation of the possible geological factors contributing to the establishment of the Ronek (coralline) biogenic formation (RBF) located just north of Cape Ronek.

We used onshore geological mapping, acquisition and interpretation of offshore single-channel seismic profiles and analyzed a sediment core taken in the middle of the RBF. The core was radiocarbon dated and age-depth modelled.

The interpreted seismic profiles clearly show a several hundred meters wide last interglacial wave-cut marine terrace at a depth of approximately 50 ms (38 m) which was previously described on flysch by Zecchin et al. (2024). However, our study site documents the first example of these terraces in the GoT formed on carbonate, namely the Alveolinid-Nummulitid Limestone Formation. The terrace surrounded a carbonate high which was an islet during the last interglacial, an inselberg after MIS 5 and a hard substrate for the RBT after the post-LGM transgression. The sediment core captures the sedimentary record on the RBF for the last ca. 2000 years. While sedimentation rates for the last 500 years are comparable to modern values, the older core sections show a significant decrease with values in the range of several tenths of a mm/yr – an order of a magnitude less than the Holocene value for the GoT (Ogorelec et al., 1981).

Our results demonstrate that Quaternary geomorphological processes were important in shaping the bedrock morphology which later hosted the RBF. Even in the Holocene the inherited bedrock morphology significantly influences currents and sedimentation rates resulting in suitable conditions for coralline occupation. Finally, our study demonstrates the importance of understanding the local geological context at study sites as specific locations (such as the RBF) can present a geological outlier compared to their regional surroundings and are thus ill-suited for regional interpretations.

REFERENCES

Ogorelec, B., Mišič, M., Šercelj, A., Cimerman, F., Faganeli, J., Stegnar, P., 1981. Sediment sečoveljske soline. Geologija 24, 180–216.

Zecchin, M., Caffau, M., Busetti, M., Masoli, C.A., Baradello, L., Civile, D., Dal Cin, M., Petronio, L., Romeo, R., Zampa, L.S., Lenaz, D., Lucchi, R.G., Caburlotto, A., 2024. Late Quaternary transgressions and regressions in the Trieste Gulf (north-eastern Adriatic Sea). Quat Int 695, 1–17. https://doi.org/10.1016/j.quaint.2024.03.001

QUATERNARY MARINE GEOLOGY CONTRIBUTIONS TO THE EMODNET GEOLOGY PORTAL FROM THE EASTERN ADRIATIC SEA

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The EMODnet Geology network has been providing open access to harmonised marine geological data products and metadata from a distributed network of geoscience organisations across Europe for more than fifteen years, supporting a better understanding of the seafloor, its processes, and its resources (EMODnet, 2026). Data and products are delivered in accordance with international standards and made available at multiple scales, ranging from regional overviews to more detailed levels where data coverage allows. The Geological Surveys of Croatia and Slovenia have been members of the EMODnet consortium for more than a decade.

Quaternary geology and other Quaternary-related features dating back to the Last Glacial Maximum are also included in the range of EMODnet products. We show examples of contributions from the eastern Adriatic Sea provided to the portal by the Croatian and Slovenian surveys, which include: seabed substrate, modern sedimentation rates, seabed geomorphology, submerged archaeological sites, paleocoastlines, sea-level index points, different submerged landforms, and submerged springs.

The newest phase of EMODnet Geology, which started in September 2025, will further expand the set of published data products. Quaternary geology and Quaternary-related data from the eastern Adriatic will include: organic carbon content of sediments, radiocarbon (C14) measurements, and information on flora and fauna associated with submerged landscapes.

REFERENCES

EMODnet, 2026. EMODnet Geology. url: https://emodnet.ec.europa.eu/en/geology

QUATERNARY DEPOSITS BETWEEN KRANJSKA GORA AND PODKOREN (UPPER SAVA VALLEY, NW SLOVENIA)

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A topographic ridge named Brda-Peči, composed of Quaternary deposits, is located between Kranjska Gora and Podkoren in the Upper Sava Valley. The S-shaped ridge is 1.8 km long, up to 50 m in height and stretches along the left bank of Sava Dolinka River (Melik, 1955). We conducted geological and geomorphological mapping, stratigraphic logging, and clast provenance analysis of Quaternary deposits on the Brda-Peči ridge. Results show five units with distinct sedimentary characteristics. Unit 1 (Figure 1) forms the easternmost end of the Brda-Peči ridge and is composed of partly lithified layers of medium- to coarse-grained sand, clast-supported sandy gravel, and clast-supported open-framework gravel. Between 10 cm to 1 m thick layers dip 20 to 30° towards the west. Clasts are composed of Upper Triassic carbonates sourced south of the Upper Sava Valley in the Julian Alps (Buser, 2010). The thickness of these deposits exceeds 70 m. Unit 2 forms the central part of the Brda-Peči ridge and is composed of subrounded sandy gravel of Upper Triassic carbonates, sourced from the Julian Alps, or Carboniferous clastic rocks sourced from the Karavanke mountains north of the Upper Sava Valley. Unit 3 forms the western part of the Brda-Peči ridge as well as some isolated outcrops surrounding Podkoren village, and is composed of sandy gravel of Carboniferous clastic rocks sourced from the Karavanke mountains. Unit 4 is located on top of the Brda-Peči ridge and is composed of Upper Triassic carbonate boulders. Unit 5 comprise alluvial deposits of Sava Dolinka River and its tributaries that are surrounding the Brda-Peči ridge. Unit 1 is interpreted as a Gilbert-type delta and based on superposition, is the oldest. Units 2 to 4 are glacial or glacially reworked sediments showing different stages of glacial activity. Unit 5 is the youngest deposit and represents the post-LGM erosional and depositional stage of the research area.



Figure 1: Layers of coarse grained sand, clast-supported sandy gravel and clast-supported open-framework gravel deposited in a Gilbert-type delta. Scale is 70 cm long with 5 cm sections.

REFERENCES

Buser, S. (2010). Geološka karta Slovenije 1 : 250.000 = Geological Map of Slovenia 1 : 250.000 . In Kartografsko gradivo. Geološki zavod Slovenije.

Melik, A. (1955). Nekaj glacioloških opažanj iz zgornje Doline. Geografski Zbornik, 3, 299–318.

SEVEN YEARS IN PLANICA: UAV MONITORING OF SEDIMENTARY PROCESSES ON ALLUVIAL FANS (JULIAN ALPS, NW SLOVENIA)

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Alpine alluvial fans are characterised by sedimentation processes that range from dilute (stream and sheet flows) to dense flows (gravity flows). They are usually triggered during intense rainfall. The Planica Valley in NW Slovenia is an area where these processes occur on alluvial fans on a sub-annual basis. Since 2019 we have been monitoring the five most active areas in the Planica valley, each with different aims and purposes. We have been using a small Unmanned Aereal Vehicle (UAV) and linking the detected processes to the rainfall triggers. We produced a time series of high-resolution digital elevation models with structure-from-motion photogrammetry. The first location is the Suhi vrh alluvial fan, where we perform UAV monitoring several times per year since December 2019. Here the aim is to detect sieve-lobe deposition process and surface changes after every rainfall event that exceeds the 50 mm/24h threshold (Novak et al., 2022). At Ciprnik, we monitor surface changes and reactivation of the Ciprnik complex landslide which occurred in November 2000 (Novak et al., 2025). This location has been surveyed annually since 2020. Third, fourth and fifth areas are several active alluvial fans of different sizes, that are scattered along the valley and are surveyed annually. The results on Suhi vrh alluvial fan show predominantly sieve-lobe deposition that occurs regularly after rainfall events several times per year. A major reactivation event in October 2023 measuring 26.000 m^3 was documented on the Ciprnik complex landslide. On other fans we have detected deposition and erosion processes measuring up to 4000 m^3 of sediment per year, channel avulsion and lateral channel migrations of several 10s of metres. Results show that small alpine alluvial fans can experience drastic surface changes in relatively short timescales.

REFERENCES

Novak, A., Vrabec, M., Popit, T., Vižintin, G., & Šmuc, A. 2022. Facies analysis, depositional activity, and internal structure of sieve deposits on an active alluvial fan. Earth Surface Processes and Landforms. https://doi.org/10.1002/ESP.5508

Novak, A., Vrabec, M., & Šmuc, A. 2025. Long-term post-event processes and major reactivation of a complex landslide: 2000–2023 evolution of the Ciprnik landslide, Julian Alps, Slovenia. Landslides, 1–15. https://doi.org/10.1007/S10346-025-02598-5

INVESTIGATING PROXY-CLIMATE RELATIONSHIP USING INSTRUMENTAL DATA: MODERN STALAGMITE RECORD FROM NOVA GRGOSOVA CAVE, CROATIA

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Due to an accelerating rate of global climate change, increasing efforts are made towards understanding Earth's natural climate variability. Global climate projection models help to anticipate future climate system behaviour, relying on instrumental data with a limited spatiotemporal extent. Natural climate archives represent important tools for overcoming this issue, offering a glance into the Earth's climate history from proxy data. Annually laminated cave sediments, speleothems, have been successfully employed to expand the instrumental database of past climate conditions, through calibration with proxy time-series (e.g. Warken et al., 2018).

Meteorological station Zagreb-Grič provides the longest continuous record of precipitation (P) and temperature (t) measurements in Croatia, extending back to 1861. The Nova Grgosova Cave is positioned about 30 km west of Zagreb, Croatia's capital, and experiences similar atmospheric circulation regime. The sensitivity of this area to seasonal P-t variations was established via daily precipitation monitoring (Palatinuš et al., 2025), as well as in-cave measurements of CO_2 and dripwater studies, suggesting seasonally-driven speleothem precipitation, biased towards cool-season conditions (Bajo et al., 2024, 2026). The speleothem utilized in this study was actively growing at the time of collection in 2013 and exhibits well-defined annual fluorescent and trace-element (Sr/Ca) bands, that reflects seasonal variability of dripwater trace element concentrations (Bajo et al., 2024), supporting their use as hydroclimatic indicators. Speleothem stable isotope ratios, $\delta^{18}O$ and $\delta^{13}C$, show a more complex signal, reflecting the combined influence of the North Atlantic Oscillation and solar irradiation changes, both modulating temperature and precipitation regimes. Here, we combine evidence from long-term cave monitoring and annually-resolved multi-proxy time series with instrumental data to deliver calibration curves for quantitative paleoclimate reconstructions in this region, extending the existing instrumental record.

REFERENCES

Bajo, P., Briški, M., Benutić, A., Piplica, A., Brčić, V., Marciuš, B., Palatinuš, I., Stroj, A., 2024. Seasonality in cave dripwater and air properties – implications for speleothem palaeoclimatology, Nova Grgosova Cave (Croatia). Geologia Croatica, 77/3, 243-251. https://doi.org/10.4154/gc.2024.16

Bajo, P., Stroj, A., Brčić, V., Palatinuš, I., Briški, M., Kordić, B., Belušić, D., 2026. Karst vadose zone hydrology explored through cave drip water dynamics: the roles of soil, epikarst and climate. Hydrological Processes, 40:e70584, 1–14. https://doi.org/10.1002/hyp.70584

Palatinuš, I., Bajo, P., Briški, M., Belušić, D., Brčić, V., 2025. Assessing the influence of climatic parameters and moisture sources on precipitation isotope composition from central Croatia: Insights from a two-year long daily-resolved dataset . Journal of Hydrology: Regional studies, 62, 102836, 1–13. https://doi.org/10.1016/j.ejrh.2025.102836

Warken, S.F., Fohlmeister, J., Schröder-Ritzrau, A., Constantin, S., Spötl, C., Gerdes, A., Esper, J., Frank, N., Arps, J., Terente, M., Riechelmann, D.F.C., Mangini, A., Scholz, D., 2018. Recontruction of late Holocene autumn/winter precipitation variability in SW Romania from a high-resolution speleothem trace element record. Earth and Planetary Science Letters, 499, 122–133. https://doi.org/10.1016/j.epsl.2018.07.027

SEDIMENTARY ARCHIVES OF GLACIALLY TRIGGERED EARTHQUAKES IN THE SOUTHERN BALTIC REGION

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The Baltic Sea region experienced numerous seismic events during the Pleistocene. Based on sedimentological analyses, OSL dating, and geophysical modelling conducted across five Baltic countries, we propose two principal mechanisms responsible for this seismic activity.

The first mechanism is related to the growth and decay of the Fennoscandian Ice Sheet (FIS). During ice-sheet expansion, the increasing ice load depressed the Earth's crust, while a peripheral uplift zone, known as a forebulge, developed beyond the ice margin. During deglaciation, unloading of the crust triggered glacio-isostatic rebound, whereas the surrounding uplifted areas began to subside. This adjustment commonly occurred in a stepwise manner and was accompanied by seismic activity. In some cases, earthquakes may also have been triggered by forebulge migration, causing deformation even in areas located ahead of the advancing ice margin.

The second mechanism is associated with the dynamic behaviour of the FIS itself. Potential triggers include basal stick–slip motion, ice movement over major bedrock obstacles such as cuestas (klints in the Baltic region), ice fracturing, iceberg calving, and glaciotectonic processes.

The resulting chronological framework reveals two principal phases of enhanced seismic activity: (1) during the MIS 6 glaciation and (2) during the Last Glaciation (MIS 2).

BIRDS FROM THE HOLOCENE DEPOSITS OF THE CAVE VELA PEĆ IN ISTRIA

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Vela peć near Vela draga (Mt Učka) in Istria is an archaeological site where excavations were carried out from 1997 to 2001. Bones of almost all vertebrate classes were found at the site, as well as remains of human activity, which indicates that the cave was an occasional human dwelling place in the period from Late Pleistocene to the Iron Age (Radović *et al*., 2008; Forenbaher *et al*., 2006). The total of 107 bird bones that were found have been anatomically and taxonomically determined and taphonomically analysed (Rebić, 2026). The sample includes 12 orders (Galliformes, Anseriformes, Columbiformes, Gruiformes, Otidiformes, Pelecaniformes, Charadriiformes, Strigiformes, Accipitriformes, Piciformes, Falconiformes, Passeriformes), 16 families, 18 genera and 17 species. Most of the species identified in the assemblage were forest dwelling birds, followed by species typical of open and transitional habitats. Nowadays, Vela draga is characterised by limestone cliffs with sparse vegetation and is surrounded by diverse habitats, including open habitats and forests. Almost all the species identified in the sample are also present today in the area which indicates that the local climate has not drastically changed in the period of Early Holocene to the Neolithic compared to nowadays. Traces of burning were the only traces of human predation, and they were found on 23,3 % of the sample, while other traces of predation make up 6,5% of the sample. Based on the evidence and determined species, bird bones were partly introduced by predators, while the majority appears to have accumulated naturally.



Figure 1: Specimen VP9993.106, left tarsometatarsus, Anatidae, plantar and dorsal view, visible traces of burning.

REFERENCES

Forenbaher, S., Rajić Šikanjić, P., Miracle, P. T., 2006. Pottery from Vela Cave near Vranja (Istria). Histria archaeologica, 37, 5–44.

Radović, S., Forenbaher, S., Brajković, D., Mauch Lenardić, J., Malez, V., Miracle, P. T., 2008. Use of caves in the mountains: a view from the sheepfold. Studies of the Institute of Geography UJK, 17, pp. 33–50.

Rebić, D., 2026. Birds from the holocene deposits of the cave Vela peć in Istria. Master thesis, University of Zagreb, Faculty of Science, pp. 1–41.

A HUGE CHANGE IN THE DRAINAGE PATTERN OCCURRED IN THE LOWER QUATERNARY IN CENTRAL APENNINES: TECTONIC AND EROSIONAL ROLE

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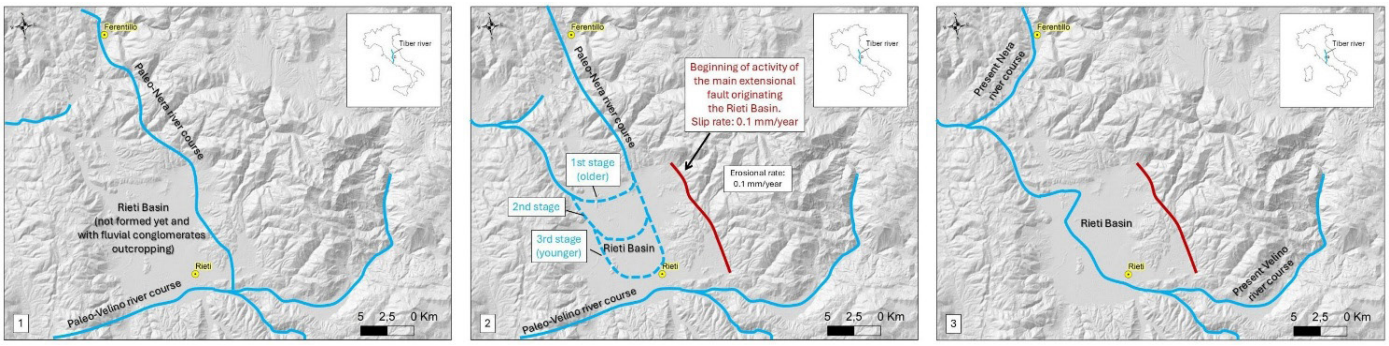
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This study reconstructs the Plio-Quaternary evolution of a Central Apennines river drainage (the Nera River), and examines its relationship with the tectono-sedimentary development of the Rieti intramountain and its position in relation to the Tiber river drainage system. Despite the absence of absolute chronological constraints, the spatial distribution of fluvial deposits and relict geomorphological features preserved along mountain ridges and valley slopes allows the identification of successive paleo-courses of the Nera River and the reconstruction of the main evolutionary phases of the hydrographic network.

Field observations focused on conglomeratic deposits and erosional landforms distributed at different elevations between the Nera Valley and the northern margin of the Rieti Basin. The investigated deposits consist predominantly of well-cemented polygenic conglomerates of fluvial origin, characterized by rounded carbonate clasts embedded in sandy-gravelly matrices, locally associated with sands, silts, and lignite-bearing levels indicative of fluvio-lacustrine environments. Their altimetric distribution suggests multiple depositional phases spanning from the Pliocene to the Lower Pleistocene.

The reconstructed model identifies three main stages in the evolution of the paleo-drainage network. In the older phase, the paleo-Nera flowed southward toward the paleo-Velino system, crossing sectors currently occupied by the Rieti Basin. During a second phase, linked to the progressive development of the basin, the river entered the evolving depression and subsequently migrated southwestward due to retrogressive erosion connected to the Tiber Basin. In the most recent phase, the Nera River assumed a course broadly corresponding to the present NE-SW valley configuration. Relict saddles and paleovalleys preserved along the valley margins provide geomorphological evidence for these former drainage pathways. These phases are summarized in Figure 1.

The study also highlights the significant role played by erosional processes since the Pliocene in shaping the present morphotectonic framework of the inner Central Apennines, locally exceeding the geomorphic effects of active tectonics.



SEDIMENTOLOGICAL CHARACTERISTICS OF DOLINE INFILLS IN THE DINARIC KARST OF SLOVENIA

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Dolines are closed karstic depressions typically filled with fine-grained sediment which has been interpreted in different ways; as the insoluble residue of dissolved carbonate bedrock (Cvijić, 1893), as slope-derived material accumulated in the floor (Coleman & Balchin, 1959), as allochthonous cave fills exposed by denudation (Mihevc & Zupan Hajna, 2007), or their combination. This study determines the textural, geochemical and mineralogical composition of infills in morphometrically distinct dolines.

Four areas were selected in the karst area of Slovenia by the prevailing doline type: Karst plain, Logatec–Begunje plain, Kočevski Rog and Loški Potok (Stefanovski, Cof, et al., 2025; Stefanovski, Ferk, et al., 2025). Three dolines per area were sampled (N = 12), one sample per doline, taken with a hand auger from the deepest accessible sediment (70–300 cm) to exclude bioturbation and anthropogenic disturbance. Particle-size distribution was determined by laser diffraction, elemental composition by XRF and mineralogy by XRD with Rietveld quantification, including oriented mounts of the clay fraction.

Silt dominates every sample (74–94%) and clay is below 7% throughout. Sand content is highest on Karst plain (14–29%) and lowest at Kočevski Rog (2–7%). Quartz, illite and chlorite occur in every sample, with quartz most abundant on Karst plain. Dolomite is restricted to two samples in Loški Potok (59% and 37%). Clay-fraction mineralogical composition is comparable across all four areas.

Only two components can be attributed to local bedrock: dolomite at Loški Potok, and the coupled sand and quartz maxima on Karst plain, where chert occurs in the limestone. The remaining composition, notably illite and chlorite, cannot be derived from the bedrock, since the areas which are tens of kilometres apart, differ drastically in lithology, topography and palaeogeographical settings. Silt dominance is consistent with aeolian origin (Muhs & Bettis, 2003), reported from karst elsewhere in the Dinarides (Wacha et al., 2011; Zhang et al., 2018), while aeolian sediment on Slovenian karst remains understudied and should be a focus of further research, because it obviously represents a possible origin of the infill composition.

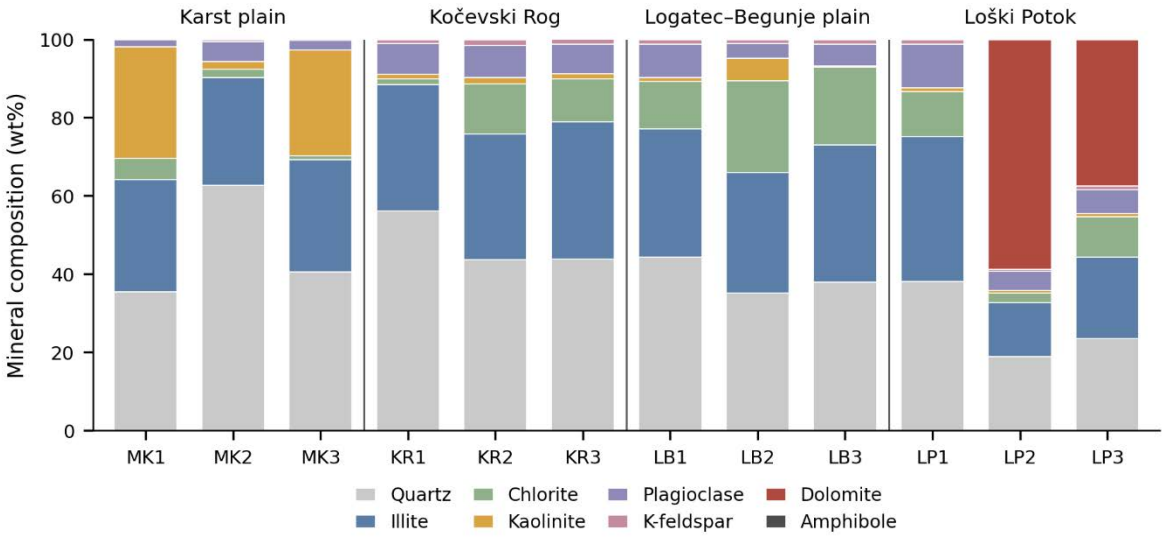


Figure 1: Mineral composition (XRD) of twelve doline infills from four karst areas.

REFERENCES

Coleman, A. M., & Balchin, W. G. V. (1959). The origin and development of surface depressions in the Mendip Hills. *Proceedings of the Geologists' Association*, *70*(4), 291–309. https://doi.org/https://doi.org/10.1016/S0016-7878(59)80011-0

Mihevc, & Zupan Hajna, N. (2007). Sestava in izvor klastičnih sedimentov iz vrtač in brezstropih jam pri Divači. In M. Knez & T. Slabe (Eds.), *Kraški pojavi, razkriti med gradnjo slovenskih avtocest* (pp. 153–162). Založba ZRC.

Muhs, D. R., & Bettis, E. A. (2003). Quaternary loess-paleosol sequences as examples of climate-driven sedimentary extremes. In *Geological Society of America Special Paper* (Vol. 370, pp. 53–74).

Stefanovski, S. (2026). *Razporeditev in morfogeneza vrtač v Sloveniji: doktorska disertacija* [Doktorska disertacija, Filozofska fakulteta]. Repozitorij Univerze v Ljubljani. Ljubljana. https://repozitorij.uni-lj.si/IzpisGradiva.php?lang=slv&id=185178

Stefanovski, S., Cof, K., Ferk, M., Verbovšek, T., & Stepišnik, U. (2025). Subsurface structure of different doline types in Slovenia: Results from electrical resistivity tomography. *Dela*, *63*.

Stefanovski, S., Ferk, M., Verbovšek, T., & Stepišnik, U. (2025). Morphometric classification and spatial distribution of dolines in southern Slovenia. *Acta geographica Slovenica*, *65*(2). https://doi.org/10.3986/AGS.13940

Wacha, L., Mikulčić Pavlaković, S., Frechen, M., & Crnjaković, M. (2011). The Loess Chronology of the Island of Susak, Croatia. *E&G Quaternary Sci. J.*, *60*(1), 12. https://doi.org/10.3285/eg.60.1.11

Zhang, J., Rolf, C., Wacha, L., Tsukamoto, S., Durn, G., & Frechen, M. (2018). Luminescence dating and palaeomagnetic age constraint of a last glacial loess-palaeosol sequence from Istria, Croatia. *Quaternary International*, *494*, 19–33. https://doi.org/ https://doi.org/10.1016/j.quaint.2018.05.045

CONTINENTAL QUATERNARY SEDIMENTS IN SERBIAN PART OF PANNONIAN PLAIN

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Thematic investigations of Quaternary sediments in Serbia commenced in parallel with the compilation of the Basic Geological Map of the SFRY at a scale of 1:100,000 and have continued since 1996 within the framework of the Formation Geological Map of the Republic of Serbia at a scale of 1:50,000. The principal methods include sedimentological, stratigraphic, morphogenetic, remote sensing, geophysical, and absolute dating techniques.

In the southern part of the Pannonian Basin, three lithogenetic complexes have been recognized following the Middle Miocene: (1) sediments of Lake Pannon, deposited during the Upper Miocene–Middle Pliocene; (2) lacustrine sediments deposited during the Upper Pliocene; and (3) continental deposits of Quaternary age, whose development was controlled by fluctuations in sea level, tectonic activity, and climatic changes. These factors significantly influenced the paleogeographic evolution of the region west of the Carpathians, resulting in changes in depositional environments, sedimentary processes, hydrographic networks, and ecosystems.

The Pannonian Plain in Serbia is covered by Quaternary deposits of diverse genetic origin, including limnic, fluvial, aeolian, colluvial, and mixed-origin sediments. The wide range of depositional environments reflects the influence of tectonic activity and paleogeographic evolution throughout the Quaternary (Rakić et al., 2002).

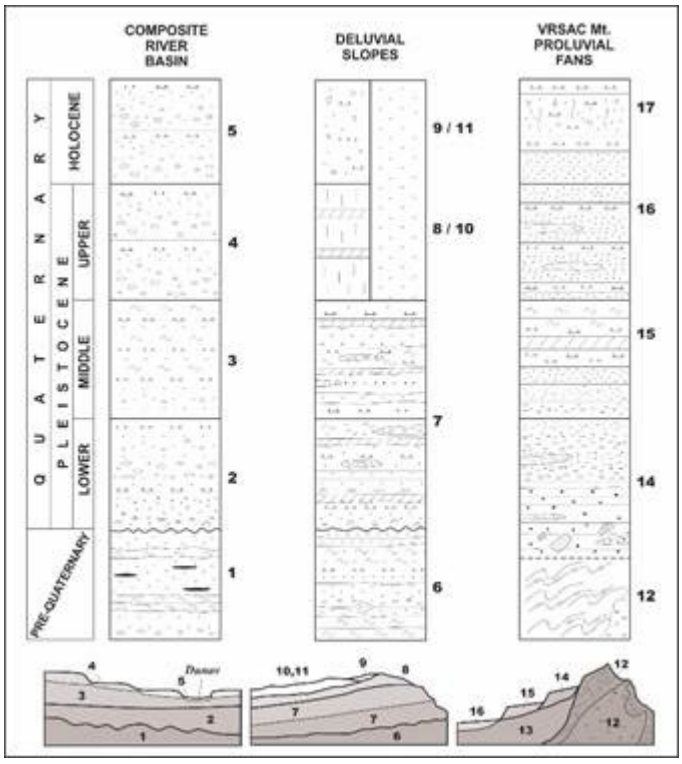


Figure 1. Correlation chart of genetic types of Quaternary sediments (Serbia).

REFERENCES

Rakić, M., Stejić, P., Simonović, S., 2002. Paleogeography of southeastern part of Pannonian Basin during Pliocene and Quaternary. Proceedings of XVII Congress of Carpathian-Balkan Geological Association in Bratislava, Geologica Carpathica, Special issue, 53, 6 p. http://www.geologicacarpathica.sk/special/R/Rakic_etal.pdf

PRELIMINARY RESULTS OF THE PROJECT MOKRO - ENVIRONMENTAL CHANGE OF THE LITTORAL KARST DURING THE LATE QUATERNARY

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The littoral karst of the Eastern Adriatic has undergone major environmental transformations driven by Quaternary sea-level fluctuations. The Modrič region, situated at the foothills of the Velebit Mountain range (Croatia) and known for its rich geo- and biodiversity, serves as an ideal natural laboratory for studying the gradual transition from subaerial to brackish to fully marine settings. To capture current ecological dynamics, we conducted a thorough monitoring of the recent physical and chemical properties in subaerial caves, brackish shallows and coastal ponds, along with identifying biological species in both cave and brackish/freshwater habitats. The evolution of the now-submerged landscape of Modrič Bay will be reconstructed using acoustic geophysical methods (MBES, SBP), combined with detailed analyses of marine sediments and geochemical proxies from speleothems in the submerged Vrulja Modrič spring. Finally, to evaluate Late Quaternary human-nature interactions, these environmental reconstructions will be integrated with historical records (cartographic sources, ships' logs, travelogues, etc.) to correlate ecosystem shifts with historical socio-economic changes.

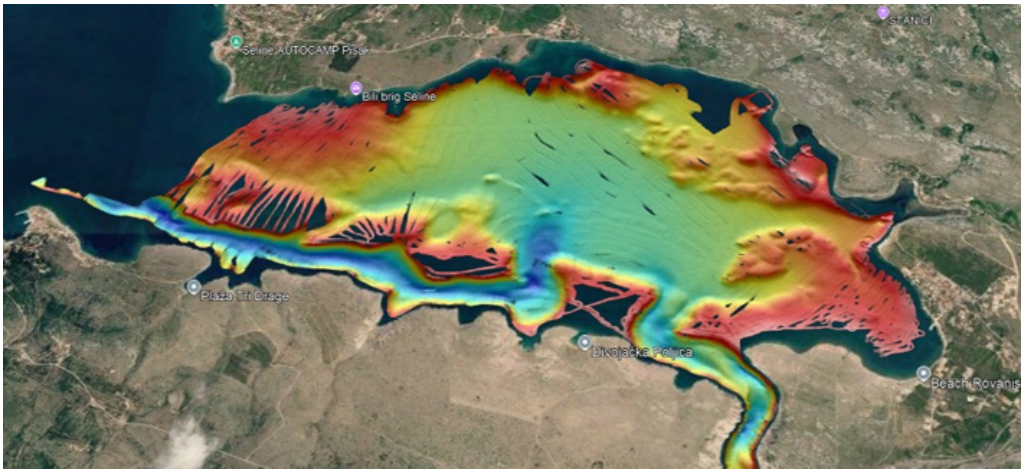


Figure 1: MBES bathymetry image showing paleorelief of the Modrič Bay and part of Velebit Channel.

The research is conducted within the project MOKRO (Environmental change of the littoral karst during the late Quaternary, IP-UNIZD2025-28060) funded by the European Union – NextGenerationEU.

COMPLEMENTARITY OF THE CAVE SEDIMENTS IN QUATERNARY ENVIRONMENTAL RECONSTRUCTION

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Following the successful speleothem-based reconstruction of the regional hydroclimate conditions during the Late Quaternary within the REQUENCRIM project (e.g. Surić et al., 2021; 2025), we launched the new QUEECAD project (*Quaternary Environmental Evolution Archived in Croatian Cave Deposits,* HRZZ IP-2025-02-6560), both funded by the *Croatian Science Foundation*. We have broadened our scope by encompassing both speleothems and clastic cave sediments, utilizing their complementarity in terms of genesis and speleogenetic phases, since the former records hydroclimate changes during calmer episodes, while the latter are produced during the tectonically and hydrogeologically more dynamic phases. We selected three caves with distinct geographical locations (Modrič Cave on the Adriatic coast, Cerovac Caves in the Velebit Mountain range and Barać Caves in northernmost Lika) and with specific environmental characteristics (varying altitudes, distances from the sea, and geological settings) in order to cover a transect from the Mediterranean, across the Dinarides, toward Central Europe. Initial site inspection and preliminary sampling have confirmed the high potential of these sites.

REFERENCES

Surić, M., Columbu, A., Lončarić, R., Bajo, P., Bočić, N., Lončar, N., Drysdale, R., Hellstrom, J. (2021): Holocene hydroclimate changes in continental Croatia recorded in speleothem $\delta^{13}C$ and $\delta^{18}O$ from Nova Grgosova Cave. Holocene, 31 (9), 1401-1416.

Surić, M., Bajo, P., Columbu, A., Lončarić, R., Lončar, N., Drysdale, R.N., Hellstrom, J.C., 2025. Reconstruction of environmental and hydroclimate changes in the Adriatic region over the last 367 kyr from Modrič Cave (Croatia) speleothems, Quaternary Science Review, 109351, 17.

TRACING THE JADRO PALAEORIVER FROM THE KAŠTELA BAY TO THE MID-ADRIATIC DEEP: EVIDENCE FROM HIGH-RESOLUTION GEOPHYSICAL DATA

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The present morphology of the eastern Adriatic coast was strongly influenced by sea-level changes during the Late Quaternary. During the Last Glacial Maximum (LGM; ca. 30–19 ka BP), sea level was approximately 120–134 m lower than today (Lambeck et al., 2014), exposing large parts of the Adriatic shelf and allowing rivers to incise into the bedrock (Maselli and Trincardi, 2013). Following deglaciation, the subsequent Holocene transgression led to the inundation of these subaerial landscapes and their gradual infilling by younger sediments (Crmarić et al., 1998; Pikelj, 2010).

This study investigates the geomorphological evolution of the Jadro River palaeosystem and its associated submerged landscapes extending from the Kaštela Bay across the Split Channel towards the Mid-Adriatic Deep (MAD). Particular attention is given to identifying the geometry and continuity of palaeochannels and assessing their possible connection with the MAD during the LGM. The reconstruction is based on the integration of high-resolution sub-bottom profiler and multibeam bathymetric data, comprising more than 500 km of geophysical profiles, supported by GIS analyses and sediment-core investigations including sedimentological, mineralogical, geochemical, palaeontological and radiocarbon analyses. Preliminary results reveal a distinct palaeofluvial network extending seaward from the present-day Jadro River mouth and record progressive environmental changes associated with Holocene transgression. These findings provide the first high-resolution reconstruction of the Late Quaternary evolution of the Jadro palaeolandscape and contribute to a better understanding of sea-level-controlled geomorphic processes in karst-dominated coastal systems of the eastern Adriatic.

This work was part of the project „Rivers Into MAD - Resolving the Jadro and Cetina palaeoriver landscapes during the Last Glacial Maximum", funded by the Ministry of Science and Education, and supported by the Croatian Science Foundation project "QMAD" (HRZZ IP-04-2019-8505).

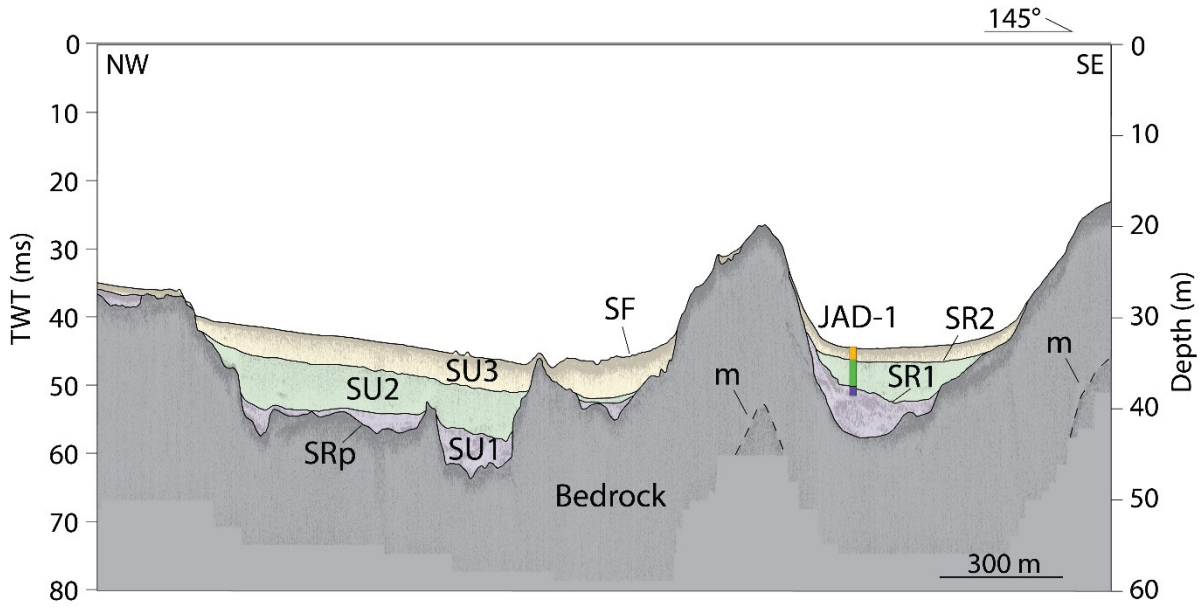


Figure 1: A well-defined palaeochannels on SBP profile in Kaštela Bay (grey – bedrock, flysch and carbonates; purple- fluvial sediment; green – estuarine sediment; yellow – marine sediment)

REFERENCES

Crmarić, R., Bogner, D., & Juračić, M., 1998. Holocenski sedimenti i sedimentacija u Kaštelanskom zaljevu. In M. Hodžić (Ed.), Znanstveno-stručni kulturološki skup, Kaštela, Zbornik radova, pp. 178-182.

Lambeck, K., Rouby, H., Purcell, A., Sun, Y., Sambridge, M., 2014. Sea level and global ice volumes from the Last Glacial Maximum to the Holocene. Proceedings of the National Academy of Sciences of the United States of America 111,

Maselli, V., Trincardi, F., 2013. Large-scale single incised valley from a small catchment basin on the western Adriatic margin (central Mediterranean Sea). Global and Planetary Change 100, pp. 245–262. https://doi.org/10.1016/j.gloplacha.2012.10.008 pp. 15296–15303. 10.1073/pnas.1411762111

Pikelj, K., 2010. Sastav i porijeklo sedimenata dna istočne strane Jadranskog mora. Sveučilište u Zagrebu, pp. 1-239.

QUATERNARY FLUVIAL FEATURES AS MORPHOTECTONIC MARKERS ABOVE A BURIED INVERSION FAULT ZONE AT THE NORTHERN SAVA BASIN MARGIN, CENTRAL CROATIA

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The northern margin of the western Sava Basin is a part of the SW Pannonian Basin System, where Miocene syn-rift extension and post-rift subsidence were followed by Late Miocene to Quaternary compression and positive inversion of inherited structures (Prelogović et al., 1998; Tomljenović and Csontos, 2001). Although the basin subsurface tectonic evolution is relatively well constrained (e.g., Velić, 1983; Lučić et al., 2001; Pavičić et al., 2019), its surface expression remains poorly understood. This study presents preliminary surface-to-subsurface observations from the Sesvete–Ivanić-Grad–Kutina sector (Fig. 1), based on LiDAR-derived DEM interpretation, geomorphic mapping and interpretation of the 3D reflection-seismic data. Possible Quaternary morphotectonic markers were detected within the fluvial landscape above the broader fault zone, including terrace-like surfaces, abandoned meanders, linear topographic scarps and possible uplifted terrains (Fig. 1a). Three terrace levels are tentatively distinguished along the valley

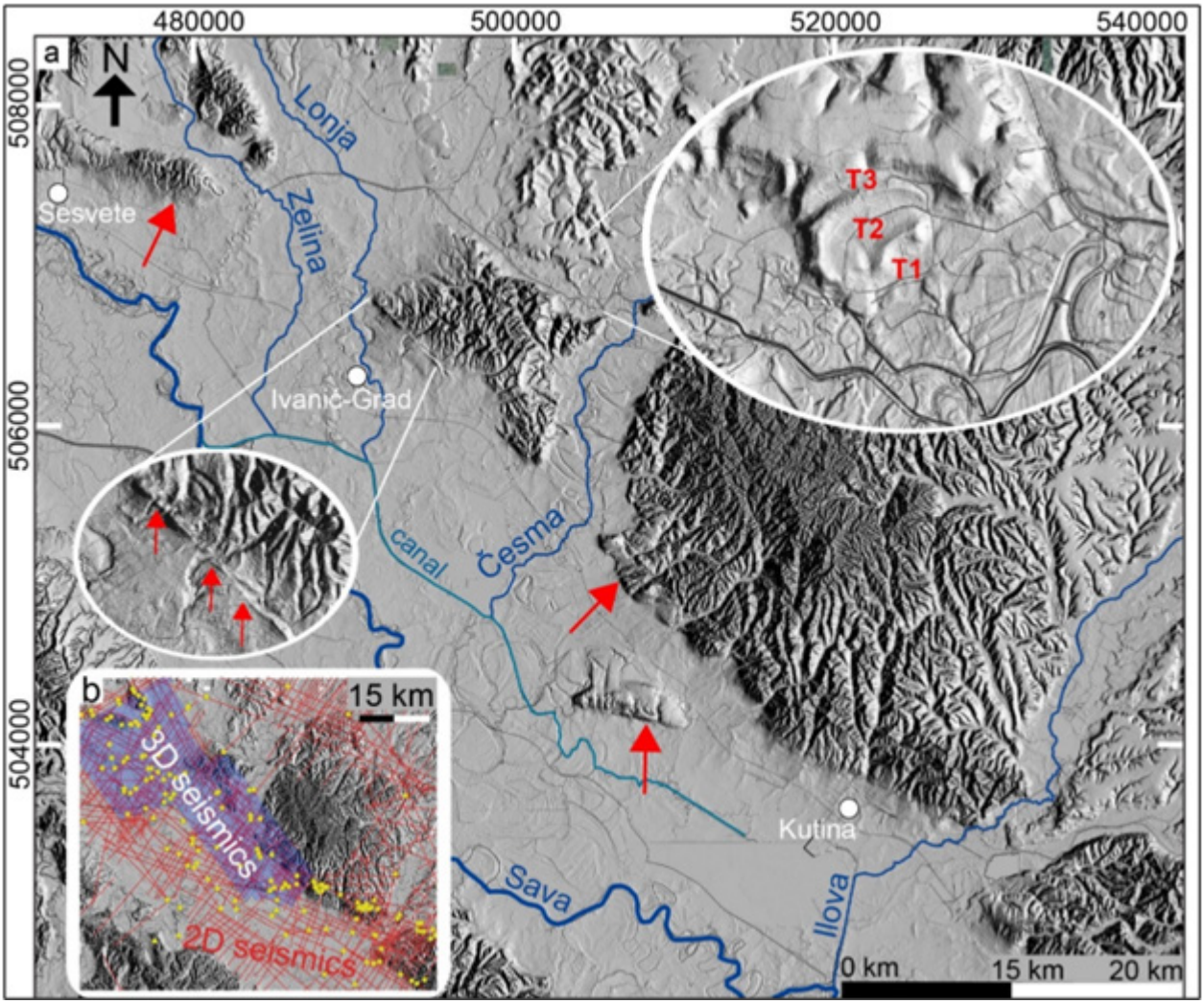


Figure 1: (a) LIDAR-derived hillshade DEM of the study area showing three levels of fluvial terraces (T1–T3) and linear topographic scarp (red arrows). (b) Available 3D, 2D seismic and well data (data available from the State Geodetic Administration (DGU) and Croatian Hydrocarbon Agency (AZU)).

of the present-day left tributaries of the Sava River. The most indicative geomorphic feature is a distinct topographic scarp that, within the mapping uncertainty, overlies an inverted basin–margin fault zone imaged in the 3D seismic data (Fig. 1b), and can potentially present a fault scarp. Additional features show orientations comparable to NW–SE- and NE–SW-trending marginal faults and associated folds deforming the Upper Miocene to Pliocene sedimentary succession. At this stage, the observed correlation between surface relief morphology and subsurface structure is treated as a working hypothesis for a possible geomorphic expression of a blind inversion-related fault zone that needs to be further examined. This distinction is relevant because NW Croatia contains active seismogenic fault zones, whereas this sector is comparatively weakly expressed in instrumental seismicity (Herak et al., 2009). The distinction between tectonic and fluvial or inherited structures control will be tested through morphostratigraphic analysis, field verification, sedimentological logging, dating of selected terrace levels and near-surface geophysics.

REFERENCES

Herak, D., Herak, M., Tomljenović, B., 2009. Seismicity and earthquake focal mechanisms in north-western Croatia. Tectonophysics 465, 212–220. https://doi.org/10.1016/j.tecto.2008.12.005

Lučić, D., Saftić, B., Krizmanić, K., Prelogović, E., Britvić, V., Mesić, I., Tadej, J., 2001. The Neogene evolution and hydrocarbon potential of the Pannonian Basin in Croatia. Marine and Petroleum Geology 18, 133–147. https://doi.org/10.1016/S0264-8172(00)00038-6

Pavičić, I., Rukavina, D., Matoš, B., Tomljenović, B., 2019. Interpretation of the tectonic evolution of the western part of the Sava Depression: structural analysis of seismic attributes and subsurface structural modeling. Journal of Maps 15, 733–743. https://doi.org/10.1080/17445647.2019.1663374

Prelogović, E., Saftić, B., Kuk, V., Velić, J., Dragaš, M., Lučić, D., 1998. Tectonic activity in the Croatian part of the Pannonian basin. Tectonophysics 297, 283–293. https://doi.org/10.1016/S0040-1951(98)00173-5

Tomljenović, B., Csontos, L., 2001. Neogene–Quaternary structures in the border zone between Alps, Dinarides and Pannonian Basin (Hrvatsko Zagorje and Karlovac Basins, Croatia)· International Journal of Earth Sciences 90, 560–578· https://doi.org/10.1007/s005310000176

Velić, J., 1983. The Neotectonik Relations and development of the western part of the Sava river depression· Geološki vjesnik 13 (2), 26-65·

RECONSTRUCTING PLIOCENE–PLEISTOCENE CHANGES OF CAVE SEDIMENTATION USING TECTONIC UPLIFT PHASES (POSTOJNA CONTACT KARST, W SLOVENIA)

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Sedimentological changes and speleogenesis in the Postojna Karst were primarily attributed to climatic fluctuations. Recent multidisciplinary research demonstrates that karst development is controlled by a combination of factors, among which tectonic activity may play a dominant role. Using the Slovenian Classical Karst tectonically active areas is therefore key for understanding Pliocene to Pleistocene karst evolution (e.g. Zupan Hajna et al., 2020, 2024). This study reconstructs sedimentological changes in the contact karst of the Postojna Basin (W Slovenia) by linking them to tectonic uplift phases recorded in cave systems. The region is influenced by the compressional tectonic regime of the External Dinarides and the counter-clockwise rotation of the Adria Microplate since ~6 Ma. These processes have altered drainage patterns within fragmented karst blocks, as evidenced by studies of cave allogenic sediments. Two main sedimentary records are preserved in levelled and extensive cave systems: allogenic clastic sediments deposited under (epi)phreatic conditions and speleothems formed in vadose environments. Their succession provides a chronological framework for interpreting hydrological shifts. Dating techniques, including paleomagnetism and U-Th methods, enable the timing of transitions between these depositional environments. Results indicate that major hydrological changes in the Postojna Basin, particularly the redirection of the Nanoščica River, occurred between 3.59 Ma and 1.77 Ma and were driven by tectonic uplift rather than climate. Tectonically stable phases correspond to periods of horizontal cave development with allogenic sedimentation, whereas uplift phases are reflected by vertical percolation and speleothem formation. By combining geomorphological mapping, cave investigations, sedimentological data, and geochronological analyses, this approach identifies tectonic uplift as the key factor controlling hydrological evolution in tectonically active contact karst regions, including the Dinaric Mountains. The methodology also offers a reliable framework that can be applied to comparable karst environments worldwide.

REFERENCES

Švara, A., Kdýr, Š., Pruner, P., Bosák, P., Horáček, I., Zupan Hajna, N., 2022. Preliminary results on the sedimentation and speleogenesis of the cave Šimčev spodmol (Slavinski ravnik corrosional plain, SW Slovenia), in: Švara, A., Zupan Hajna, N., Gabrovšek, F. (Eds.): 29th International Karstological School »Classical Karst«, Speleology, within the International Year of Caves and Karst, Abstracts & Guide Book, 13th-17th June, 2022, Postojna. Založba ZRC, pp. 129-130.

Zupan Hajna, N., Bosák, P., Pruner, P., Mihevc, A., Hercman, H., Horáček, I., 2020. Karst sediments in Slovenia: Plio-Quaternary multi-proxy records. Quaternary International, 546, 4-19. https://doi.org/10.1016/j.quaint.2019.11.010

Zupan Hajna, N., Pruner, P., Bosák, P., Mihevc, A., 2024. Temporal insights into karst system evolution: A case study of the unroofed cave above Škocjanske Jame, NW Dinarides. Geomorphology, 461. https://doi.org/10.1016/j.geomorph.2024.109282

BIRDS FROM THE QUATERNARY DEPOSITS OF THE CAVE PUPIĆINA PEĆ IN ISTRIA

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Pupićina Cave represents an important Quaternary cave site in the north-eastern Istria, spanning the period from the late Pleistocene to the late Holocene, with a rich archaeological and paleontological record (Miracle, 2006).

The study analyses 258 avian bone remains recovered during excavations conducted between 1995 and 1999, with the aim of determining taxonomic diversity, taphonomic processes, and the role of birds in the paleoenvironment (Trčak, 2026). Anatomical and taxonomic identification of the avian bones was carried out, accompanied by a detailed analysis of taphonomic marks.

The assemblage comprises 8 orders, 10 families, 26 genera, and 29 species. Order Passeriformes is the most abundant, followed by order Strigiformes, Accipitriformes, and Galliformes, while Piciformes, Columbiformes, and Falconiformes are present in smaller numbers. The identified avian fauna reflects a diverse environment that included both open and forested habitats, with a limited presence of aquatic habitats. Taphonomic analysis indicates that predators, particularly owls, played a significant role in the accumulation of avian remains, while anthropogenic traces, such as burning and cut marks, suggest occasional human interaction with the avian fauna. The proportions of bird species that live in forest habitats do not change dramatically which indicates minor changes in the dominant habitat over time (Figure 1). These results contribute to the reconstruction of environmental conditions and human interactions with birds in north-eastern Istria during the Late Pleistocene and Holocene.

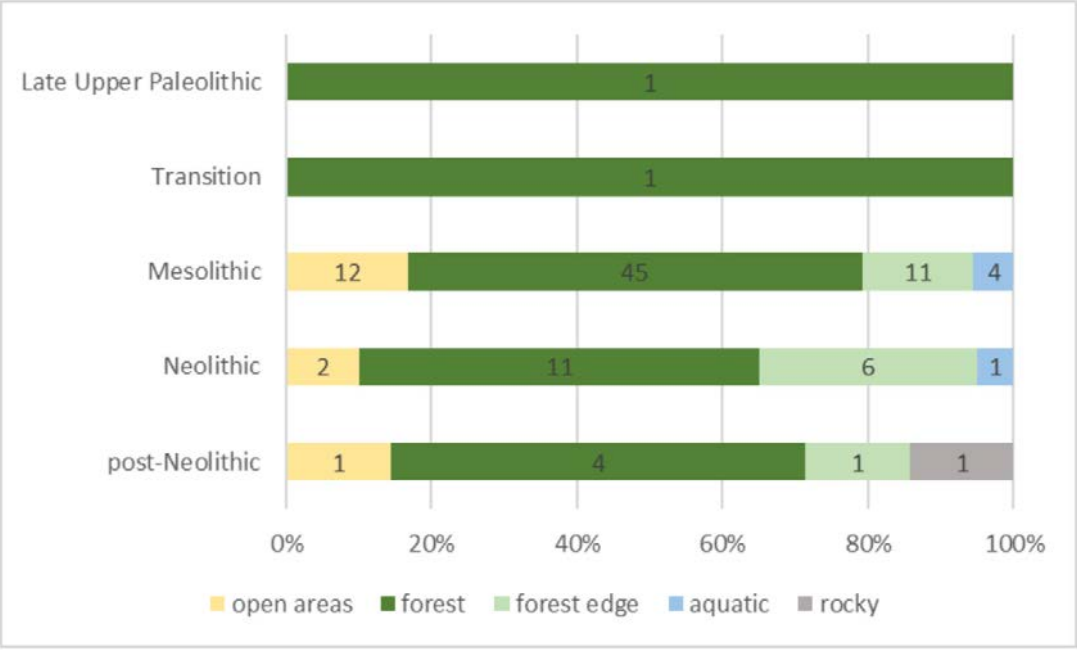


Figure 1: The graph shows habitat types and number of bird species inhabiting them found in the area of Pupićina Peć cave throughout the periods.

REFERENCES

Miracle, P. T., 2006. Prehistoric herders of northern Istria: the archaeology of Pupićina Cave. 1. Archaeological Museum of Istria, pp. 1-542.

Trčak, T., 2026. Ptice iz kvartarnih naslaga Pupićine peći u Istri, Master's thesis, University of Zagreb, Faculty of Science, Department of Geology, pp. 1-66.

CONSTRAINING TECTONIC MOVEMENTS USING QUATERNARY DEPOSITS PRESERVED ON THE CENTRAL ADRIATIC OFFSHORE ISLANDS

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Quaternary deposits are only occasionally preserved along the eastern Adriatic coast and on the Adriatic islands. Despite their limited occurrence, these deposits provide valuable records for reconstructing past environmental conditions, particularly climate variability and sea-level fluctuations, as well as tectonic activity. Consequently, they represent an important source of information for understanding the Quaternary evolution of the eastern Adriatic region. Within the framework of the SALTECTA project (Salt diapirs and active tectonics in the central Adriatic - HRZZ_IP-2024-05-2957) funded by the Croatian Science Foundation, we investigated three offshore Adriatic islands where such deposits have been found. The SALTECTA project aims to study salt tectonics and the relation between salt diapirs and moderate seismic activity in the central Adriatic. One objective of this project is to determine the timing of uplift of the basement of the Quaternary deposits and, consequently, the possible occurrence of salt diapirs exposed at the surface. On the Island of Biševo, eolian sand deposits are very similar to the Last Glacial eolian sand from the Island of Vis, while on the Island of Palagruža, several layers of colluvial deposits are preserved and exposed. The Island of Brusnik is characterised by uplifted marine conglomerates deposited during the former Quaternary sea-level highstands. Establishing a reliable chronology of Quaternary sedimentary records on the offshore Adriatic islands using multiple dating methods is essential for reconstructing the timing of depositional events and constraining the tectonic uplift of the area, which is primarily associated with vertical movements driven by salt tectonics. Our results will thus provide new insights into the Quaternary palaeoenvironmental evolution and tectonic history of the central Adriatic region.

ALLOGENIC DEPOSITS OF BARAĆ AND CEROVAC CAVES: DESCRIPTION, SAMPLING AND FIRST RESULTS

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As part of the project Quaternary Environmental Evolution Archived in Croatian Cave Deposits (QUEECAD), sediments from the Upper and Lower Barać and Upper Cerovac caves were logged and sampled at high resolution for a multi-proxy study to reconstruct their depositional mechanisms and provenance and to establish a chronological framework.

The sampled cave sediments are usually up to 2 m thick and show alternating intervals of authigenic and allogenic detritus deposited in various settings, interrupted by several phases of flowstone deposition. These alternations likely reflect regional groundwater-level fluctuations that caused repeated shifts between phreatic and vadose conditions, thereby controlling sedimentary environments within the cave and influencing speleogenesis. First results obtained from samples from the Upper Barać cave clearly distinguish deposits from the diamicton, slackwater and entrance talus sediment facies. The grain size and XRF data points to a shift from allogenic fluvial sediment input to authigenic deposition, a change that can be correlated with the evolution of the local landscape. Preliminary U-Th dating results for the flowstone imply continuous sediment accumulation until around 106 ka ago, while OSL dating and paleomagnetic measurements, if successful, could provide the timing of the sediment's entry into the cave system. The first insight into the mineralogical composition of the samples links the siliciclastic detritus to local surface sources, in particular Miocene lake deposits in the area. Magnetic proxies will reveal information about past environmental conditions in the caves and their surface environment.

FIRST RESULTS FROM THE GEOFRAME-BOVEC PROJECT

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The Geomorphological and Geochronological Framework for DOVE Phase 2 Drilling in Bovec Basin (GEOFRAME-BOVEC) project provides scientific support to Phase 2 of the ICDP DOVE (Drilling Overdeepened Alpine Valleys) initiative, which aims to reconstruct the Quaternary glacial, environmental, and climatic history of the Alps using sediment cores from overdeepened valleys. Reliable interpretation of the Slovenian DOVE drilling site in the Bovec Basin requires a robust geomorphological, sedimentological, and geochronological framework of the surrounding area, which forms the central objective of this project.

Building on previous work that established a national database of glacial landforms (Žebre et al., 2021) and the first glacial chronology of the Soča Valley (Žebre et al., 2026), GEOFRAME-BOVEC refines and extends these datasets through three main objectives: (1) producing a high-resolution geomorphological map of glacial and related landforms, (2) constraining the age of key landforms and deposits using state-of-the-art geochronological methods, and (3) integrating spatial and temporal data to reconstruct the extent and timing of past glaciations in the Soča Valley as well as providing a contextual basis for drill-core interpretations. The project runs from May 2026 to April 2028 and is structured into three scientific work packages (WP). WP1 focuses on the characterization of palaeoglacial landforms and deposits through GIS-based analysis and detailed field geomorphological mapping, complemented by sedimentological analyses and geophysical investigations, WP2 will establish a chronological framework, while WP3 will deliver a spatio-temporal reconstruction of glacial evolution in the Bovec Basin. The project is currently in its initial phase, with active work on WP1, primarily involving GIS analysis and field-based geomorphological mapping.

This work has received funding from the Slovenian Research and Innovation Agency (ARIS) under the Development Pillar project Geomorphological and Geochronological Framework for DOVE Phase 2 Drilling in the Bovec Basin (GEOFRAME-BOVEC).

REFERENCES

Žebre, M., Gostinčar, P., Jamšek Rupnik, P., Mencin Gale, E., Jež, J., Stepišnik, U., Atanackov, J., Bavec, M., 2021. Database of glacial landforms of the Alps-Dinarides junction. eGeologija. Available at: https://egeologija.si/geonetwork/srv/slv/catalog.search#/metadata/e1dfec8c-d485-453b-aa7e-d058069751ed

Žebre, M., Gostinčar, P., Jamšek Rupnik, P., Mencin Gale, E., Jež, J., Stepišnik, U., Gerčar, D., Monetato, G., 2026. Soča glacier during the Last Glacial Maximum, SE European Alps. Book of abstracts, 11th International Conference on Geomorphology (IAG), Christchurch, New Zealand, p. 940.

4–6 November 2026

Čatež ob Savi, Slovenia

Pliocene-Quaternary evolution of the Krško Basin:

FIELD TRIP GUIDE

Eva Mencin Gale, Petra Jamšek Rupnik, Jure Atanackov, Miloš Bavec,
Rok Brajkovič, Josipa Maslač Soldo

8th RMQG



INTRODUCTION

The Krško Basin is situated in the southeastern Alpine foreland at the junction of the Alps, Dinarides, and Pannonian Basin System (Schmid et al., 2020). Its geological and geomorphological evolution is controlled by the NNE-SSW trending Krško Syncline, where the interaction of sedimentation, folding, uplift, and subsidence is reflected in the fluvial morphostratigraphy. The preserved fluvial succession spans from the Pliocene to the Holocene, providing a long-term archive for reconstructing landscape evolution.

On the excursion we will visit key Quaternary sites in the Krško Basin where the Pliocene to Quaternary evolution of the Krško Basin will be presented through a combination of surface and subsurface geomorphological, sedimentological, geophysical, drilling, geochronological, structural, and archaeological data (Fig. 1). At **Globoko pit (stop 1)** we will visit typical succession of Early Pleistocene fluvial sediments. At **Dečno selo (stop 2)** the results of subsurface and paleoseismological studies will be presented. At the viewpoint near **Prilipe (stop 3)** we will observe geomorphological features of the Krško Basin and succession of fluvial and colluvial sediments. Results of the cross-border geomorphological investigations of the Sava Basin in Croatia will also be presented. Lastly, we will visit the **Drnovo site (stop 4)** where subsurface data on basin infill and structural evolution, surface data of the Holocene floodplain, and Roman municipium Neviodunum will be presented, illustrating the interaction between Quaternary landscape evolution and human settlement.

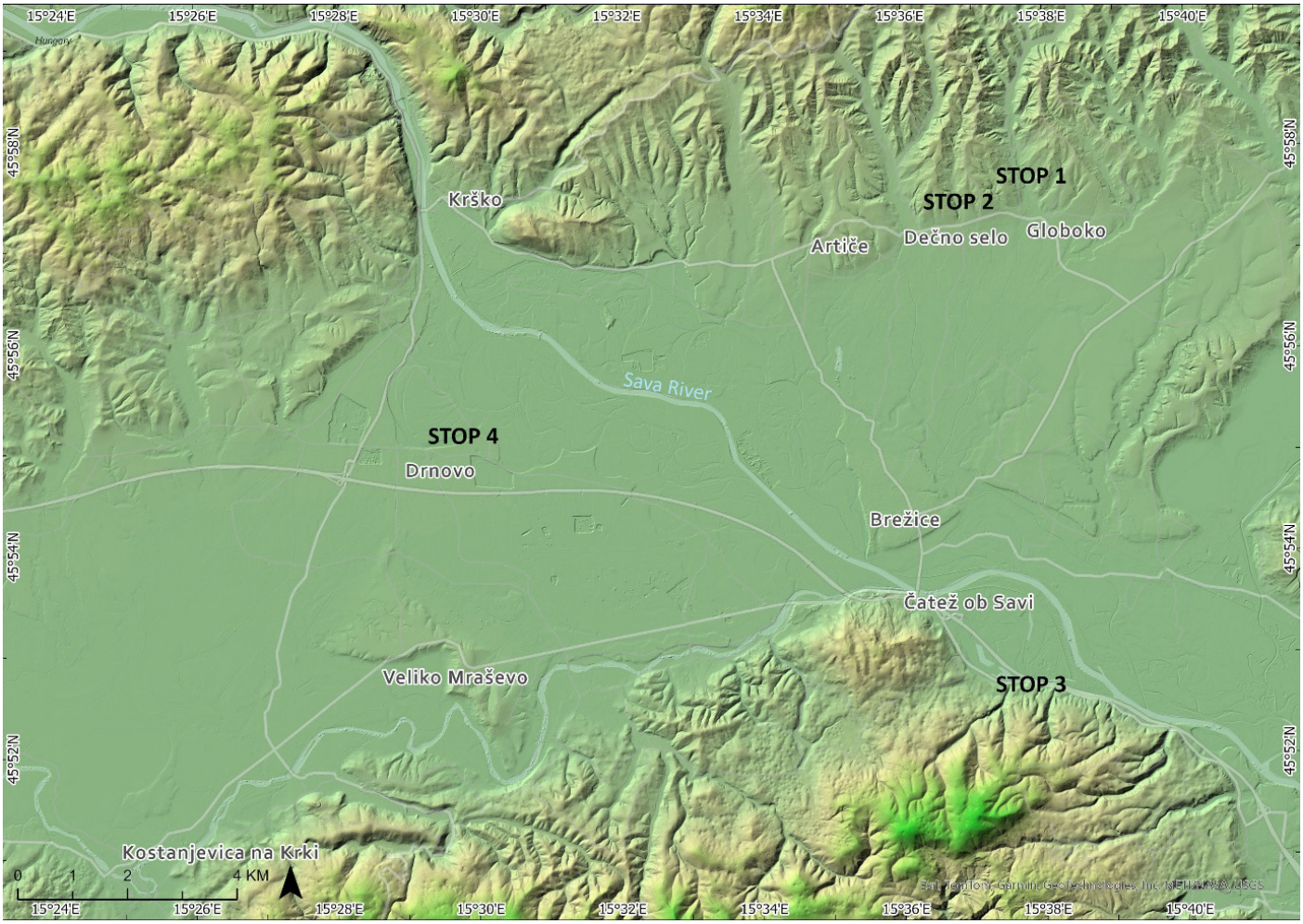


Figure 1: Overview of location stops in field trip with stops in Globoko (stop 1), Dečno selo (stop 2), Prilipe (stop 3) and Drnovo (stop 4).

The basin extends between the Krško and Bizeljsko Hills to the north and the Gorjanci Mountains to the south. It covers approximately 280 km², with a floodplain at around 150 m a.s.l. drained by the Sava, Krka, and Sotla rivers. The surrounding hilly catchment reaches elevations of up to 1178 m a.s.l. The pre-Tertiary basement of the Krško Basin is composed of Mesozoic sedimentary rocks overlain by more than 2000 m of Neogene deposits, reflecting a transition from marine and deltaic to fluvial environments (Figs. 2-4; Poljak, 2017). The Quaternary record comprises an extensive sequence of fluvial terraces preserved across the basin or buried beneath younger deposits. Their morphology and distribution represent a classic syncline depositional model with Pliocene, Pleistocene, and Holocene record. Terrace staircase is generally divided into Pliocene – Middle Pleistocene surfaces, Middle Pleistocene surfaces and Late Pleistocene-Holocene surfaces (Figs. 5-6). This makes the Krško Basin an important site for investigating long-term fluvial evolution in the Southeastern Alpine Foreland.

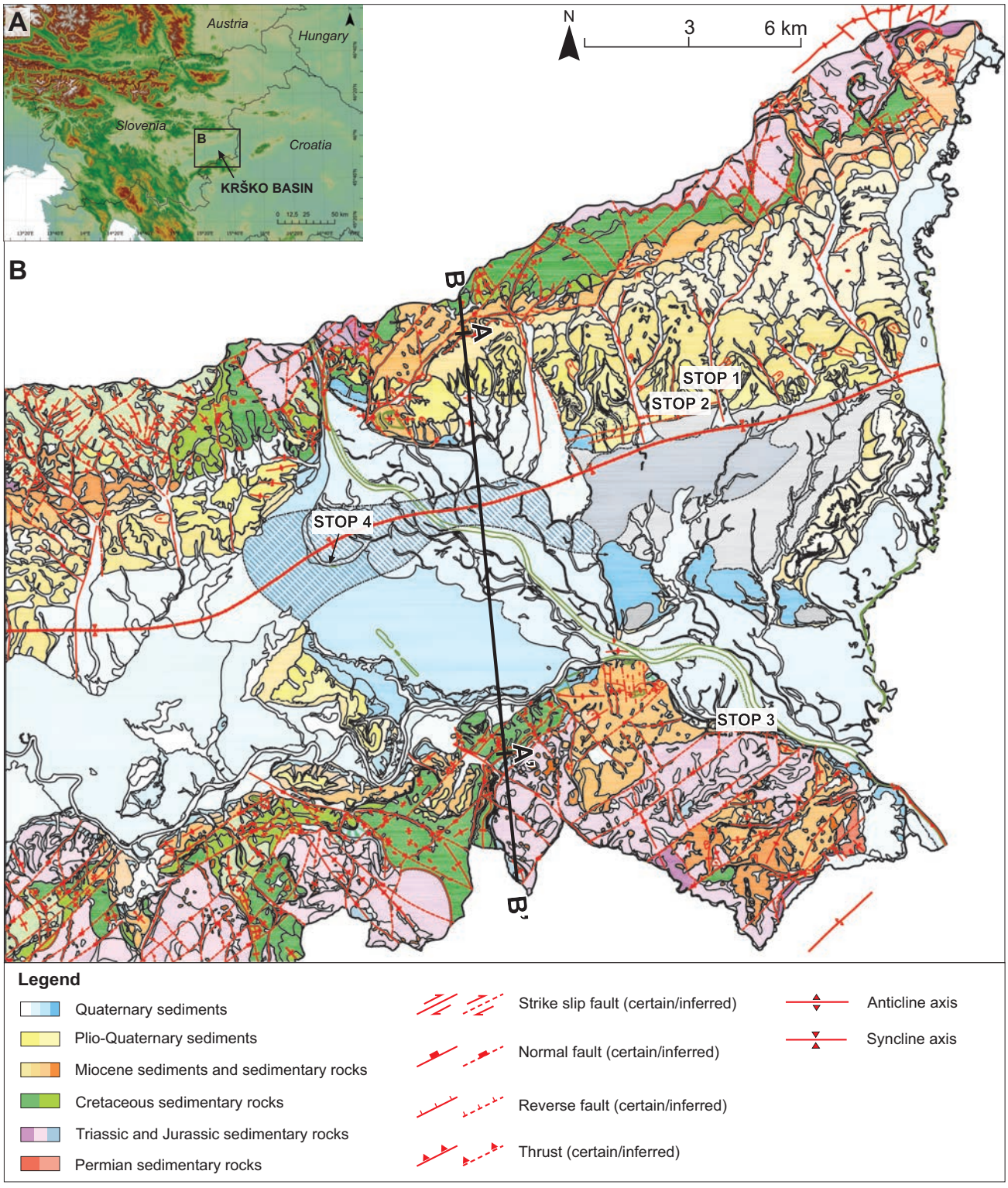


Figure 2: A - Location of Krško Basin in SE Slovenia. B - Geological map of the eastern part of the Krško Basin with indicated excursion stops (simplified after Poljak 2017; for a fully detailed map legend see Poljak, 2017).

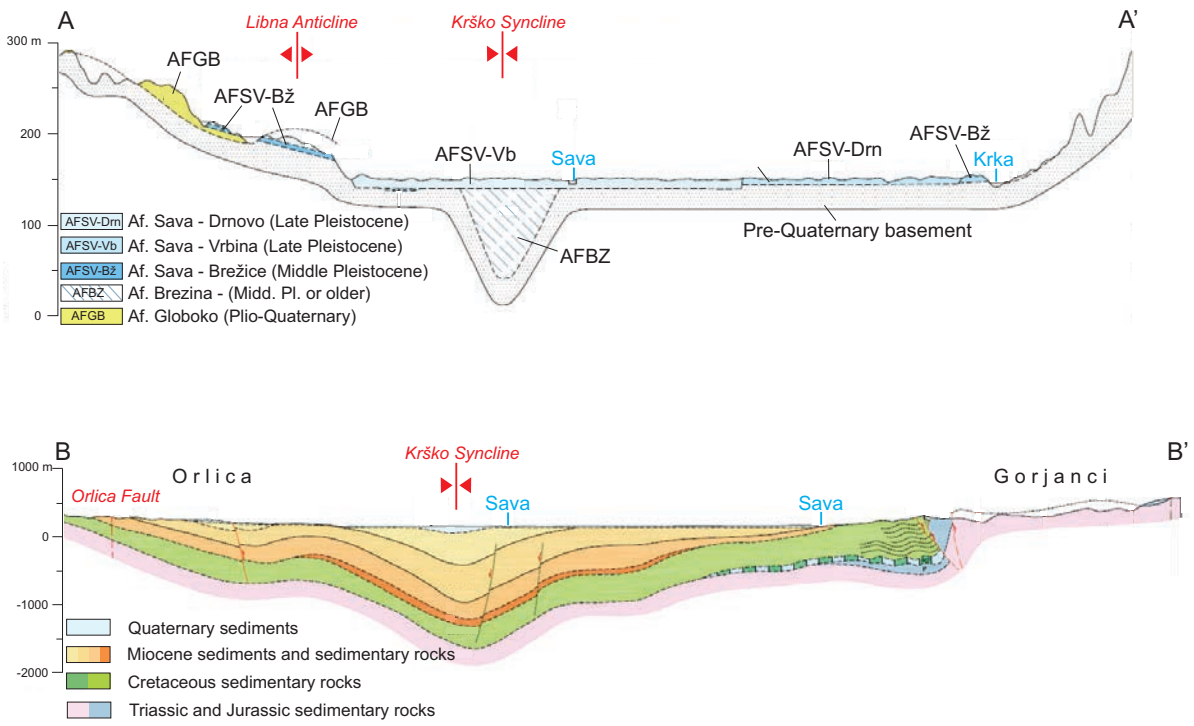


Figure 3: Geological cross sections of the Krško Basin (modified after Poljak (2017)). Location of the sections is depicted in Figure 1.

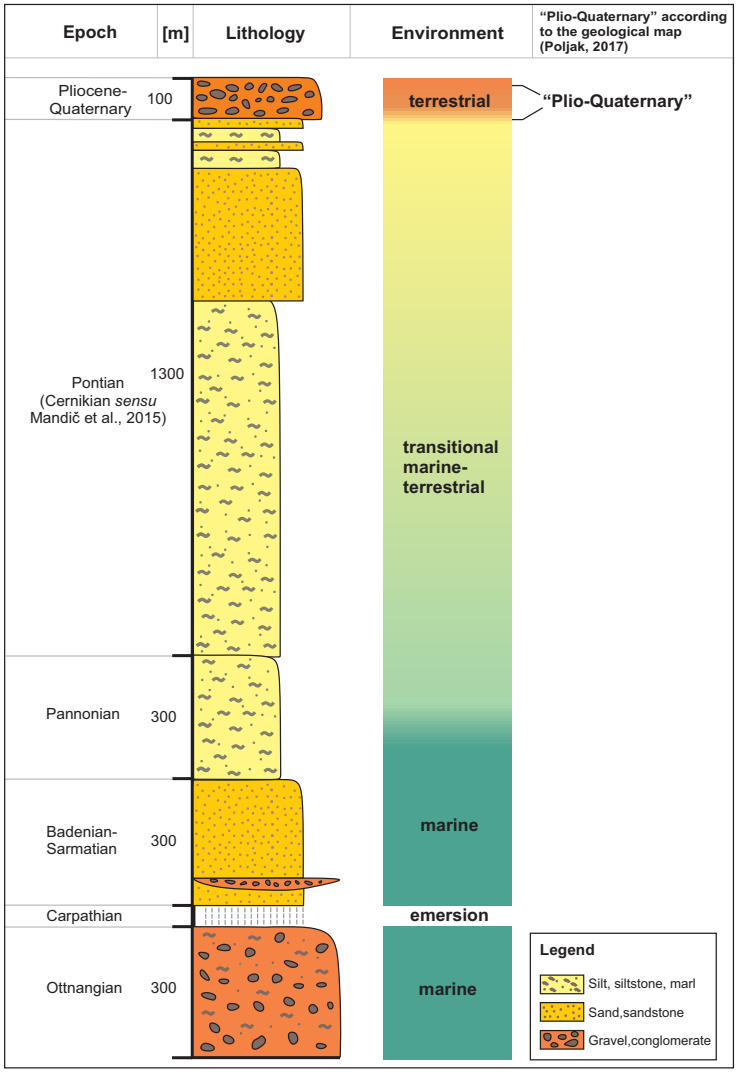


Figure 4: Geological column of the Krško Basin (Mencin Gale, 2021; modified after Poljak, 2017).

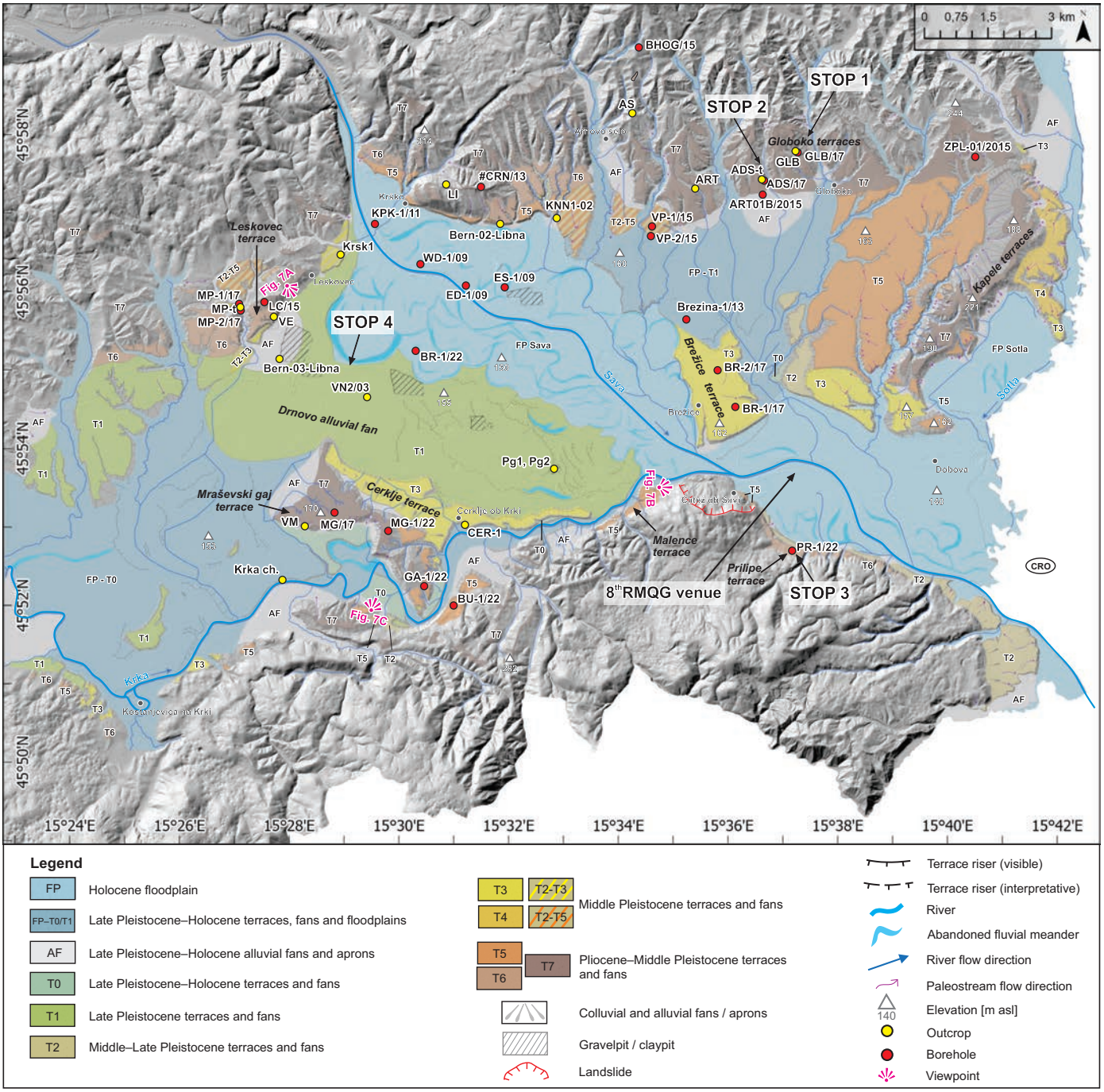


Figure 5: Geomorphological map of the Krško Basin (modified from Mencin Gale, 2021) with indicated excursion stops.

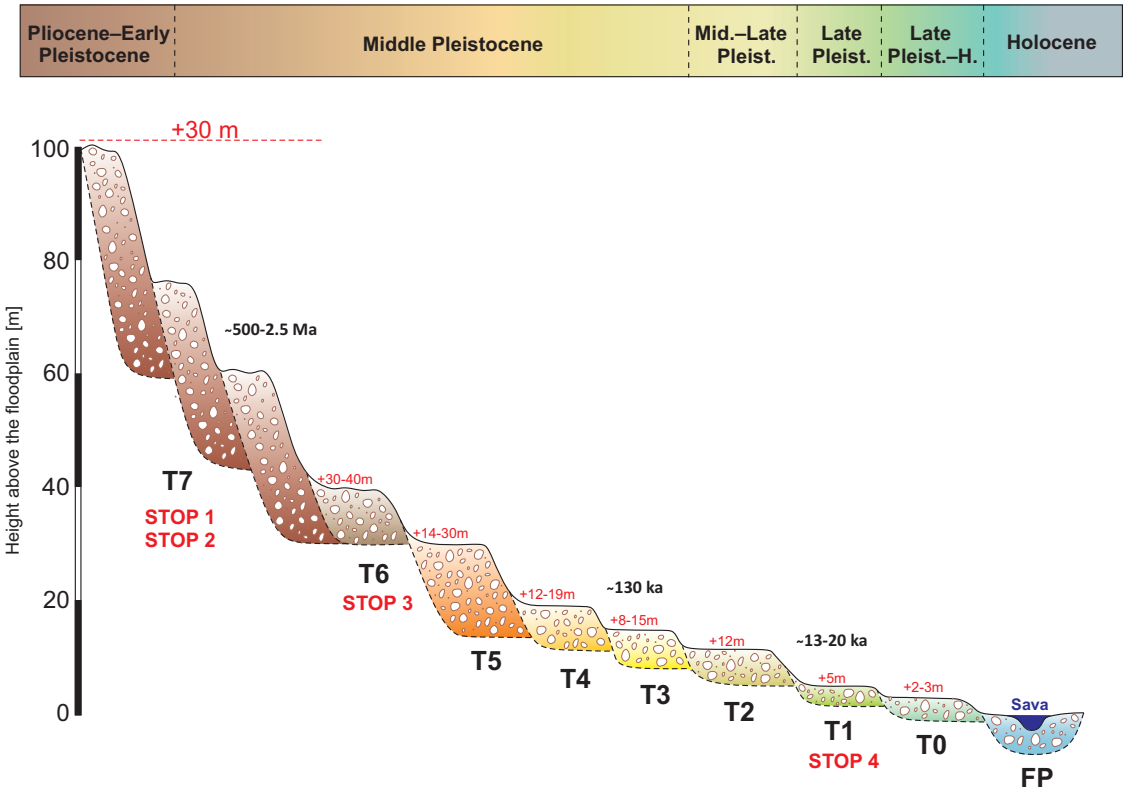


Figure 6: Schematic profile of the terrace and fan systems in the Krško Basin with levels marked (T0, T1, T2, T3, T4, T5, T6 and T7), together with their relative heights above the Holocene floodplain (FP) and a summary of age constraints.



Figure 7: Field photos of geomorphic features associated with Pliocene-Quaternary deposition and erosion in the Krško Basin.

STOP 1: GLOBOKO

The area surrounding the Globoko village and the Globoko abandoned pit is located in the northern rim of the Krško Syncline and represents a key locality for studying the Pliocene-Middle Pleistocene succession in the Krško Basin. In the abandoned pit the succession of the Neogene coal-bearing series is overlain by the terrestrial "Plio-Quaternary" succession formally defined as the Globoko Alloformation (Verbič, 2004; Poljak, 2017; Figs. 2, 3). Sedimentary succession begins with thick gravel deposits that fine upward and terminate with sand and silt horizons, which are often pedogenized (Poljak, 2017, Fig. 8). The palaeosols developed within the sedimentary succession are relatively thin, approximately one metre thick, whereas the uppermost soil horizon reaches a thickness of 5–6 metres. Within the gravel and sand deposits, small lenses of poorly rounded and strongly weathered chert occur. This material is derived from the local catchment, most likely from Jurassic–Cretaceous deep-marine sedimentary rocks (Poljak, 2017).

The total thickness of the succession exposed in the Globoko abandoned pit is approximately 30 metres, now mostly overgrown due to the abandonment of the mining. The gravel is dominated by non-carbonate material derived from the Sava River (Verbič, 2004; Poljak, 2017; Mencin Gale, 2021).

The morphology of the succession exhibits rough and strongly degraded relief because of degradation processes. The surfaces are often only remnants of the former morphology of sedimentary bodies, preserved in narrow, flat-crested tops. Risers are still partly preserved, although numerous ephemeral and perennial streams and extensive water erosion of the hillslopes are observed.

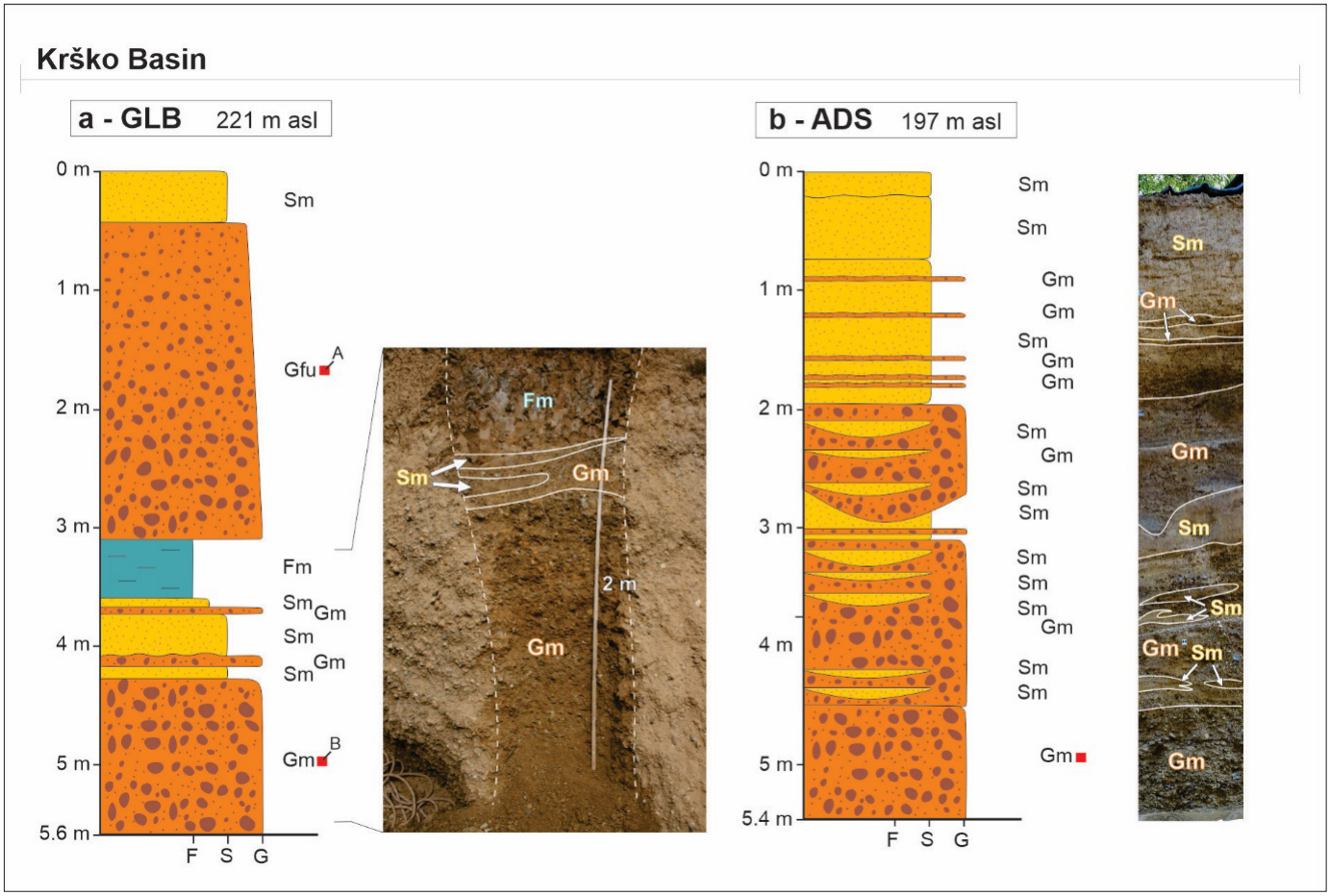


Figure 8: Sedimentological sections from the Globoko pit (GLB, stop 1) and Artiče-Dečno selo exploratory trench (ADS, stop 2; Mencin Gale, 2019).

STOP 2: ARTIČE - DEČNO SELO

Artiče and Dečno selo villages are located on the northern rim of the Krško Basin along the NNE-SSW trending Artiče scarp (Fig. 9). The sediments at the Artiče scarp are a part of the high-level terrace group and were deposited in a predominantly fluvial environment where local re-sedimentation of the material with slope processes was also very influential. The observed facies associations in the studied section (Fig. 8) and geomorphological observations (Fig. 5) indicate a high-energy fluvial environment exchanging with low-energy fluvial environments and (re-)sedimentation in alluvial and colluvial fans. Well-rounded clasts point to long-distance transport which is supported by clast lithological analysis. Based on the observed facies architecture in the exploratory pit at the Artiče-Dečno selo locality braided river system is interpreted, which was already suggested by previous authors (Verbič, 2004). An approximate east-west direction of the paleo-flow was observed.

The Artiče scarp is the surface expression of the folding above the Artiče blind reverse fault tip, a fold scarp. The Artiče fault is an ENE-WSW striking. north-dipping blind reverse fault (Jamšek Rupnik et al., 2019; Atanackov et al., 2021). The structure of the fold (Fig. 10) was constrained in the 1980s with the data from the Globoko clay pit and coal mine (Markč et al., 1986; Markič and Rokavec, 2002; Markič et al., 2025). The fold is approximately 600 m wide with the T7-T5 sediments uplifted across the fold by approximately 240 m (Markič and Rokavec, 2002). The structure was confirmed by seismic reflection data (Gosar and Božiček, 2007; Accaino et al., 2014) and P-wave and S-wave shallow, high-resolution seismic reflection data (Fig. 11; Jamšek Rupnik et al., 2016). The strata north of the fold transition into a south-dipping monoclinal north limb of the Krško Syncline (Gosar and Božiček, 2006). A paleoseismological trench was excavated on the Artiče scarp to investigate the near-surface sediments and structure (Jamšek Rupnik et al., 2019).



Figure 9: Artiče scarp in the northern rim of the Krško Basin.

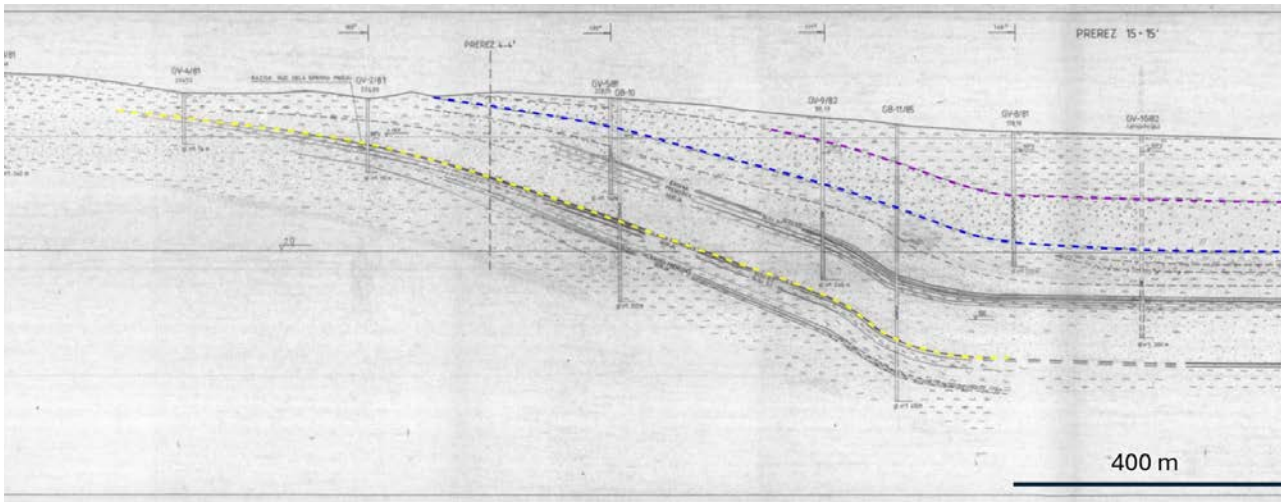


Figure 10: Geological cross section (generally N-S, N on the left) across the Artiče fold scarp based on geological data from the Globoko clay pit and coal mine. Violet – top of Plio-Quaternary fluvial gravels (T7-T5), blue – base of Plio-Quaternary fluvial gravels (T7-T5), yellow – middle lignite coal seams of the Globoko coal mine, Late Pannonian (cross section from Markič et al., 1986).

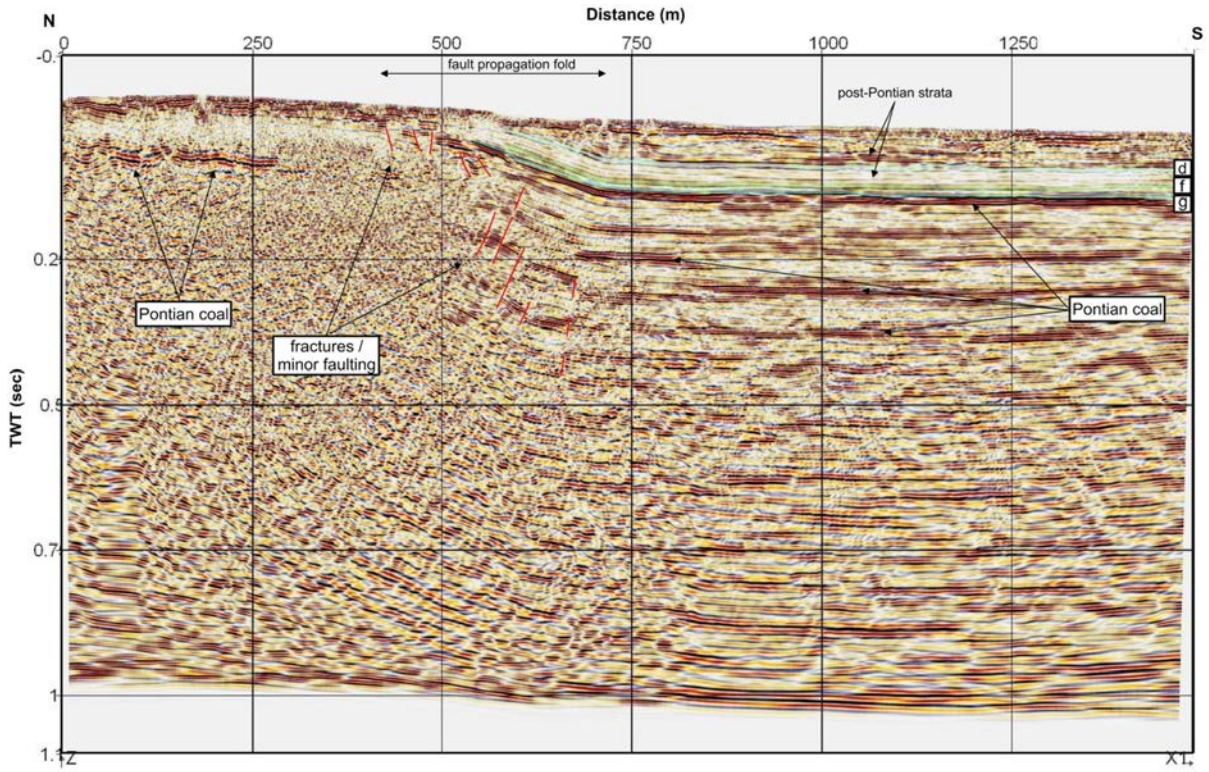


Figure 11: HRS Artiče B 2015 seismic reflection line across the Artiče fold scarp (Jamšek Rupnik et al., 2016).

STOP 3: PRILIPE

The viewpoint near Prilipe is located on the southern rim of the Krško Basin on the Pliocene – Middle Pleistocene terrace. The succession consists of fluvial and colluvial sediments that are overlying the Neogene Lithotamnium limestone (Fig. 12). The sediment composition is represented by considerably finer fraction, containing low amount of gravel and therefore makes dating this sequence challenging.

This viewpoint offers an overview of the Krško Basin with the northward tilted Brežice terrace (Fig. 5), which consists of carbonate Sava gravel that has been dated to the Middle Pleistocene. To the north, the elevated Pliocene to Middle Pleistocene Kapelske gorice area is visible.

The terrace sequence continues eastward into the cross-border area of Croatia, where preliminary geomorphological mapping based on high-resolution lidar data indicates the continuation of several terrace and low-relief surfaces along the Sava valley, east of the Gorjanci (Žumberak-Samoborsko gorje) range. A first preliminary geomorphological map of this area has recently been compiled, providing a basis for linking the terrace systems mapped on both sides of the Slovenian-Croatian border. At present, these correlations are primarily based on geomorphological position and surface morphology, while the sedimentological characteristics and stratigraphic relationships of individual units still need to be investigated in greater detail. Future cross-border collaboration, integrating geomorphological mapping with sedimentological and chronological data, will therefore be essential for establishing a more consistent regional framework for the Plio-Quaternary fluvial evolution of the Sava valley.



Figure 12: Pedogenized section at Prilipe terrace.

STOP 4: DRNOVO

The Drnovo site is located in the center of the Krško Basin on the Holocene floodplain. The floodplain exhibits a flat surface crossed by modern tributaries of the Sava, Krka, and Sotla Rivers. The surface is well-preserved with abandoned river meanders visible. Based on its position and morphology the floodplain is attributed to the Holocene. Its historic age is confirmed near Drnovo by a Roman port, as well as by historic topographic maps (Verbič, 2008).

In some places, the surfaces exhibit characteristics of a floodplain and in others the characteristics of a terrace level, but the boundary between these landforms is not always visible. Such surfaces were attributed to a common geomorphic unit, spanning from floodplain to individual terrace level, e.g. FP (Krka and Krško Hills streams)–T0 and FP (Bizeljsko Hills streams)–T1. These surfaces were attributed to Late Pleistocene-Holocene on the basis of their geomorphology and the radiocarbon age dating: unit FP (Krka and Krško Hills streams)–T0 yielded 17684 ± 100 yr cal BC (Poljak and Milanič, 2011) and unit FP (Bizeljsko Hills streams)–T1 yielded 9804 ± 65 yr cal BC (Poljak, 2017).

South of Drnovo, a northwestward sloping Mraševski gaj terrace is present as a remnant surface that has been tectonically tilted in the southern part of the Krško Syncline (Fig. 5). Sedimentary and chronological constraints place this terrace into Pliocene to Middle Pleistocene. Geomorphological analysis of Pliocene to Quaternary fluvial landforms of the Krško Basin offers a unique opportunity to study the evolution of Krško Syncline folding.

Drnovo is also a site of a Roman settlement. Inhabitants of minor Roman settlements often relied on locally available building materials, seeking rock sources that offered the desired – or at least satisfactory – physical properties while allowing cost-effective extraction and transport (Russell, 2013). One such settlement was Neviodunum, a small Roman town in the province of Pannonia, occupied from the late 1st to the 4th century AD. Neviodunum was predominantly supplied with lithologies from three local lithostratigraphic units (Zanier et al., 2025): the Lower Jurassic Krka Limestone Member of the Podbukovje Formation; the “Lithothamnium” Limestone Member of the Laško Formation; and Upper Cretaceous limestone, chert, and breccia from the Krško Formation (Fig. 13). Additionally, pebbles (most likely from the Drnovo Alloformation) and some marble monuments are attested. The functional characteristics of the rocks likely determined the choice of material for specific uses. The dense Krka Limestone Member of the Podbukovje Formation was used in the construction of the fluvial harbour area, which represented the town’s most demanding construction site in terms of block volume and size. The very soft “Lithothamnium” Limestone Member was used for architectural decoration, while the predominantly platy limestone and chert of the Krško Formation were employed in wall structures. Given their contemporary use, the most probable provenance for all three lithologies is the Šutna area, located approximately 7 km from Neviodunum as the crow flies.

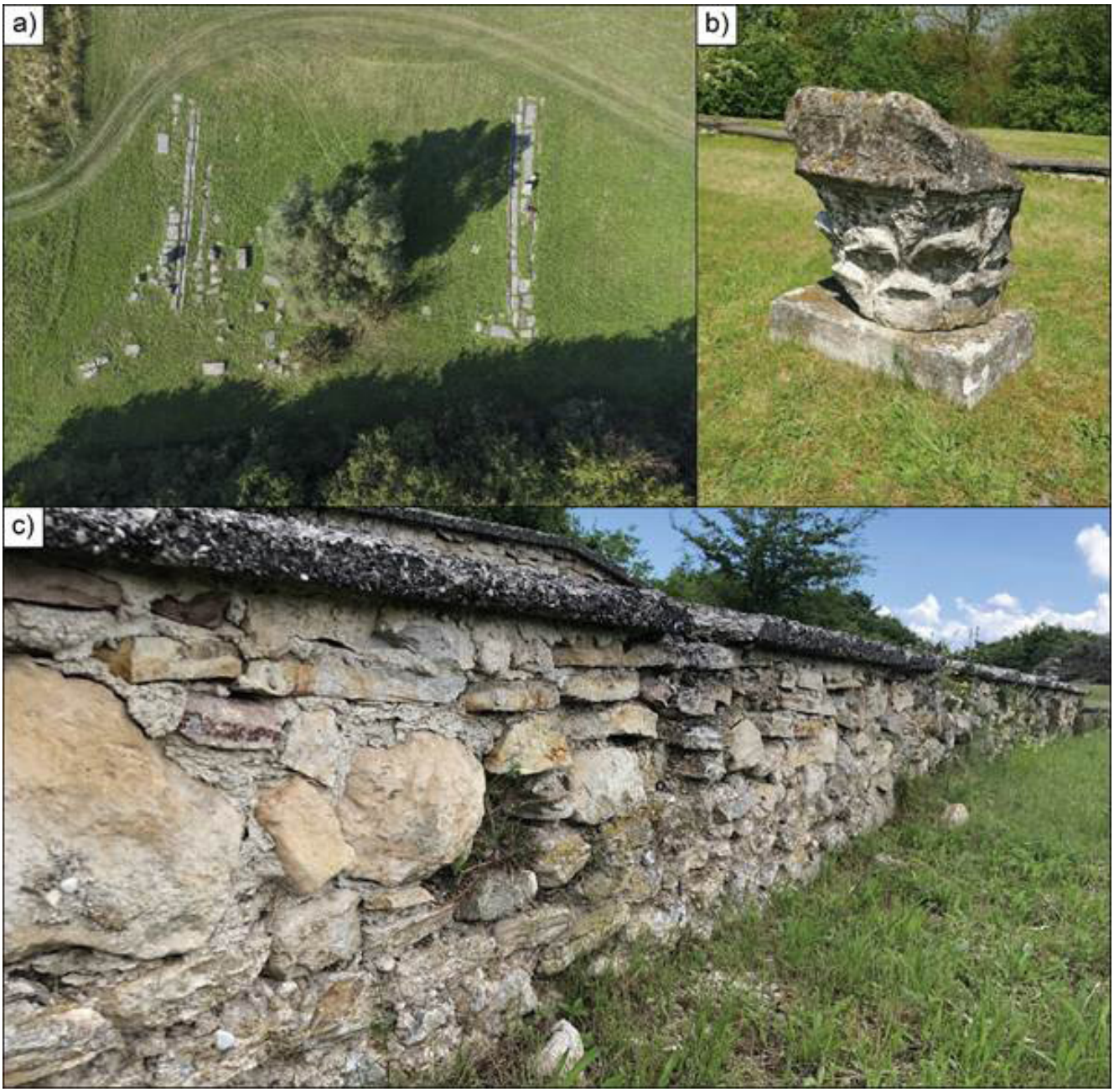


Figure 13: A - Displayed remains of the fluvial harbour of Neviodunum; B -unfinished composite capital; and C - wall of the elongated building.

REFERENCES

Atanackov, J., Jamšek Rupnik, P., Jež, J., Celarc, B., Novak, M., Milanič, B., Markelj, A., Bavec, M., Kastelic, V., 2021. Database of Active Faults in Slovenia: Compiling a New Active Fault Database at the Junction Between the Alps, the Dinarides and the Pannonian Basin Tectonic Domains. Frontiers in Earth Science 9.

Accaino, F., Cernobori, L., Nicolich, R., Rossi, G., Zgur, F. 2014. Tomographic inversion and pre-stack depth migration of seismic profile KK-02 across the Krsko plain. Bollettino di Geofisica Teorica ed Applicata 55(1):197-213.

Gosar, A., Božiček, B. 2006. Structural maps of seismic horizons in the Krško basin Strukturne karte seizmičnih horizontov v Krški kotlini. RMZ-materials and geoenvironment. 53(3):339-352.

Jamšek Rupnik, P., Atanackov, J., Cline, M.L., Cline M., Rižnar, I., Celarc, B., Markelj, A.,Milanič, B., Jež, J., Novak, M., Bavec, M. 2016. Fault characterization field campaign related to probabilistic seismic hazard assessment for nuclear infrastructure in the Krško Basin, Slovenia. In: McCalpin, J. (ed.), Gruetzner, C. (ed.). proceedings of the 7th International INQUA Workshop on Paleoseismology, Active Tectonics and Archaeoseismology (PATA Days), 30 May- 3 June 2016, Crestone, Colorado, USA. Crestone: Crestone Science Center, 2016. p.128-131.

Jamšek Rupnik, P., Atanackov, J., Markelj, A., Milanič, B., Skaberne, D., Mencin Gale, E., Ivančič, K., Žebre, M., Celarc, B., Rižnar, I., Cline, M.L., Logan, K.M., Bavec, M. 2019. Paleoseimological investigations on Artiče and Orlica Faults near Krško, Slovenia. In: Rožič, B. (ed.). Razprave, poročila = Treatises, reports. 24. posvetovanje slovenskih geologov = 24th Meeting of Slovenian Geologists, Ljubljana, november 2019. Ljubljana: Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za geologijo, 2019. p. 45-47.

Markič, M., Peček, D., Marin, M. 1986. Poročilo o raziskavah premoga na območju Globoko - Dečno selo v letih 1984-1985. Knjiga 1: tekst, karte, prerezi. GeoZS.

Markič, M., Rokavec, D. 2002. Geološka zgradba, nekovinske mineralne surovine in lignit okolice Globokega (Krška kotlina). Rudarsko metalurški zbornik 49, 2: 229–266.

Markič, M., Lapanje, A., Rajver, D., Rman, N., Sachsenhofer, R. 2025. Fossil fuels and potential for CO2 storage in the Slovenian part of the Pannonian Superbasin. Geological Society London Special Publications 555(1): DOI: 10.1144/SP555-2023-191

Mencin Gale, E., 2021. Pliocene to Quaternary sedimentary evolution of intramountain basins at the junction of Alps, Dinarides and Pannonian Basin Faculty for Natural Sciences and Engineering. PhD thesis. Univerza v Ljubljani, Ljubljana, p. 187. https://repozitorij.uni-lj.si/IzpisGradiva.php?id=127012&lang=eng

Poljak, M. 2017. Geološka karta vzhodnega dela Krške kotline 1:25.000: tolmač. Ljubljana, Geološki zavod Slovenije: p. 108.

Poljak, M., Milanič, B. 2011. Nekaj novih podatkov o starosti nekaterih kvartarnih sedimentov v Krški kotlini. In: Rožič, B. (ed.). 20. posvetovanje slovenskih geologov : Razprave. Poročila. Ljubljana, Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za geologijo: p. 100–103.

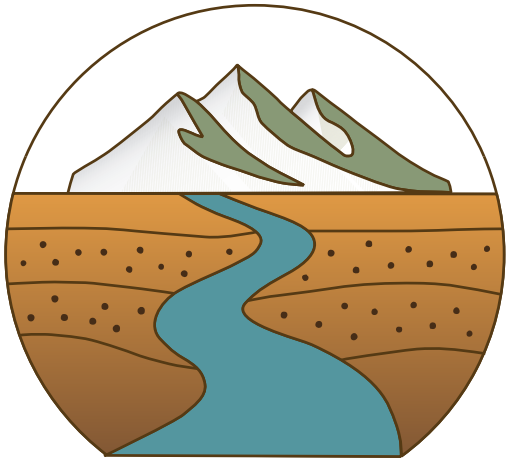
Russell, B. (2013). The economics of the Roman stone trade. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199656394.001.0001

Schmid, S.M., Fügenschuh, B., Kounov, A., Maţenco, L., Nievergelt, P., Oberhänsli, R., Pleuger, J., Schefer, S., Schuster, R., Tomljenović, B., Ustaszewski, K., van Hinsbergen, D.J.J. 2020. Tectonic units of the Alpine collision zone between Eastern Alps and western Turkey. Gondwana Research 78: 308–374.

Verbič, T. 2004. Stratigrafija kvartarja in neotektonika vzhodnega dela Krške kotline. 1. del: Stratigrafija. Razprave 45, 3: 171–225.

Verbič, T. 2008. Kvartarni sedimenti, stratigrafija in neotektonika vzhodnega dela Krške kotline. Doctoral dissertation. Ljubljana, Univerza v Ljubljani, Naravoslovnotehniška fakulteta, Oddelek za geologijo: 140 ff.

Zanier, K., Brajkovič, R., Gale, L., & Novak, M. (2025). Stone products of the Roman municipium of Neviodunum, Pannonia (modern Drnovo, Slovenia). Archaeometry, 67(2), 284–312. https://doi.org/10.1111/arcm.13029



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