

# Contribution to the origin and age determination of some Quaternary sediments in the Krško Basin

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## Introduction

During the preparation of the Geological map of the Krško basin in scale 1:25 000, a number of Quaternary units have been mapped and defined as alloformations. In addition to their spatial position, lithological content, origin, and other characteristics, their ages are of particular interest. Thus, we present here some results of the U/Th radiometric age dating of Middle Pleistocene sediments in the Krško basin, in addition to new ideas of their origin.

## Geological setting

The Middle Pleistocene sediments are exposed along the northern and southern rims of the Krško basin. They form morphological terraces in at least two levels (Fig. 1). The terrace is cut into pre-Quaternary basement rocks, as well as into so called Plio-Quaternary unit that forms a higher and presumably older river terrace. Two younger (Late Pleistocene and Holocene) terraces are cut into the Middle Pleistocene terrace.

The Middle Pleistocene sediments consist predominantly of gravel with minor sand lenses. Most of the material is unconsolidated, however, some lenses of gravel are poorly to well cemented with sparry calcite. Lithologically, the composition of the material corresponds to the general lithology of the Slovenian part of the Southern Alps and Dinarides. Pebbles as well as sand grains are formed of various sedimentary carbonate and siliciclastic rocks from Carboniferous to Cretaceous age, in addition to rare magmatic rocks such as Triassic keratophyre and Oligocene andesite. The carbonate component generally dominates the silicious one. The maximum exposed thickness of these sediments is around 10 meters.

## Origin of the sediments

On the geological map of this area, the sampled sediments are labeled as a Pleistocene river terrace ( $a_3$ ), which is cut into older Sava river sediments, and into which two younger Holocene terraces are cut (Šikić et al., 1978; 1979). The authors connect all these sediments with both the Sava and Krka Rivers. T. Verbič (2004) names this unit the Brežice Alloformation of Middle Pleistocene age, and relates it to the Sava only.

A detailed facies analysis on the best preserved exposure of this terrace at the Leskovec village (Fig.1) indicates that this sediment also carries signs of its glacial origin. Sediment characteristics, clast morphology (common shapes typical for subglacial transport), and well preserved striae of presumably glacial origin indicate proglacial paleoenvironment, which needs to be studied further.

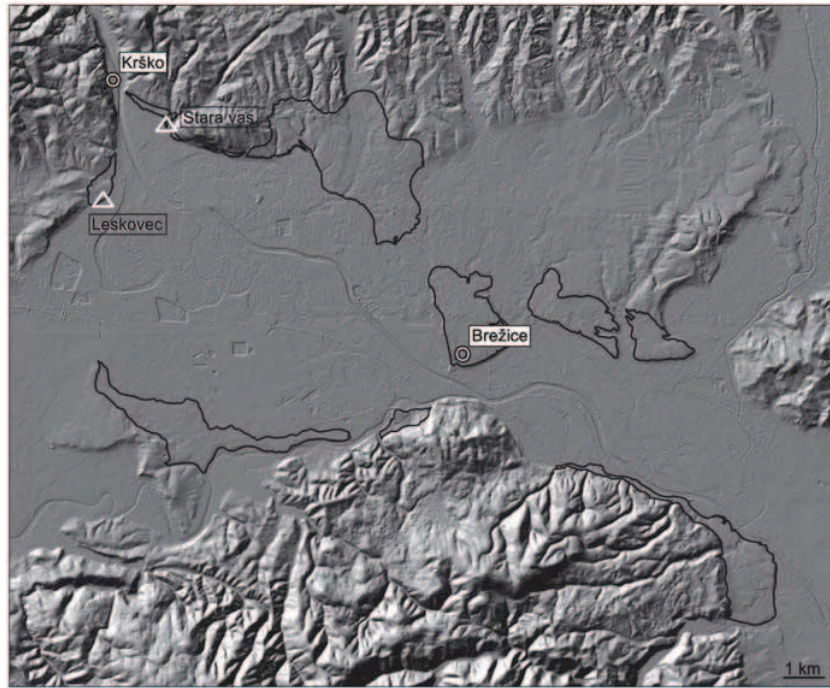


Figure 1. Position of the Late Middle Pleistocene sediments (Brežice Alloformation) in the Krško basin. Sampling locations are marked with triangles.

### The age of the Alloformation

The Middle Pleistocene age of the Brežice Alloformation was previously determined by the thermoluminescence from a sand lens within carbonate and silicate gravel at Dolenja Vas village. The obtained results were  $139\,500 \pm 11\,840$  and  $151\,710 \pm 14\,810$  a. b.p. (Verbič, 2008) from which the author estimates the most probable age to 145 000 a. b.p.

During our investigation, we have sampled the Middle Pleistocene sediments on two locations; near Leskovec and Stara Vas on the northern rim of the Krško basin. In both cases, the samples have been taken in the lower terrace level from lenses of cemented gravel that contains calcite.

We first analysed samples from Leskovec (Leskovec 1a sample) and from Stara Vas (Stara vas 1b sample) but both have large contributions from detrital material (125% and 104%). The age calculation for Stara Vas-1b sample does not converge on a sensible value. Detrital correction for Leskovec -1a sample is essential but age calculation, is realistically impossible. A further 2 scrapings from the same hand specimen achieved somewhat lower detrital contributions, 34% for Leskovec -1b sample and 2.5% for Stara Vas - 1a samples. Both give acceptable detrital-corrected ages (Table 1 in italics) but still with large uncertainties. The increase in uncertainty for the detrital corrected ages is due to the uncertainty in the  $^{232}\text{Th}$  concentration determination. The  $^{232}\text{Th}/^{238}\text{U}=3.13$  for detritus is an assumption and is for an average continental sediment. It is possible that a large component of the detrital material is actually old limestone, with a much lower  $^{232}\text{Th}/^{238}\text{U}$  ratio, and then the calculated ages would actually be mixing ages between the authigenic carbonate precipitation age and secular equilibrium.

There is unambiguous evidence for U-series disequilibrium in all samples and thus for ages <350 ka. Cleaner samples collected from sites with low energy sedimentation during authigenic precipitation may yield more satisfactory results.

**Table 1:** ratios in brackets are activity ratios calculated from analytical data using decay constants:  $\lambda^{238}\text{U}$ :  $1.55125 \cdot 10^{-10}$ ,  $\lambda^{232}\text{Th}$ :  $4.94750 \cdot 10^{-11}$ ,  $\lambda^{234}\text{U}$ :  $2.82629 \cdot 10^{-6}$ ,  $\lambda^{230}\text{Th}$ :  $9.15771 \cdot 10^{-6}$ . Unc is 1 sigma uncertainty apart from the values in ages, OC indicates that the value was overcorrected and NC indicates that the age calculation did not converge. Values calculated using an assumed  $^{232}\text{Th}/^{238}\text{U}$  ratio for the detrital contributions are in italics.

Name	Leskovec	unc	Leskovec-	unc	Stara Vas-	unc	Stara Vas-	unc
Weight g	0.2773		0.5986		0.2043		0.2952	
$^{238}\text{U}$ ppm	0.1616	0.000	0.1839	0.001	5.3836	0.028	0.5623	0.003
$^{232}\text{Th}$ ppb	616.4	111.7	190.5	34.5	406.1	73.6	1786.3	323.6
$(^{230}\text{Th}/^{232}\text{Th})$	1.1060	0.071	2.9253	0.188	36.9940	2.382	1.1313	0.072
$(^{230}\text{Th}/^{234}\text{U})$	0.9674	0.030	0.9323	0.029	0.9232	0.029	1.1300	0.035
$(^{234}\text{U}/^{238}\text{U})$	1.4063	0.012	1.0533	0.009	0.9881	0.009	1.0351	0.010
convergence=1	1.000		1.000		1.000		0.924	
AGE ka	247		273		285		NC	
2 * uncertainty		44		58		67		NC
2 * uncertainty		-52		-84		-102		NC
%err 2se	19.4		25.9		29.7			
Blank contribution %	1.17E-07		3.78E-07		1.77E-07		4.03E-08	
$^{230}\text{Th}/\text{U}$	3.8143		1.0359		0.0754		3.1766	
$^{232}\text{Th}/^{238}\text{U}$ detr mol rat	3.13		3.13		3.13		3.13	
detrital fraction in %	125.0		34.0		2.5		104.1	
$(^{230}\text{Th}/^{234}\text{U})$ corr	0.7064	0.055	0.9002	0.047	0.9212	0.041		
$(^{234}\text{U}/^{238}\text{U})$ corr	OC		1.0807	0.016	0.9878	0.013		
convergence=1			1.000		0.999			
AGE ka			234		284			
2 * uncertainty				67		94		
2 * uncertainty				-92		-147		
%err 2se			34.1		42.5			

## Conclusion

On the basis of our investigations presented in this paper, we can draw two main conclusions.

Firstly, indications of probable glacial origin of Middle Pleistocene sediments in the Krško basin, if they are confirmed by facts in further studies, suggest that the Pleistocene Alpine ice cover might have a much larger extend than previously interpreted (e.g. Bavec & Verbič, 2011).

Secondly, the age dating results of the same sediments obtained by thermoluminescence and uranium-series (U/Th) method, taking into account restrictions due to quality of analyzed material, suggest that sedimentation during the Late Middle Pleistocene (Rissian) glaciation took place within larger time span than previously interpreted.

## References

- Bavec, M. & Verbič, T., 2011: Glacial History of Slovenia. In: Quaternary Glaciation – Extent chronology (J. Ehlers, P.L. Gibbart & P.D. Hughes, eds.), *Developments in Quaternary Sciences*, 15,385-392, Elsevier.
- Šikić, K., Basch, O. & Šimunić, A., 1978: Geological Map of SFRY in scale 1:100 000, sheet Zagreb.- Federal Geological Survey, Beograd.
- Šikić, K., Basch, O. & Šimunić, A., 1979: Geological map of SFRY in scale 1 : 100 000, Explanatory booklet to sheet Zagreb.- Federal Geological Survey, Beograd.
- Verbič, T., 2008: Quaternary Sediments, Stratigraphy, and Neotectonics of the Eastern Krško Basin.- Ph. D. Thesis, University of Ljubljana, Ljubljana.

## NAPOMENA / NOTE

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