FLOWSTONE DATATIONS IN SLOVENIA

DATACIJE SIG V SLOVENIJI

N A D J A Z U P A N

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Abstract UDC 551.442.4 (497.12):902.6

Zupan, Nadja: Flowstone datations in Slovenia

This report represents the number and the results of absolute dating analyses which were made in Slovenia. Many of analyses were done by ^{14}C dating method, some of them by Uranium series dating and just few by ESR dating method. The relationship among the results made by the first mentioned methods are presented. Some new results from 1991 made by ^{238}U and ^{230}Th dating methods are annexed.

Izvleček UDC 551.442.4 (497.12):902.6

Zupan, Nadja: Datacije sig v Sloveniji

Članek predstavlja število in rezultate analiz absolutnih datacij, ki so bile narejene v Sloveniji. Veliko analiz je bilo narejenih s ^{14}C metodo, nekaj z U/Th metodo ter samo nekaj z ESR metodo. V članku je prikazano tudi razmerje rezultatov med prvima omenjenima metodama. Tu je tudi nekaj novih rezultatov, narejenih 1991, z ^{238}U in ^{230}Th metodo.

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INTRODUCTION

Slovenia is classical karst area because of limestone and dolomite prevailing and of because speleological research started here. Several thousands of caves of different dimensions are known (HABIČ, 1982). The advantage of caves as repositories of paleoenvironmental information is the great stability of climatic conditions within the cave. The stages of karstification processes and paleoclimatic interpretations are based on chronostratigraphy of cave sediments, but in several cases are not yet explained enough (BRODAR, 1952, 1956; GOSPODARIČ, 1976, 1981, 1985, 1988).

Karstic caves are commonly filled by: clastical material from outside carried in the caves by the water; collapsed blocks of the walls of the cave; organic material and of course by chemical deposited calcite. Speleothems can give us the absolute age of their formations. And if the time of speleothem formations is known then the time of other processes which are present in the cave is known too.

In Slovenia the studies of cave sediments from Postojna cave started in the last century, but the first absolute age of speleothem from Slovenia is known from 1971; it was partly published by FRANKE and GEYH (1971). The most of speleothems samples were analyzed by Radiocarbon dating, some of them by U series dating and three only by ESR method.

DATING RESULTS

All the results on Table 1 were published. From the results is seen that those made by radiocarbon method are not good for samples older than 35.000, as some of the oldest samples which were repeated by U/Th method prove to be much older. My opinion is that a lot of results made by ^{14}C are not precise especially for the oldest samples, they are marked by*. ^{14}C analyses were made on Radiokohlenstoff und Tritiumlaboratorium des Niedersächsischen Landesamst für Bodenforschung in Hannover and on Institut Rudjer Boškovič in Zagreb. Positions of all caves which are represented in this article are shown on figure 1.

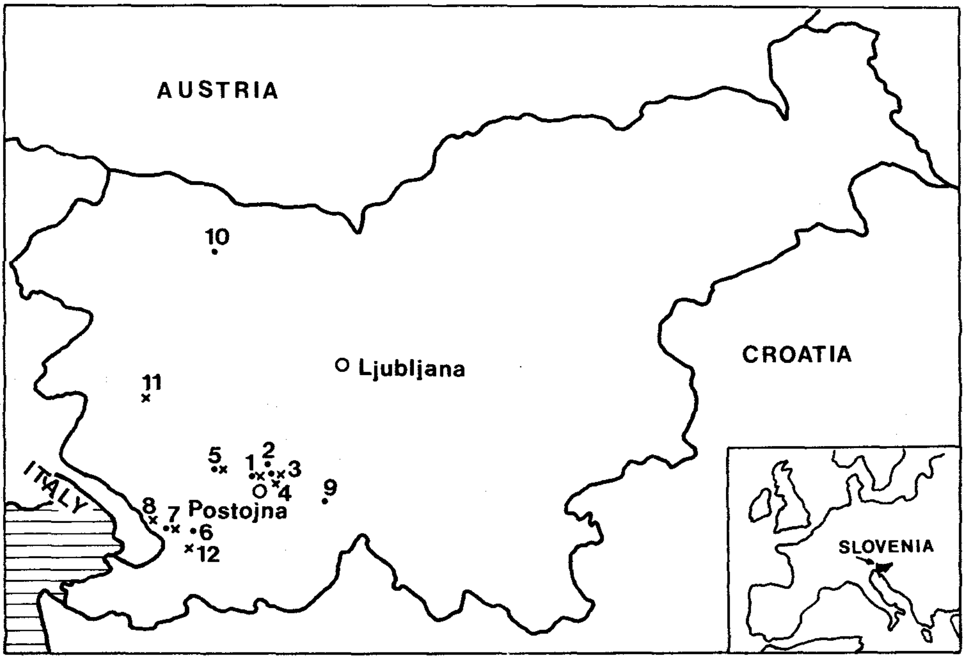

Figure 1: Positions of caves in Slovenia
Slika 1: Lega jam v Sloveniji
• - published analyses / objavljene analize
x - new analyses / nove analize
1- Postojna cave, 2- Planina cave, 3- Zelše caves, 4- Small Natural Arch, 5- Fiženca, 6- Škocjan caves, 7- Vilenica, 8- Lipiška cave, 9- Križna cave, 10- Babji zob cave, 11- Paradana, 12- Mejame

Table 1 (Tabela 1)
Revue of published flowstone datations from Slovenia
Pregled objavljenih datacij sig iz Slovenije

Location/method		sample	age	
Postojna cave (GOSPODARIČ, 1972,1977)				
^{14}C:				
	1.	brown flowstone	39.060	±3820
	2.	brown flowstone	39.440	±2660
	3.	broken stalagmite, top	39.060	+3820
	4.	white stalagmite	20.740	±860
	5.	white stalagmite	17.000	±250
	6.	white stalagmite (on the broken one)	10.200	±200
	7.	white stalagmite (on the broken one), top	10.250	±290

Location/method		sample		age	
	8.	white stalagmite (on the broken one)		7.470	±100
	9.	stalagmite, 30 cm:	base	14.222	±185
			top	12.310	±175
	10.	stalagmite, 120 cm:	base	42.900	
			top	39.175	±1205
	11.	stalactite, middle:		37.050	±3.560
	12.	stalagmite:	base	13.365	±260
			middle	7.960	±185
	13.	stalagmite		8.640	±140
	14.	stalagmite		8.685	±140
ESR		(IKEYA, MIKI & GOSPODARIČ, 1983)			
	15.	stalactite:	base	530.000	
			middle	280.000	
			top	125.000	
	16.	stalactite		190.000	
Planina cave (GOSPODARIČ, 1977)					
^{14}C:					
	1.	stalagmite:	top	30.715	
		outside layer		9.735	±285
	2.	stalagmite,	top	32.875	±1810
	3.	stalagmite:	base	* 49.900	
			top 1	* 45.265	
			top 2	* 45.780	
	4.	stalagmite:	base	* 45.610	
			top a	32.225	±1450
	5.	flowstone		* 44.240	±2125
	6.	flowstone		8.205	±355
	7.	flowstone		3.630	±260
	8.	red flowstone		* 44.635	
	9.	flowstone		* 46.025	
U/Th:					
	4.	repeated, base		79.700	
	10.	flowstone		77.800	
Zelše caves (GOSPODARIČ, 1977)					
^{14}C:					
	1.	flowstone		9.000	
	2.	flowstone		4.500	
Predjama caves system (GOSPODARIČ, 1977)					
^{14}C:					
	1.	stalagmite,	top	34.925	
	2.	stalagmite: (20 cm)	base	9.490	
			top	2.380	

Location/method		sample		age	
	3.	stalagmite:	base	10.425	
		(82 cm)	top	3.585	
	4.	stalagmite:	base	6.380	
			top	2.200	
Škocjan caves (GOSPODARIČ, 1977)					
^{14}C:					
	1.	broken stalagmite		11.325	±145
	2.	stalagmite:	base	8.905	±155
		(40 cm)	top	1.495	±115
	3.	stalagmite:	base	12.245	±155
		(22 cm)	top	10.300	±175
Vilenica (GOSPODARIČ, 1977)					
^{14}C:					
	1.	stalagmite		36.000	
	2.	stalagmite:	base	29.333	
			top	18.865	
Babji zob cave (GOSPODARIČ, 1977)					
^{14}C:					
	1.	stalagmite		* 42.500	
	2.	stalagmite,	top	23.745	
	3.	stalagmite:	base	* 43.050	
		(17 cm)	top	32.850	
	4.	calcite		* 40.335	
	5.	stalagmite:	base	37.930	
		(21 cm)	top	32.510	
Križna cave (FORD, GOSPODARIČ, 1989)					
U/Th:					
	1.	YUGK 1A		198.000	
	2.	YUGK 2A		146.000	
	3.	YUG K22:	top	126.000	
			middle	132.000	
			base	146.000	
	4.	YUG K4:	top	146.000	
			middle	173.000	
			base	251.000	
	5.	KYU 2:	top	218.000	
			middle	>350.000	
			base	150.000	
	6.	KYU 4S,	base	133.000	
	7.	KYU 6,	base	190.000	

ANALYSES MADE ON MCMASTER UNIVERSITY (1991) BY U/TH DATING METHOD

Some new samples of speleothems were made on the McMaster University, Hamilton, Canada in 1991 by U/Th dating method. Samples were selected from different caves from Karst of Slovenia. For the beginning were analysed the speleothems which are the oldest in the stratigraphic position in the caves and we supposed that they are really the oldest. The description of the samples and results follow.

Postojna Cave, Pisani rov

Stalactite, Po 1

In Pisani rov behind the subsided column there are on the roof, at 532 m above sea level, several stalactites; although some of them have fallen off, their bases are left on the roof. The flowstone generations with interlayered flood loams are well seen; as they are not appropriate for sampling we have taken the specimen for analyses from carrot-shaped stalactite, one meter long. In the middle of the stalactite there is reddish brown nucleus, which was eroded, and eroded remain of brown flowstone. Around these two layers is thicker ring of brown-white rather porous flowstone containing a lot of loam. The flowstone is encircled by brown flood loam, some millimeters thick. The following ring is white pure flowstone, encircled by second layer of flood loam, followed by another set of white flowstone and loam, finally covered by external belt of pure white flowstone. Cross-section of stalactite Pol is shown on figure 2.

Reddish brown nucleus Po 1/1 does not contain any argillaceous alloy. The age could not be dated but it surpasses 350.000 years.

Brown flowstone Po 1/2 contains a lot of loam which was successfully removed during the filtration. Established age is 269.400 years (+ 130.300, - 80.800).

Brown white porous flowstone Po 1/3 contains a lot of loam which was well removed either. The age is established to 76.000 years (+ 24.900, - 21.900). The age for the samples Po 1/4, Po 1/5 and Po 1/6 was not established due to too low Uranium content.

Some years ago the samples for ESR method (IKEYA, MIKI & GOSPODARIČ, 1983) were taken close to the analysed stalactite. The red nucleus was dated to 530.000 years. This flowstone probably grew in one of Mindel Interglacials and was eroded in Mindel already. Brown flowstone near the red one belongs to Mindel-Riss Interglacial and was eroded in Riss probably, as the following brown white flowstone belongs to Riss-Würm Interglacial. This flowstone is rather porous and contains a lot of loamy material evidencing the intermediary periodical floods. Around this flowstone there is a belt of flood loam, about 2 mm thick, which was, according to previous datations probably deposited in Late Würm. The following three belts of flowstone, which could not be dated

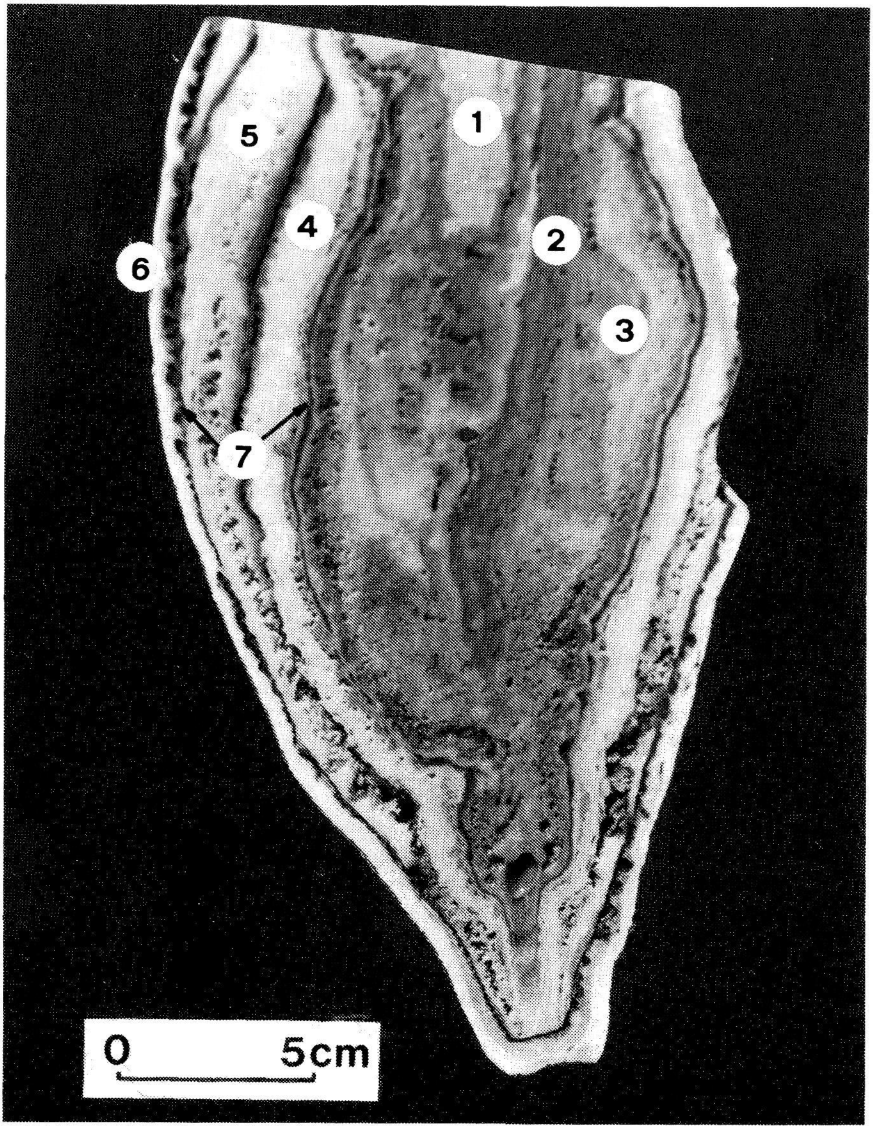

Figure 2: Cross-section of stalactite Po1 from Pisani rov, Postojna cave
Slika 2: Presek stalaktita Po1 iz Pisanega rova, Postojnska jama
1- Po 1/1, reddish brown nucleus / rdeče rjavo jedro
2- Po 1/2, brown flowstone / rjava siga
3- Po 1/3, brown white porous flowstone / rjavo bela porozna siga
4- Po 1/4, white flowstone / bela siga
5- Po 1/5, white flowstone / bela siga
6- Po 1/6, white flowstone / bela siga
7- brown flood loam / rjava poplavna ilovica

because of too low content of Uranium, belong, according to alternation of flood loams and flowstones to Würm Interglacials, the belts of flood loams to Middle and Early Würm. The last flowstone belt was probably deposited after the last glaciation. It would be convenient to date the last three flowstone belts by ^{14}C and check our suppositions.

From Podorna dvorana (Collapse Chamber) in Pisani rov another two samples were analysed. The sample Po 2 from the top of the stalactite under the collapse block has grown when the collapse block was still on the roof of the chamber. The sample Po 3 is from the base of the stalagmite which continues to grow on the collapsed rocky block.

The stalactite Po 2 is composed by three layers of flowstone with two interlayered flood loams. Unfortunately the age was not possible to be determined. According to ressemblance of flowstone and interlayered flood loams to the stalactite Po 1 I infer that Po 2 is younger than 76.000 years.

The age of the stalagmite Po 3 was established to be 19.900 years (+ 25.200, - 24.700). Thus it follows that the collapse occurred in Late or Middle Würm probably and the stalagmite started its growth on the collapsed block during the last Würm glacial.

Zelške jame

From Blatni rov of Zelške jame, at 523 m above sea level, the top of stalagmite, covered by flood loam, was analysed. There was a lot of loamy material in the flowstone that was easy to be removed. The top of stalagmite is older than 350.000 years meaning, that flood loam in this passage is younger.

In the collapse doline below the Small Natural Arch there is on the wall, at 520 m above sea level a lot of flowstone deposited above the moss. The sample was taken from the center of the flowstone and its age is established to 37.300 years (+9.900, - 9.100). It shows that the collapse doline is older as moss needs light for its growth; the flowstone was deposited below the wall in the interglacial between Late and Middle Würm.

Fiženca

In Fiženca, at 539 m above sea level, lies smaller chamber with brown white curtain on the wall. The flowstone sample was taken from the contact between the wall and the curtain and is 153.900 years old (+237.700, + 94.600). This chamber existed in Riss glacial and the flowstone was deposited in this time already.

Vilenica

On the right side before the entrance to Fabrisov rov, at 300 m above sea level, there are some millimeters of red loam deposited over yellow flood loam and both are covered by brown crusty flowstone. In the cave there is above this flowstone no yellow flood loam noticed. Brown crusty flowstone is 80.200 years old (+ 56.900, - 44.400). One can infer that after Riss-Würm interglacial in upper parts of Vilenica there were no more floods and that the yellow flood loams belong to Riss age if they are not even older.

Lipiška jama

In front of the passage to Kozinski rov, at 268 m above sea level, yellow flood loam was deposited the most high in this cave. It is covered by yellow laminated flowstone which is older than 350.000 years.

In upper part of Kozinski rov, at 248 m above sea level, a crust of flowstone is deposited over the flood loam where the stalagmites are growing. The base of broken triangular speleothem is 160.400 years old (+ 116.900, - 61.300). This flowstone belongs to Riss while the flood loams are indoubtedly older.

Mejame

In yellow brown flowstone from Mejame, at 345 m above sea level, the trees leaves are well preserved. The age of flowstone is 42.100 years (+ 29.900, - 28.000), it belongs to Würm.

Velika ledenica in Paradana

The crust of brown flowstone was taken in front of Gamsovo brezno, at 1020 m above sea level. The flowstone is older than 350.000 years.

CONCLUSION

The results of all datations are presented on the Table 2. We can say that the flowstones, recently analysed, are older than those, dated by ^{14}C. It is true that the ^{14}C method enables the datation up to 40.000 years only and as the authors realized the limits of the method they have chosen stratigraphically younger flowstones for datation. Also it was evidenced that the results, got by ^{14}C are not reliable for the flowstones older than 37.000 years and that in fact they are older.

From new analyses it appears that many samples are older than 350.000 years, which is the limit of the method, that is why it could be necessary to date them by ESR method too. All the others have to be repeated by U/Th in order to get more reliable results.

For better understanding of our karst development the systematic flowstone datations have to be continued.

Translated by Maja Kranjc

Table 2 (Tabela 2)
New flowstone datations from Slovenia
Nove datacije sig iz Slovenije

location	samples			age
Postojna cave	17.	stalactite	Po 1/1	>350.000
				+130.300
			Po 1/2	269.400
				-80.000
				+24.900
			Po 1/3	76.000
				-21.900
	18.	stalactite	Po 2, top	>350.000
				+25.200
	19.	stalagmite	Po 3, base	19.900
				-24.700
Zelše cave	3.	stalagmite,	top, Z1	>350.000
				+13.100
S. Natural Arch	2.	flowstone,	MNM	35.000
				-12.400
				+23.700
Fiženca	5.	flowstone,	F1	153.900
				-94.600
Lipiška cave	1.	flowstone,	L2	>350.000
	2.	stalagmite,	base, L3	
				+56.900
Vilenica	3.	flowstone,	V1	80.200
				-44.400
Paradana	1.	flowstone,	Pa1	>350.000
				+29.900
Mejame	1.	flowstone,	Me1	42.100
				-28.000

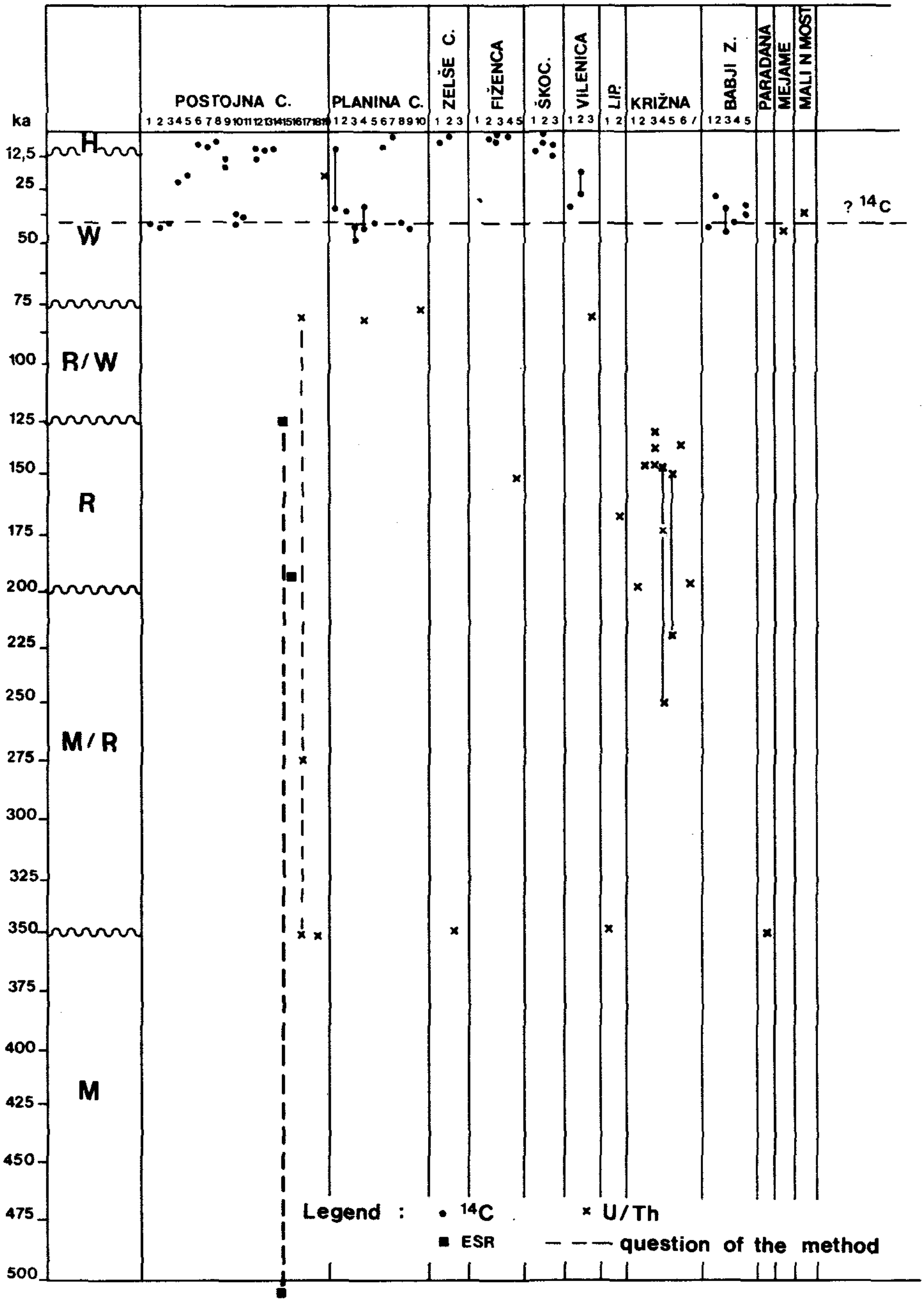

Figure 3: Revue of all datations from Slovenia
Slika 3: Rezultati vseh datacij iz Slovenije

DATACIJA SIG V SLOVENIJI

Na povabilo prof. dr. C.D.Forda, sem bila od 2.2. do 1.5. 1991 na izpopolnjevanju na McMaster University v Hamilton, Kanada. Sprejeli so me na oddelku za geologijo, pri prof. dr. H.P.Schwarczu, kjer so razvili metodo določanja starosti sig s pomočjo U in Th in so na tem področju vodilni v svetu. Vse laboratorijske stroške so mi krili na univerzi v Hamiltonu, za kar se jim najlepše zahvaljujem. Laboratorij je opremljen za ekstrakcijo urana in torija iz sig ter z alfa spektrometrom znamke Northeren za merjenje njihovih koncentracij.

Moj namen je bil spoznati metode določanja starosti sig z U/Th od priprave vzorca do ugotavljanja deleža U in Th v sigi. Za praktičen preskus sem vzela s seboj nekaj vzorcev sig iz Slovenije. te metode pri nas še nihče ni uporabljal. Z njo pa so v Hamiltonu do sedaj analizirali tudi že 14 vzorcev sig iz Slovenije. Določanje starosti sig je pomembno, ker omogoča kronološko opredelitev sedimentacijskih pogojev in spremembe v jamah in s tem posredno spoznamo časovni razvoj krasa in spremembe v kraškem okolju.

OPIS METODE
(po GASCOYNE M., SCHWARZ H.P. & FORD D.C., 1978)

Za določitev starosti sige glede na razmerje ^{234}U in ^{230}Th, je treba U in Th ločiti iz vzorca in narediti njun koncentrat. Ekstrakcija U in Th iz enega vzorca traja okrog 14 dni. Iz tehničnih razlogov ne obdelujemo več kot 5 vzorcev hkrati.

Vzorce za analizo najprej mehansko očistimo, jih raztopimo s koncentrirano HNO_3. Nato dodamo spike $^{228}Th/^{232}U$ ter Fe-klorid. Iz raztopine odfiltriramo glino in dodamo amonijev hidroksid, da dobimo rjavo usedlino, ki ima vezan nase U in Th. Precipitat odstranimo iz raztopine in ga raztopimo s koncentrirano HCl. V naslednji stopnji odstranimo z etrom Fe. Potem z anionskim in kationskim izmenjevalcem iz raztopine ločimo U in Th ter ju nanesemo na jeklene ploščice. Te ploščice vložimo v alfa spektrometer in izmerimo deleže U in Th.

Primarni izvor urana in torija je geokemijski cikel pri preperevanju felzičnih magmatskih kamnin. $Th^{(IV)}$ je zaradi zelo nizke topnosti skoraj ves izključen iz podzemeljskega kroženja vode in s tem iz možnosti obarjanja iz teh vod. Zelo hitro se veže z glinenimi minerali in delčki sedimentov. Uran je takoj oksidiran iz +4 v +6 obliko in tvori topljiv UO_2^{2+} ion, ki je lahko prenosljiv v raztopini ter pogosto tvori anionski kompleks s karbonati $[UO_2(CO_3)_3]^{4-}$). Poznejša izguba CO_2 in sousedanje s $CaCO_3$ v morskem okolju tvori karbonatne sedimente, ki vsebujejo 2-4 ppm U in manj kot 0.1 ppm Th. Na drugi strani so klastični sedimenti obogateni z Th in vsebujejo tudi nekaj U in ta lahko kontaminirata karbonatne sedimente. Organske usedline so pogosto obogatene z U zaradi visoke topljivosti U v kislih okoljih in zaradi tendence U po absorbciji v organskih spojinah. Pri eroziji sedimentnih kamnin je U s preperevanjem spet mobiliziran in odnešen v podzemeljski vodni sistem. V področjih z apnencem se lahko pojavi drugi krog usedanja, ko voda v jamah z izgubo CO_2 izloča kalcit. V tej vodi in novo nastalem kalcitu opazujemo cepitev ^{238}U in ^{234}U. Normalno je kemijsko nemogoče, vendar proces tu poteka, ker ^{234} U zasede mesta v kristalni mreži, ki je bila poškodovana z radioaktivnim žarčenjem pri razpadu ^{238}U. V sladkih vodah razmerje $^{234}U/^{238}U$ variira med 1.0 in 12, oceanska voda ima razmerje 1.14±0.02. Koncentracija U v sigi je odvisna od vsebnosti U v krovnih kamninah, od morebitne prisotnosti organskih skrilavcev, od časa zadrževanja vode v podzemlju, od koncentracije CO_2 in hitrosti razplinjevanja jame. V sigah so bile najdene koncentracije urana med 0.01 ppm in več kot 90 ppm, toda večina vsebnosti urana je v območju od 0.1 do 2 ppm.

V datacijske namene se lahko uporabi naslednje razpadne sheme U:

	razpad v	razpadni čas
1.	^{235}U ------- ^{231}Pa	v 200.000 letih, samo v sigah bogatih z U
2.	^{238}U ------- ^{234}U	v 1.5 miljona let, ne poznamo pa njunega začetnega razmerja
3.	^{234}U ------- ^{230}Th	v 350.000 let, odvisno od začetnega deleža ^{234}U

1. Metoda $^{231}Pa/^{235}U$

Problem prve metode je v tem, ker se zaradi nizkega relativnega deleža ^{235}U, razmerje $^{238}U/^{235}U$ = 137.9, lahko to datacijo uporablja samo za datacije z U bogatih sig, seveda v razmerju z razpadnim produktom ^{231}Pa. Ta metoda je uporabna do 200 000 let nazaj.

2. Metoda $^{234}U/^{238}U$

Delež ^{234}U napram ravnotežju z ^{238}U je razvidno iz naslednje enačbe:

$$(^{234}U/^{238}U)_t - 1 = (^{234}U/^{238}U)_o - 1 \cdot e^{-\lambda_{234} t}$$

$(^{234}U/^{238}U)_t$	-	merjeno aktivnostno razmerje
$(^{234}U/^{238}U)_o$	-	začetno razmerje pri odložitvi
λ_{234}	-	razpadna konstanta ^{234}U
t	-	čas od odložitve do meritve

Glavna neugodnost te metode je, da zahteva natančno poznavanje začetnega razmerja ^{234}U in ^{238}U. Kot je bilo že to prej omenjeno, to razmerje zelo varira v večini sladkovodnih sistemov, tako da prevzem vrednosti za sedanjo prenikajočo vodo, za datiranje fosilnih sig, ni primerno. Razmerje $^{234}U/\ ^{238}U$ se lahko spremeni pri vsaki prekinitvi in nadaljnji rasti sige.

3. Metoda $^{230}Th/^{234}U$

Metoda sloni na dejstvu, da se v sigah odloži nepomembna količina ^{230}Th. Njegova prisotnost v sigah je odvisna od "in situ" razpadlih ^{234}U in ^{238}U, ki sta se precipitirala skupaj s kalcitom, zato ju je več v starejših sigah.

Enačba razmerja med vsebnostjo ^{230}Th in starostjo sige je seveda mnogo bolj kompleksna kot pri prejšnji metodi. ^{230} Th izvira lahko tudi iz pribitka ^{234}U, zato je tudi to treba upoštevati.

$$(^{230}Th/^{234}U)_t = (1 - e^{-\lambda_{230}t}) / (^{234}U/^{238}U)_t) + (\lambda_{230} / (\lambda_{230} - \lambda_{234})) \cdot$$
$$\cdot (1 - (1/(^{234}U/^{238}U)_t). (1 - e^{-(\lambda_{230}-\lambda_{234})t})$$

$(^{230}Th/^{234}U)_t$ in $(^{234}U/^{238}U)_t$ - merjeni aktivnostni ravnotežji t let po odložitvi
λ_{230} - razpadna konstanta ^{230}Th

Če sta v kalcitu zaradi poplav prisotna pesek ali glina, se lahko pojavi kontaminacija z detritičnim ^{230}Th. Ta teži k povečanju prave starosti. ^{230}Th pojavlja skupaj s ^{232}Th, katerega prisotnost se da ugotoviti v spektru in ga je zato mogoče upoštevati. To seveda ni enostavno, ker je razmerje $^{230}Th/^{232}Th$ v sedimentih zelo odvisno od izvora, starosti in tipa sedimenta.

DATIRANJE SIG Z U/TH METODO NA MCMASTER UNIVERSITY (1991), KANADA

Za analizo smo izbrali 22 vzorcev iz različnih slovenskih jam, slika 1. Od tega je pet vzorcev vsebovalo premajhne količine Th ali U za detekcijo, dva od vzorcev pa sta bila ponovljena, tabela 2.

Postojnska jama, Pisani rov

Stalaktit Po 1

Na stropu za posedenim stebrom v Pisanem rovu, na višini 532 m, je več stalaktitov, nekateri od njih so odpadli. Na stropu so njihove baze. V njih so lepo vidne generacije sige z vmesnimi poplavnimi ilovicami. Ker baze niso primerne za vzorčevanje smo vzorce za analize vzeli iz meter dolgega korenastega stalaktita. V sredini stalaktita je rdečkasto rjavo jedro, ki je bilo erodirano, ob njem je tudi že erodiran ostanek rjave sige. Okrog teh dveh je debelejši obroč rjavo bele precej porozne sige, ki vsebuje tudi veliko gline. Siga je obrobljena z nekaj milimetri rjave poplavne ilovice. Naslednji obroč je iz bele čiste sige, ki ga obdaja druga plast poplavne ilovice, nato sledi nova plast bele sige in ilovice, ki ga obdaja zunanji obroč čiste bele sige. Presek stalaktita je prikazan na sliki 2.

Rdečkasto rjavo jedro Po 1/1 ne vsebuje glinenih primesi. Starost se ni dala določiti, je pa večja od 350.000 let.

Rjava siga Po 1/2 je vsebovala veliko gline, vendar se je pri filtriranju dala lepo odstraniti. Določena starost je 269.400 let (+130.300, -80.800).

Rjavo bela porozna siga Po 1/3 je tudi vsebovala veliko gline, ki se je tudi dala lepoodstraniti. Starost je določena na 76.000 let (+24.900, -21.900). *Vzorcem Po 1/4., Po 1/5. in Po 1/6, starosti nismo mogli določiti* zaradi prenizke vsebnosti urana.

Tik ob analiziranem stalaktitu so pred leti vzeli vzorce za analize z ESR metodo (IKEYA, MIKI & GOSPODARIČ,1983). Rdečemu jedru so določili starost 530. 000 let. Ta siga je verjetno zrasla v enem od mindelskih interglacialov in je bila že v mindlu tudi erodirana. Rjava siga ob rdeči je iz mindel-riške medledene dobe in je bila tudi erodirana, verjetno v risu, saj je naslednja rjavo bela siga iz riško-würmske medledene dobe. Ta siga je precej porozna in vsebuje veliko glinenega materiala, kar kaže na vmesne občasne poplave. Okrog te sige je približno 2 mm debel obroč poplavne ilovice, ki se je glede na prejšnje datacije verjetno odložila v starejšem würmu. Naslednji trije obroči sige, ki niso datirani zaradi premajhne količine urana, so glede na menjavanje poplavne ilovice in sige iz würmskih interglacialov. Obroča poplavne ilovice sta iz srednjega in mlajšega würma. Zadnji obroč sige je verjetno zrasel po zadnji poledenitvi. Zadnje tri obroče sige bi bilo dobro datirati s ^{14}C in preveriti naše domneve.

Iz Podorne dvorane Pisanega rova smo analizirali še dva vzorca. Vzorec Po 2 je z vrha stalaktita pod podrtim blokom, zrasel je, ko je bil podrti blok še na stropu dvorane. Vzorec Po 3, je z baze stalagmita, ki še raste na že podrtem skalnem bloku.

Stalaktit Po 2 je sestavljen iz treh plasti sige z dvema vmesnima plastema poplavne ilovice. Na žalost se tudi ta starost ni dala določiti. Po podobnosti sige in vmesnih poplavnih ilovic s stalaktitom Po 1 sklepam, da je Po 2 mlajši od 76.000 let.

Stalagmitu Po 3 je določena starost 19.900 let (+25.200, -24.700). Iz tega sledi, da je podor nastal verjetno v starejšem ali srednjem würmu, stalagmit na podornem bloku je torej začel rasti pred zadnjim würmskim glacialom.

Zelške jame

Iz Blatnega rova Zelških jam na višini 523 m, je bil analiziran vrh stalagmita, ki je bil prekrit s poplavno ilovico. V sigi je bilo veliko *glinenega materiala, ki pa se je ves dal lepo odstraniti.* Vrh stalagmita je starejši od 350.000 let, poplavna ilovica v tem rovu je torej mlajša.

V udornici pod Malim naravnim mostom je na steni v višini 520 m precej sige, ki je prekriva mah. Vzorec je iz sredine te sige in je star 35.000 let (+13.100, -12.400). To kaže, da je udornica starejša, saj je mah potreboval svetlobo za svojo rast, siga pa se je pod steno izločala v interglacialu med starejšim in srednjim würmom.

Fiženca

Na višini 539 m v Fiženci je manjša dvoranica, kjer na steni raste rjavobela zavesa. Vzorec sige je iz stika med steno in zaveso in je star 153.900 let (+237.700, -94.600). Ta dvoranica je obstajala že v riški ledeni dobi in se je v njej tudi že odlagala siga.

Vilenica

Na desni strani pred vhodom v Fabrisov rov je na višini 300 m na rumeno poplavno ilovico odloženo nekaj milimetrov rdeče ilovice, obe prekriva rjava skorjasta siga. Nad to sigo v jami ni več opaziti rumene poplavne ilovice. Rjava skorjasta siga je stara 80.200 let (+56.900, -44.400). Iz tega lahko sklepamo, da po riško-würmski medledeni dobi v zgornjih delih Vilenice ni bilo več poplav in so rumene poplavne ilovice riške starosti, če ne celo starejše.

Lipiška jama

Pred prehodom v Kozinski rov je na višini 268 m odložena rumena poplavna ilovica, tu je najvišje v tej jami. Pokriva jo rumena laminirana siga, ki je starejša od 350.000 let.

Na višini 248 m v zgornjem delu Kozinskega rova je čez poplavno ilovico odložena skorja sige, na kateri rastejo stalagmiti. Baza odlomljenega trikotnega kapnika je staro 160.400 let (+116.900, -61.300). Ta siga je torej riška, poplavne ilovice pa so nedvomno starejše.

Mejame

Rumeno rjava siga iz Mejam je iz višine 345 m. V sigi so lepo ohranjeni drevesni listi. Starost sige je 42.100 let (+29.900, -28.000) in je torej würmska.

Velika ledenica v Paradani

Skorja rjave sige je vzeta pred Gamsovim breznom na višini 1020 m. Siga je starejša od 350.000 let.

SKLEP

Rezultati vseh datacij so podani v sliki 3. Lahko rečemo, da so novo analizirane sige starejše od onih, ki so bile datirane s ^{14}C. Res je, da s ^{14}C metodo lahko datiramo sige samo do 40.000 let. Verjetno so se zavedali meje te metode, in so zato datirali samo stratigrafsko mlajše sige. Pokazalo se je tudi, da rezultati dobljeni s ^{14}C za vzorce starejše od 37. 000 let ne držijo in so v bistvu sige starejše.

Iz novih analiz je razvidno, da je precej vzorcev starejših od 350.000, kjer je meja te metode, zato bi bilo potrebno vzorce datirati še z ESR metodo. Ostale pa bi bilo potrebno še ponoviti z U/Th medodo, da bi bili rezultati bolj zanesljivi.

Za razumevanje dogajanj na našem krasu je potrebno nadaljevati s sistematičnimi datacijami sig.

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