

# UNEXPECTED! NEW AMS DATING FROM AUSTRIAN CAVE BEAR SITES

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## Abstract

New AMS dating for three Austrian sites were conducted on cave bear bones at the Klaus-Tschira-Archaeometry Center in Mannheim, Germany. In total 14 new dates will be presented. The oldest date is 48 ka BP. The faunal remains from the Schwabenreith Cave, located near Lunz (Lower Austria), only consist of cave bears from the taxa *Ursus spelaeus eremus*. The basal and top flowstone layers of excavation area 2 yielded U-Th ages of  $116 \pm 5$  ka and  $78+30/-23$  ka BP, respectively. In the Herdengel Cave, located in the same region, the remains of *U. sp. eremus* and *U. ingressus* were found. A basal flowstone layer yielded a U-Th age of  $112+12/-11$  ka BP. The Brettstein Cave system in the Totes Gebirge (Styria) represents the two cave bear taxa *U. sp. eremus* and *U. ladinicus*. Dated cave bear bones were only known to be older than 49 ka BP.

The new AMS dates include six bone remains from Schwabenreith Cave dated in the period from 34 ka to 48 ka BP. New dating results from the Herdengel Cave show a very close timespan from 44 ka to 48 ka BP. And finally the bears of the Brettstein Cave represent one of the youngest dated remains (22.5 ka to 35 ka BP) in the Alps.

## Samenvatting

Nieuwe AMS-dateringen voor drie Oostenrijkse sites werden uitgevoerd op botten van grottenberen in het Klaus-Tschira-Archaeometry Center in Mannheim, Duitsland. In totaal worden 14 nieuwe dateringen gepresenteerd. De oudste daarvan is 48 ka BP. De faunaresten uit de Schwabenreith grot, nabij Lunz (Neder-Oostenrijk), bestaan enkel uit grottenberen van de soort *Ursus spelaeus eremus*. De druipsteenlagen van bodem en plafond in opgravingsveld 2 gaven U-Th leeftijden van respectievelijk  $116 \pm 5$  ka BP en  $78+30/-23$  ka BP. In de Herdengel grot, gelegen in dezelfde regio, werden de resten gevonden van *U. sp. eremus* en *U. ingressus*. Een bodemdruipsteenlaag gaf een U-Th leeftijd van  $112+12/-11$  ka BP. Het Brettstein grottencomplex in het Totes Gebirge (Stiermarken) vertegenwoordigt de twee grottenbeersoorten *U. sp. eremus* en *U. ladinicus*. De enige bekende gedateerde botten hebben een ouderdom van meer dan 49 ka BP.

De nieuwe AMS-dateringen omvatten zes botresten van de Schwabenreith grot uit de jongere periode van 34 tot 48 ka BP. Nieuwe data van de Herdengel grot geeft een nauwe tijdspanne van 44 tot 48 ka BP. Tot slot vertegenwoordigen de grottenberen uit de Brettstein grot één van de jongst gedateerde resten in de Alpen (22,5 tot 35 ka BP).

## DESCRIPTION OF THE CAVE BEAR SITES

The Schwabenreith Cave (Austrian cave cadaster no. 1823/32) is located near Lunz am See in the western part of Lower Austria (Fig. 1) at 959 m above sea level. In excavation area 2, a 1.3 m thick bone layer only consisted of cave bear remains (*Ursus spelaeus eremus*) (Fig. 2). They were analysed from a taphonomic point of view for the first time by Pacher (2000). The radiometric data from flowstone samples considered the bear remains to be of an early Würmian age. The basal and top flowstone layers yielded Uranium-Thori-

um (U-Th) ages of  $116 \pm 5$  ka and  $78+30/-23$  ka, respectively (Frank & Rabeder, 1997a). The abundance of cave bear remains is very high. All skeletal elements are represented. Despite the density of remains, a taphonomic analysis verifies a certain transport of bones. It probably must have taken place within humid sediment with plasticized consistency.

The Herdengel Cave (Austrian cave cadaster no. 1823/4) is located near the Schwabenreith Cave (Fig. 1) at 878 m above sea level. Beneath remains of cave bears (*U. sp. eremus* and *U. ingressus*) other pleistocene animals like cave lion and wolf were found (Frank & Rabeder, 1997b; Pacher, 2009). Even a Mousterian artifact is documented

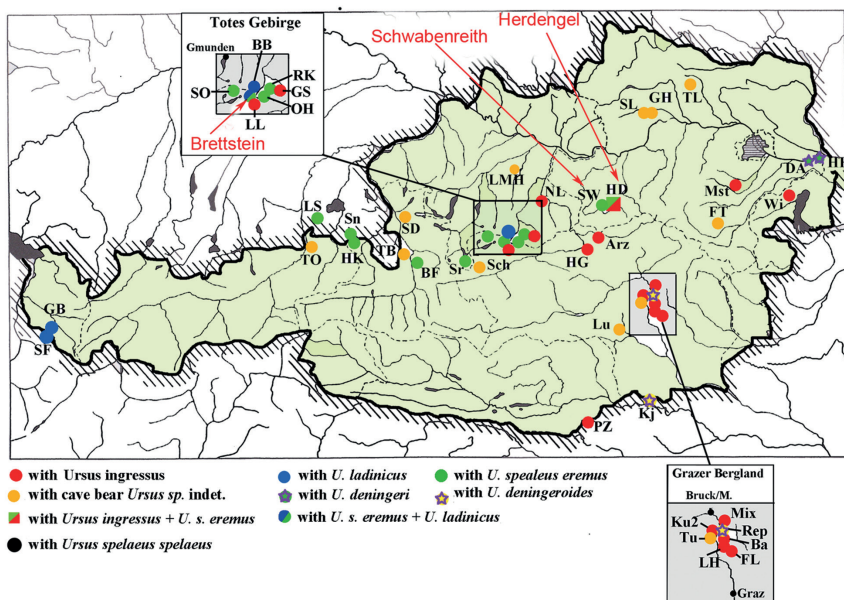


Figure 1: (modified after Rabeder et al., 2011): Important cave bear sites in Austria with different cave bear species, and the locations of the three studied caves

Figuur 1: (naar Rabeder et al., 2011) Belangrijke Oostenrijkse vindplaatsen van verschillende soorten grottenberen en de locaties van de drie onderzochte grotten

from the approximately 3 m thick bone layer (Frank & Rabeder, 1997b). A basal flowstone layer yielded a U-Th age of  $112 \pm 12/-11$  ka and  $111 \pm 11/-10$  ka BP (Leitner-Wild et al., 1994). Cave bear bones were dated by radiocarbon and U-Th method from  $37 \pm 0.59$  ka to  $135 \pm 11/-10$  ka (Leitner-Wild et al., 1994; Frank & Rabeder, 1997b).

The huge Brettstein Cave system ("Brettstein Bärenhöhle", Austrian cave cadaster no. 1625/33), is over 4 km long and is located in the southern area of the eastern Totes Gebirge, near Bad Mitterndorf (Fig. 1) at 1664 m above sea level (entrance a). Six excavation areas were installed in four different cave parts. In none of the six excavation areas the fossil remains were found in original position (Döppes et al., 1997). The Pleistocene large mammal fauna consists mainly of cave bear (*U. sp. eremus* and *U. ladinicus*). Cave lion, wolf, wolverine and ibex are presented by several bones (Ehrenberg, 1958; Rabeder et al., 2001). The chronological position of the cave bear remains from the Brettstein Cave is confirmed by radiocarbon dates older than 37, 41 and 44 ka BP (Döppes, 2000; Pacher, 2003). An AMS-14C dated bear bone from the Blasloch, at 1623 m above sea level, nowadays part of the Brettstein Cave system, was dated to  $51,300 \pm 2,300/-1,800$  years BP (Pacher & Stuart, 2009).



Figure 2: Excavation area 2 of the Schwabenreith Cave  
Figuur 2: Opgravingsveld 2 van de Schwabenreith grot

## METHOD

The development of the accelerator mass spectrometry (AMS) made it possible not only to significantly minimize the quantity of samples required, but also to increase measurement speed and precision of the counting technique considerably. This method was used to establish the age of the fossils from the three caves.

Since contamination can occur during soil sedimentation, datable carbonaceous samples are freed from coarse impurities and foreign carbon that can distort age. Samples are pretreated with acid and base steps to remove carbonate and humic acids. In the case of bone samples, the collagen – a structural protein – is extracted, ultra-filtered to remove molecules of chain length lower than 30kDa (potentially younger proteins taken up by the bone from water), and freeze-dried. Bone was long considered to be unsuitable for 14C dating since it is very porous and the bone apatite is prone to exchange reactions with the groundwater and surrounding material. However, collagen is hardly prone to exchanges. In the final step, organic samples are converted into carbon dioxide by combustion of the sample material and subsequently reduced to graphite. Sample sizes in the mg range are suitable for measurement in an accelerator mass spectrometer. The graphite sample obtained is sputtered with cesium ions in order to obtain carbon ions. The ions of the carbon isotope are separated in the accelerator according to their different masses. From the measured 14C/12C ratios the age of the samples can be determined. The measured 13C serves as the control for and correction of fractionation processes in nature or in the laboratory.

Radiocarbon data is by default reported as conventional 14C age BP. This should not be taken as a calendar age. The origin of this convention lies in the fact that originally the data was converted to an age by using the radioactive decay for age determination assuming constant 14C production, hence atmospheric 14C level, in the past. Unfortunately, it turned out that this is incorrect. Radiocarbon is produced in the atmosphere by extraterrestrial irradiation of which galactic cosmic rays provide the major component. Variable shielding by the geomagnetic field and the magnetic field of the protons in the solar wind lead to fluctuations in the atmospheric radiocarbon level. To cope with this, a calibration curve was established using independent dating methods such as dendrochronology (until ~10,000 BC), Uranium-Thorium dating of speleothems and corals, and varve counting of terrestrial and marine sediments. The limit of the method is due to the fact that after approximately 10 half-lives (half-life of  $5,730 \pm 40$  years) only less than 1 permille of the original 14C remains, hence no material older than 50,000 years can be dated reliably with this method (Reimer et al., 2013; Olsson, 2009).

Calibrated ages are usually quoted with a 1-sigma error range, corresponding to a confidence probability of 68.3%. It rises to 95.5% for 2-sigma. The calibration here was performed using the programme SWISSCAL 1.0 (L. Wacker, ETH Zürich) with the INTCAL13 dataset.

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## RESULTS

The Curt Engelhorn-Centre for Archaeometry (CEZA) received 17 samples of cave bear bones to determine the age by  $^{14}\text{C}$  with the MICADAS Accelerator of their subsidiary institute Klaus-Tschira-Archaeometry Center. The radiocarbon data is shown in Table 1.

The  $^{14}\text{C}$  age is normalized to  $\delta^{13}\text{C} = -25\text{‰}$  (Stuiver & Pollach, 1977). The  $\delta^{13}\text{C}$  value originates from the measurement of the  $^{13}\text{C}/^{12}\text{C}$  isotope ratios in the accelerator; its error is reported to approximately 0.5‰. However, the value can be falsified by isotope separation during preparation and in the ion source of the accelerator over the original value of the sample material, and can only be used to correct the fractionation effects. The value is therefore not comparable with the measurement in a mass spectrometer for stable isotopes (IRMS) and should not be used for further data interpretation. Typically, the AMS-derived value is accurate within 2-3‰ compared to the original value. The C/N ratio and carbon content of the collagen extracted are in the normal range (Van Klinken, 1999), and the collagen preservation of the samples is good.

## DISCUSSION

The knowledge of the evolution and phylogeny of cave bears has changed fundamentally in recent years. While it was assumed that there had been only one cave bear species, we now know from morphological studies (Rabeder, 1999) and especially genetic analyses (Rabeder *et al.* 2004, Stiller *et al.*, 2010) that the family tree of the cave bear is very complex and its research still in progress. During the same

geological period (50 – 30 ka BP) at least three species lived in the Alps: *U. sp. eremus*, *U. ladinicus* and *U. ingressus* (Rabeder *et al.* 2004). All are extinct before the coldest phase of the last ice age (Pacher & Stuart, 2009).

Three dates from the Schwabenreith Cave excavation area 2 are consistent with the time range from the Herdengel Cave, in particular those from 46 ka BP to 49 ka BP (including errors). Two samples are approximately 10,000 years younger (range 34,010 – 37,400 years BP).

Another AMS date from excavation area 3, which is located in another part of the cave, falls at the lower range of dates from Schwabenreith Cave (52,500±1,900/-2,500 years BP) (Pacher, 2000).

Meanwhile, both speleothem layers of excavation area 2 have been redated (Christoph Spötl, University of Innsbruck, personal communication). The initial data were confirmed. The cave bear bones from this excavation area consistently dated younger than the speleothem above. Maybe the matrix of excavation area 2 influenced the data. The controlling values of C/N ratio, collagen and carbon of the new AMS data support taphonomic results. The articulated remains could have been transported beneath the speleothem. The spatial distribution of bones and a low inclination of layers indicate a transport of remains NW-SE or NW-SW. Some of the few articulated parts of single skeletons in this area have probably been transported in correct anatomical position (Pacher, 2000). Since there are cave bear bones directly covered by speleothem, new datings can perhaps clarify the situation.

The stratigraphy of the Herdengel Cave, with a cross section of nearly 5 m (Fig.3), shows cave bear bones from 2.0 to 3.7 m and below the basal speleothem layer. Con-

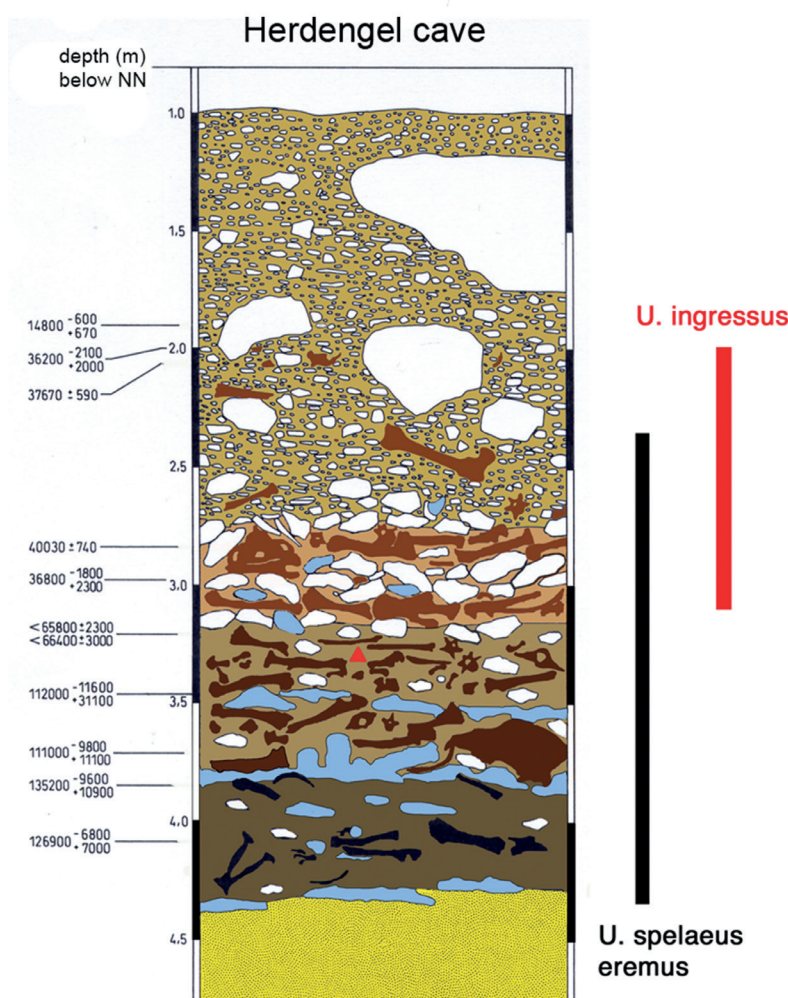


Figure 3: (modified after Frank & Rabeder, 1997b) Standardized cross section of the Herdengel Cave

Figuur 3: (naar Frank & Rabeder, 1997b) Schematische doorsnede van de Herdengel grot.

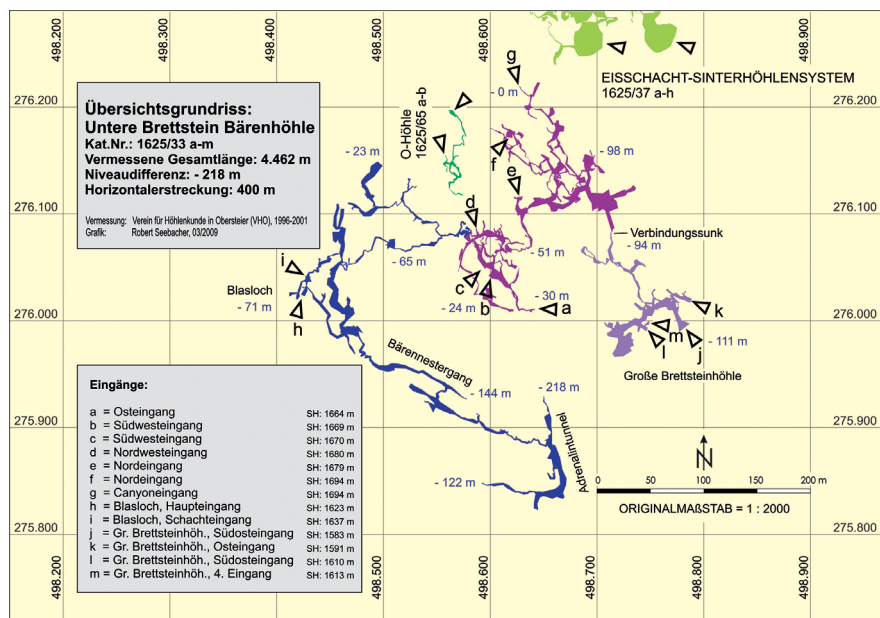


Figure 4: (by Robert Seebacher, Verein für Höhlenkunde in Obersteier 03/2009) Map of the Brettstein Cave system with excavation areas near the entrances (a, b, c) and Blasloch (h)

Figuur 4: (door Robert Seebacher, Vereniging voor Grottenkunde in Obersteier 03/2009) Overzichtskaart van het Brettstein grottencomplex met opgravingsvelden nabij de ingangen (a, b, c) en Blasloch (h)

centrations of bones were found at 3.0 to 3.6 m (layer 4-3). Layer 5 above contains a mixture of fossils and larger stones. The basal part of layer 6 contains only few cave bear bones. The cave bear bones in layer 1 were excavated below the basal flowstone layer that yielded a U-Th age of  $112 \pm 12/-11$  ka and  $111 \pm 11/-10$  ka BP. By applying the uranium series method (Frank & Rabeder, 1997b) to the Herdengel Cave cross-section, the evolutionary rate of the cave bears was determined. Uranium series data from the fossil bones were partly verified by an independent carbonate speleothem age. For both, bone layers and the carbonate formation found in stratigraphic relation, the determined ages correspond to a normal time sequence. According to the relatively precise time scale obtained by absolute dating, the evolutionary mode of the cave bears was determined as gradual (Rabeder, 1999).

The five new dates from layer 6 to layer 1 show a spread of approximately 6,000 years (using the minimum and maximum range of individual dates). The basal part of layer 6 contains probably reworked cave bear remains, because they are intermingled with younger fauna elements like marmot, and the density of finds is low within the sediment. The sediments consist of a yellow-brownish loam with rubble and differ clearly from layer 5 to 4 below. An erosion period is documented in the small layer 5 in-between. The loamy layer contains still abundant fossil remains, but also a higher degree of larger stones. Layers 4 and 3 are the richest in cave bear remains and seem to represent the original cave bear occupation phase(s). The date from layer 4 is slightly younger if errors are considered (range 42,600 – 45,660 years BP), but still overlaps with the range of one of the remaining samples. Beneath the basal flowstone layer – almost of the same age as the one in the Schwabenreith Cave (excavation area 2) – bones from layer 1 were dated the same age as bones from above this speleothem. Maybe the basal speleothem layer was broken, as is the case in Schwabenreith Cave.

The many entrances (a-m) of the Brettstein Cave system (Fig.4) and the rearrangement of the bones (Rabeder *et al.*, 2001) are evidence of the shearing action of outflowing ice during the Last Glacial Maximum. With the help of ancient DNA investigation, the cave bear species *Ursus sp. eremus* and *Ursus ladinicus* can be distinguished. Unfortunately, it is not possible to differentiate the two cave bear species based on single bones and tooth elements. Prior to our study, the cave bear remains were not confirmed by radiocarbon dates, except an AMS-14C dated bone from the Blasloch, which was dated to  $51,300 \pm 2,300/-1,800$  years BP.

For the first time, enough collagen could be obtained for dating. All three new datings show a younger time span than the sample from the Blasloch. The dates of 21,970 and 22,510 years BP would be the youngest dated cave bears, not only in the Alps but throughout its range. The youngest known specimen of cave bear in the High Alps, based on audited dates, is from the Lieglloch in the Totes Gebirge (Styria), with an age of  $26,390 \pm 110$  years BP (Pacher & Stuart, 2009).

## CONCLUSION

In general, the cave bears from the Schwabenreith Cave and the Herdengel Cave have the same main occupation phase, despite a different stratigraphy and cave morphology. The Brettstein Cave sample shows the youngest cave bear site in the Alps. As a result, contradictions arise to the current opinion, that the plateau of the Totes Gebirge was covered with ice at that time. Additional analyses are necessary to clarify this question.

The dated collagen of the Brettstein Cave samples is examined with the help of ancient DNA analysis to confirm the bear species. Furthermore, since January 2016, 19 new bone samples from the Herdengel Cave (layer 6 to layer 1), six from the Schwabenreith Cave, and four from the Brettstein Cave (29 in total) have been analysed by the Klaus-Tschira-Archaeometry Center. With more AMS dated cave bear bones and ancient DNA analysed samples, we will try to find an explanation for what was going on during the Wurm glacial in these Austrian cave bear sites.

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4.0Lab no	sample	layer	bone	$\delta^{13}\text{C}$ AMS	age	+/-	C/N	%C	%coll
MAMS-14912	SW 773	F5 or F6 / disturbed	Humerus F	-27.6	34010	210	3.3	16.2	1.7
MAMS-17791	SW 468	F5 / 150-160 cm	Vertebra	-21.8	37400	290	2.8	19.3	4.9
MAMS-14911	SW 137	F5 or F6 / disturbed	Scapula F	-27.3	47350	800	3.3	37.0	7.8
MAMS-17797	SW 793	F5 or F6 / disturbed	Calcaneus F juv	-21.3	47820	800	3.3	37.2	2.1
MAMS-17796	SW 140	F5 / wall	Costa F	-20.8	48270	930	3.2	32.5	1.0
MAMS-17795	SW 791	disturbed	Calcaneus F	-18.5	> 49000		2.9	34.8	4.5
MAMS-17793	SW 101	F5 or F6 / direct under speleothem	Calcaneus juv	-21.7	> 49000		3.2	29.6	10.6
MAMS-17794	SW 137	F5 or F6 / disturbed	Vertebra		too little collagen				
MAMS-17792	SW 773	H5 / 222	Costa F		no results				
MAMS-14899	HD 88	Layer 4 / 290-300 cm	F	-20.7	44130	1530	3.4	19.3	3.6
MAMS-14900	HD 357	Layer 3 / 330-360 cm	F	-24.9	48530	840	3.1	20.4	3.0
MAMS-14901	HD 561	Layer 2 / 360-370 cm	F	-23.6	45460	370	3.1	39.7	2.0
MAMS-14902	HD 85	Layer 1 / 380-390 cm	F	-24.0	46510	410	n. d.	40.5	4.0
MAMS-17801	BS 189	area 6 / disturbed	Metapodium F	-26.4	21970	70	3.5	38.9	1.0
MAMS-14893	BS 80	area 4 / disturbed	Radius F	-20.5	22510	120	3.1	39.2	8.0
MAMS-17800	BS 43	area 3 / 50-60 cm	Metapodium	-22.5	34820	160	3.4	3.8	2.9
MAMS-24067	BS 196	disturbed	Cranium F		too little collagen				

Table 1: New AMS dating from cave bear bones from the Schwabenreith Cave, Herdengel Cave and Brettstein Cave

Tabel 1: Nieuwe AMS dateringen van grottenbeerbotten uit de Schwabenreith grot, Herdengel grot en Brettstein grot

Abbreviations / Afkortingen: F: fragment; SW: Schwabenreith Cave; HD: Herdengel Cave; BS: Brettstein Cave, C/N: C/N ratio

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