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Prospecting for Last Interglacial speleothems in Vercors

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Abstract

The Last Interglacial (LIG, ~130–116 ka) was one of the warmest interglacials of the past 800,000 years. Speleothems offer superior age control and a few LIG records are available from the Eastern Alps. In order to prospect for LIG speleothems in the Western Alps, we drilled small diameter cores at the base of stalagmites. In the Vercors, we sampled 27 speleothems in 6 different caves and dated them using the U-Th method. Here, we present the results of these reconnaissance drilling campaigns. Although, to our surprise, we did not identify stalagmites of LIG age, the resulting ages provide useful chronological information on the individual karst settings.

Among these 27 ages, 5 are Holocene, the others belong to Marine Isotope Stage 2 (5 samples), 3 (2), 5a (1) and 5c (1), 8 (1), 9 (2), 11 (4), 12 (1), 13 (1) and 4 are beyond the U-Th dating limit. These dates can help to re-assess the age of certain cave conduits and the evolution of this well-documented karst region. In addition, they may serve as a basis for future speleothem-based paleoclimate studies of the Vercors.

Résumé

À la recherche de spéléothèmes du Dernier Interglaciaire dans le Vercors. Le Dernier Interglaciaire (LIG, ~130-116 ka) a été l'un des interglaciaires les plus chauds des 800 000 dernières années. Les spéléothèmes offrent la possibilité d'une excellente chronologie pour cette époque et quelques enregistrements sont disponibles dans les Alpes orientales. Afin de trouver des spéléothèmes LIG dans les Alpes occidentales, nous avons foré des carottes de petit diamètre à leur base. Dans le Vercors, nous avons carotté 27 spéléothèmes dans 6 grottes différentes qui ont ensuite été datés par la méthode U-Th. Nous présentons ici les résultats de ces campagnes de forage de reconnaissance. Bien que, à notre surprise, nous n'ayons pas identifié de stalagmites d'âge LIG, les âges obtenus fournissent des informations chronologiques utiles pour la connaissance du karst. Parmi ces 27 âges, 5 sont holocènes, les autres appartiennent au stade isotopique marin 2 (5 échantillons), 3 (2), 5a (1) et 5c (1), 8 (1), 9 (2), 11 (4), 12 (1), 13 (1) et 4 sont au-delà de la limite de datation U/Th. Ces dates peuvent aider à réévaluer l'âge de certains conduits et l'évolution de ce karst de moyenne montagne. En outre, elles peuvent servir de base pour de futures études paléoclimatiques du Vercors à partir des spéléothèmes.

1. Introduction

The Last Interglacial (LIG ~130–116 ka), equivalent to Marine Isotope Stage (MIS) 5e and considerably warmer than the current interglacial, is a useful test bed for the future course of the Holocene (Anthropocene). In the foreland of the European Alps, the LIG has been studied using pollen preserved in mires and lake sediments. While these records document the succession of tree and other plant species across the LIG, they are very poorly constrained chronologically. Speleothems in caves offer superior age control and a few records are already available from the Austrian Alps (SPÖTL et al., 2002;

MOSELEY et al., 2015) and the Swiss Alps (HÄUSELMANN et al., 2015; WILCOX et al., 2020). The aim of the project was to find speleothems of LIG ages in the French Alps and thus extend our knowledge about this period across the entire Alps. Mountains are of particular interest for climate science because they are highly sensitive and show higher amplitudes of climate change than surrounding regions (Mountain Research Initiative EDW Working Group, 2015). Site selection was based on previous work on the Vercors

(e.g., AUDRA 1994; DELANNOY, 1997) and discussion with colleagues and local cavers. Criteria of this selection included the availability of high-quality sample material and whether the cave has been characterized previously (including geomorphological observations and speleothems of different age).

Sites description

The four study sites (6 caves) are presented from north to south (Fig. 1). At 1144 m a.s.l. the **Antre de Vénus** is a horizontal cave of 850 m length. It partially intersects the Croix Perrin anticline and at the time of its formation, it drained the vast Méaudre-Autrains depression. It is interpreted as one of the ponors of a vast paleo-poljé and is the witness of a higher base level of the hydrographic network during the Neogene (DELANNOY *et al.*, 1998). The Coulmes karst, northwest of the Vercors, is a multi-level cave system that has recorded the landscape evolution since the Neogene. **Pra l'Etang** (1220 m a.s.l., 300 m length) is a cave marking a former higher perched base level. Three samples were taken there. Nearby, at a lower elevation, in the **Gournier system** (572 m a.s.l., 18 km length), an underground river which can be followed up to 680 m a.s.l. Six samples were collected in the first fossil gallery of this cave. Next to it, the **Coufin/Chevaline network** (580 m a.s.l., 32 km length) also hosts two underground rivers. Samples were collected in the so-called "gruyères" sectors. The **Pabro cave** (840 m a.s.l., 100 m length) is a decapitated cave facing the Coulmes karst and perched above the gorges de la Bourne. Six samples were taken in the main room. Finally, the **Chuats system** was the subject of preliminary investigations. It is an important and recently explored network of 43 km length (LANDRY *et al.*, 2019) that

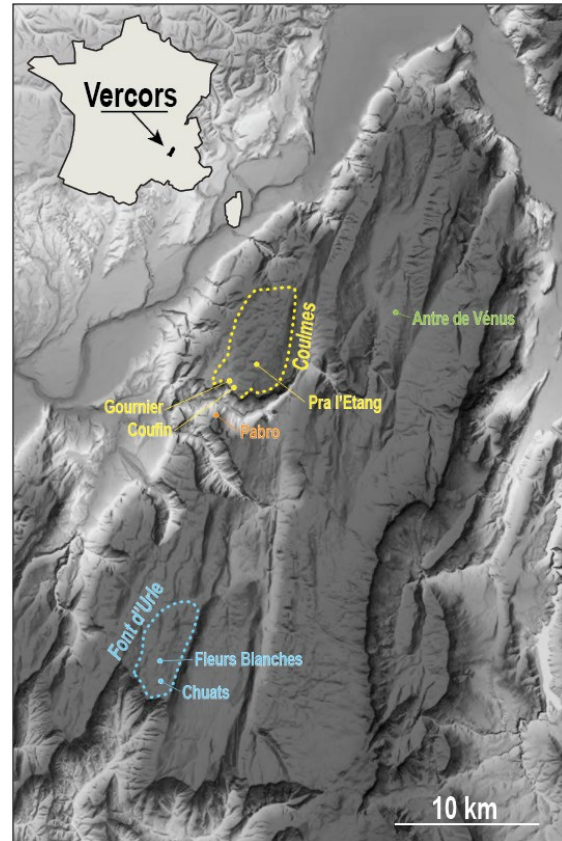


Figure 1: Map of the Vercors region with sampled caves comprises 5 known entrances. Three samples were taken from the Chuats II chasm in the sectors near the base of the entrance shafts series. These are the first dated speleothems in this major cave system of the southern Vercors.

2. Materials and methods



Figure 2: Sampling of a calcite core in a stalagmite with a hand-held drill and a water flushing unit.



Figure 3: Example of small core pieces used for dating. Both pictures: Serge Caillault

Our sampling approach of taking drill cores instead of entire dripstones minimizes the impact on the cave environment (Fig. 2) (SPÖTL and MATTEY, 2012). In order to search for LIG speleothems, we drilled small-diameter cores (Fig. 3) at the

base of 21 speleothems (stalagmite and flowstone) and exclusively retrieved broken stalagmites (6 in total). We targeted the central axis of the stalagmites and sampled the innermost part of each core.

The cores were then cleaned in an ultrasonic bath before being drilled and dated using the U-Th method. Between 30 and 70 mg were analysed at the University of Minnesota and the Xi'an Jiatong University following the same procedure

(EDWARDS et al., 1987). All measurements were performed on a ThermoFisher Neptune Plus MC-ICP-MS using the technique described by CHENG et al. (2013).

3. Results

Among the 27 analyzed speleothem samples 5 are Holocene in age, and the others fell into Marine Isotope Stages 2 (5 samples), 3 (2), 5a (1) and 5c (1), 8 (1), 9 (2), 11 (4), 12 (1),

13 (1), while 4 are beyond the U-Th dating limit (older than 650 000 years). The ages are given in year before present (BP) in table 1.

Sample Number	²³⁸ U (ppb)	²³² Th (ppt)	²³⁰ Th / ²³² Th (atomic x10 ⁻⁶)	δ ²³⁴ U* (measured)	²³⁰ Th / ²³⁸ U (activity)	²³⁰ Th Age (yr) (uncorrected)	²³⁰ Th Age (yr) (corrected)	δ ²³⁴ U _{initial} ** (corrected)	²³⁰ Th Age (yr BP)*** (corrected)
ADV-01	259.4 ±0.6	13671 ±275	294 ±6	-30.2 ±2.2	0.938 ±0.004	420669 ±25855	418950 ±25449	-99 ±10	418881 ±25449
ADV-02	186.4 ±0.3	13159 ±264	297 ±6	190.0 ±2.0	1.273 ±0.004				Beyond U/Th Limit
ADV-03-BOT	253.5 ±0.4	2733 ±55	1902 ±38	169.9 ±1.8	1.244 ±0.003				Beyond U/Th Limit
ADV-04-BOT	115.8 ±0.2	218 ±5	9881 ±229	108.0 ±1.9	1.128 ±0.003	434526 ±18286	434482 ±18281	368 ±20	434413 ±18281
COU-01	430.5 ±0.8	1865 ±38	4218 ±85	85.1 ±2.0	1.108 ±0.003	506997 ±33601	506895 ±33573	356 ±35	506826 ±33573
COU-02	378.8 ±0.7	5369 ±108	1233 ±25	87.1 ±2.0	1.059 ±0.003	325705 ±6444	325365 ±6429	218 ±6	325296 ±6429
COU-03	17.1 ±0.0	150 ±4	1769 ±54	37.5 ±1.9	0.944 ±0.011	251873 ±11203	251634 ±11183	76 ±5	251565 ±11183
COU-04	122.1 ±0.2	177974 ±3566	13 ±0	41.8 ±1.9	1.187 ±0.005				Beyond U/Th Limit
COU-06	108.4 ±0.2	117829 ±2364	16 ±0	46.8 ±2.0	1.042 ±0.005	421933 ±25213	390143 ±30279	141 ±13	390074 ±30279
GO-13-Bot	236.7 ±0.3	19251 ±386	38 ±1	356.2 ±2.1	0.190 ±0.001	16324 ±86	14585 ±1234	371 ±3	14517 ±1234
GO-14	313.2 ±0.5	12650 ±254	63 ±1	284.8 ±2.2	0.154 ±0.001	13862 ±91	12951 ±651	295 ±2	12883 ±651
GO-15	314.5 ±0.5	691 ±14	874 ±18	200.3 ±2.1	0.116 ±0.001	11088 ±66	11035 ±76	207 ±2	10967 ±76
GO-16	150.9 ±0.2	11337 ±227	34 ±1	143.5 ±2.1	0.154 ±0.001	15701 ±159	13782 ±1367	149 ±2	13714 ±1367
GO-17	107.7 ±0.1	3197 ±64	83 ±2	184.1 ±2.2	0.150 ±0.002	14745 ±192	14018 ±549	192 ±2	13950 ±549
GO-18	603.4 ±1.2	155 ±4	8194 ±206	300.1 ±2.3	0.127 ±0.000	11207 ±49	11201 ±50	310 ±2	11133 ±50
PLG-01	194.0 ±0.3	4245 ±85	133 ±3	115.1 ±2.1	0.176 ±0.001	18741 ±129	18172 ±423	121 ±2	18103 ±423
PLG-03	168.7 ±0.2	697 ±14	350 ±8	103.9 ±2.0	0.088 ±0.001	9012 ±91	8903 ±119	107 ±2	8834 ±119
PLG-04	192.6 ±0.4	1734 ±35	56 ±2	-26.5 ±2.1	0.030 ±0.001	3455 ±96	3186 ±214	-27 ±2	3117 ±214
PB-19	73.2 ±0.1	448 ±9	979 ±23	41.1 ±2.4	0.363 ±0.005	46662 ±728	46492 ±736	47 ±3	46424 ±736
PB-20-Bot	79.2 ±0.1	1291 ±26	433 ±10	66.5 ±2.0	0.429 ±0.004	55717 ±661	55276 ±728	78 ±2	55208 ±728
PB-21-Bot	96.2 ±0.1	64 ±3	2179 ±106	34.3 ±2.2	0.088 ±0.002	9642 ±223	9623 ±224	35 ±2	9555 ±224
PB-22	106.1 ±0.1	34993 ±701	32 ±1	34.5 ±1.7	0.646 ±0.006	106120 ±1588	96534 ±6960	45 ±2	96466 ±6960
PB-23	106.3 ±0.2	9943 ±199	174 ±4	7.5 ±2.3	0.988 ±0.008	416445 ±45062	413750 ±43912	24 ±8	413682 ±43912
PB-24	86.8 ±0.1	10496 ±210	134 ±3	6.9 ±2.0	0.985 ±0.008	406405 ±40974	402901 ±39666	21 ±7	402833 ±39666
CHU01-TOP	362.7 ±0.4	793 ±16	5227 ±106	275.0 ±1.8	0.693 ±0.002	82559 ±387	82512 ±388	347 ±2	82443 ±388
CHU02-BOT	1785.4 ±6.9	298 ±6	98680 ±2111	0.2 ±2.5	0.999 ±0.005	732945			Beyond U/Th Limit
CHU04-A	487.8 ±0.5	478 ±10	18678 ±382	126.2 ±1.4	1.110 ±0.002	327917 ±4573	327893 ±4572	318 ±5	327824 ±4572

Table 1: U-Th dating results. Ages are reported in Year BP; the error is 2 sigma. ADV: Antre de Vénus; COU: Couffin; GO: Gournier; PLG: Pra L'Étang; PB: Pabro; CHU: Chuat

4. Discussion and conclusion

When compared to the deep-sea δ¹⁸O curve based on benthic foraminifera (Fig. 4), the majority of the stalagmites commenced to grow during interglacial periods: 5 are Holocene in age, 2 are from MIS 9, 4 from MIS 11 and 1 from MIS 13. Some ages indicate growth during interstadials. On the other hand, one sample plots at the onset of the Younger Dryas, another sample plots into a glacial (MIS 12) but overlaps within error with the following major interglacial MIS 11 (Fig. 4). Another sample falls into MIS 8 but again its error bar overlaps with an interglacial, MIS 7. Interestingly, we found no speleothems that formed during the LIG.

Regarding the confidence of the dating, the material originating from stalagmites had almost always a higher

Uranium concentration and was cleaner (less detrital thorium) than flowstones from the same area in the cave. The high detrital content of the flowstone from the Couffin/Chevaline river were challenging to date and some samples had to be discarded. Samples with a small ²³⁰Th/²³²Th atomic ratio (on the order of tens) should be cautiously considered.

We report these new dates to serve as (a) minimum ages for speleogenetic studies of these caves (e.g. to assess the minimum age of certain conduits), and (b) as pilot data for future paleoclimate studies of this part of France. Some of these dates will later be integrated in local studies on these cave systems.

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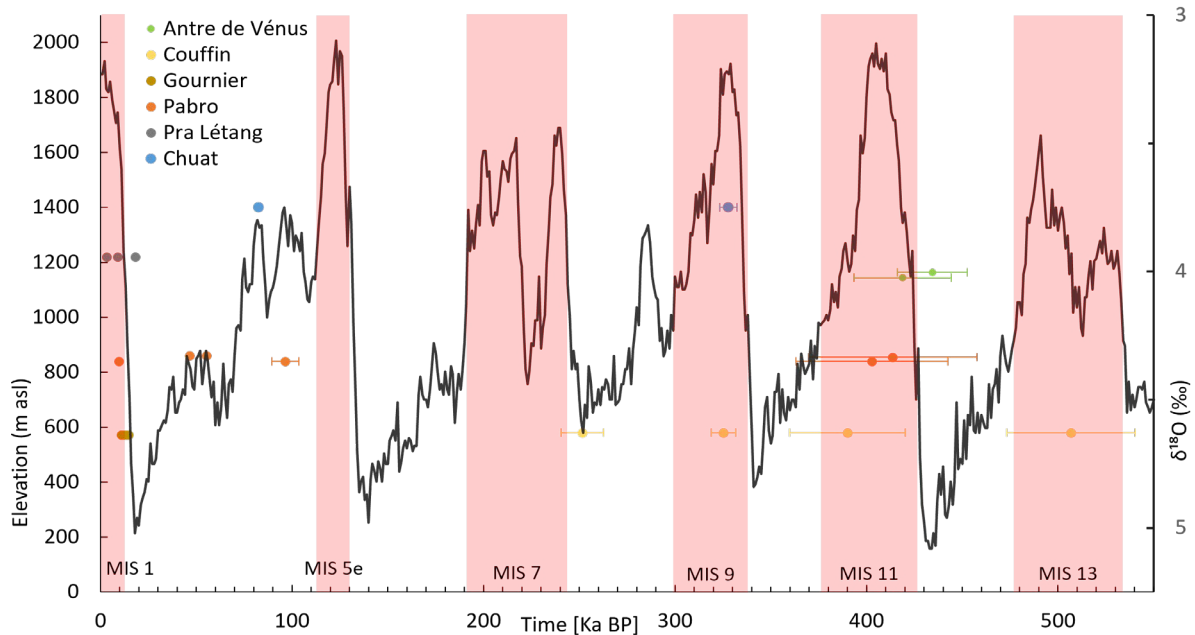


Figure 4: Basal ages with 2 sigma error bars of sampled speleothems from the Vercors arranged according to their approximate elevation (cave entrance), compared to the deep-sea $\delta^{18}\text{O}$ curve (LISIECKI and RAYMO, 2005). Interglacials are highlighted in purple.

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