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ABSTRACT. The Grotte Cosquer (southeastern France) is a Paleolithic painted cave only accessible by a deep-water dive. The cave has yielded numerous Paleolithic engravings and drawings, which were produced from wood charcoal. This article presents new radiocarbon dates obtained on samples collected in 2012 directly on 17 parietal representations and at the soil surface, and discusses the ^{14}C results obtained since the discovery of the cave in 1992. A total of 41 samples were dated with ages ranging from 33,000 to 20,000 cal BP. They show that the cave was intermittently decorated over about 10,000 yr.

KEYWORDS: decorated Cosquer cave, ^{14}C dating, Paleolithic.

INTRODUCTION

The Cosquer Cave near Marseilles was discovered in 1991 by a scuba diver (Clottes et al. 1992a). Its entrance is now 40 m below sea level, but at the height of the last glaciation, the level of the Mediterranean Sea was 135 m lower than today and the entrance of the cavity was more than 6 km from the sea. In this area, the coast was lined by islands that surrounded a steppe plateau closed on three sides, which was favorable to large herbivores and their hunting. The food resources of the three habitats (sea, plains, and mountains) made this place particularly attractive for prehistoric people. Access to the cave entrance was closed by the postglacial marine transgression about 10,000 yr ago and only a fifth of the cavity surfaces accessible to Upper Paleolithic people have survived; the rest is underwater (Figure 1). The preserved part of the cave is richly decorated with rock paintings, drawings, and carvings scattered in all areas. These representations attributed to the Paleolithic period consist of 194 animal figures, 69 hand stencils, 240 geometric signs, and 2 human shapes. Cosquer is one of the most ornate caves from the Franco-Cantabrian group (Clottes et al. 1992b, 1997). The drawings were made with red or black pigments, the latter color being obtained from wood charcoal (*Pinus sylvestris*) that can be dated by the radiocarbon method. Engraved figures are also abundant on the wall surface, which is rather soft and smooth because it is mostly composed of moonmilk formation resulting from the alteration of the limestone. Observation of the wall reveals the presence of many hollows and deep scrapings, suggesting that this creamy sediment was collected by prehistoric people (Clottes et al. 2005a).

PREVIOUS RESULTS

From 1992 to 1998, J Courtin (and J Clottes) sampled four ground charcoal specimens and charcoal splinters on nine animal representations, three hand stencils, and two undetermined marks for accelerator mass spectrometry (AMS) ^{14}C dating (Arnold et al. 1987; Clottes and Courtin 1994). The parietal samples consisted of three horses (CHV001, 005, and 007), two bison (BIS001 and 002), a feline (FEL001), a stag (CER001), a megaceros (MEG001), and a

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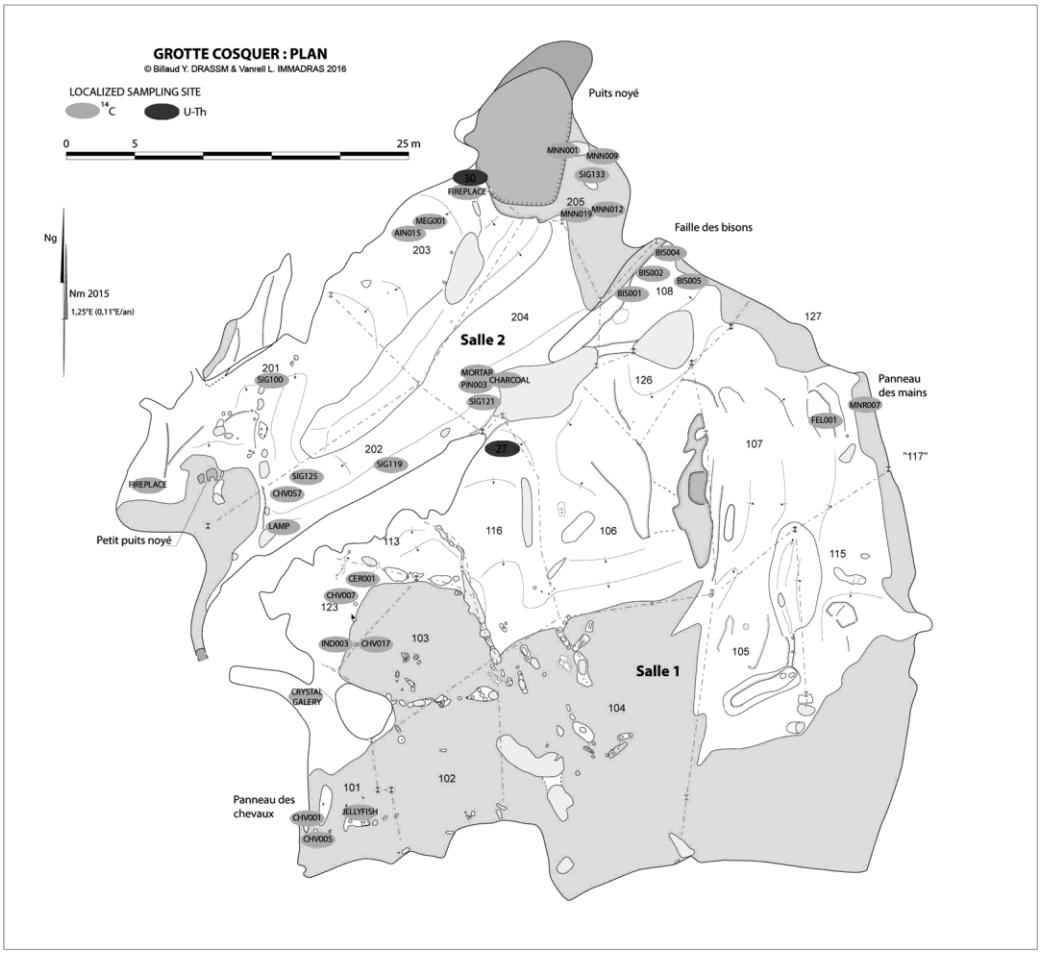

Figure 1 Map of Cosquer Cave with the location of the dated samples

jellyfish shape, three hand stencils (MNR007, MNN12, and 19), and two geometric signs (SIG100 and 121). There is no picture of the sampling being conducted, but the exact location of the samples is known for most of them (Table 1, column 4). These first ^{14}C results (Figure 2) obtained on the Tandétron (LSCE, Gif-sur-Yvette) suggested that the cave was decorated during at least two main phases about 10,000 yr apart (Clottes et al. 1992b, 1997; Valladas et al. 2001): two hand stencils (MNR007 and MNN19), a bison (BIS002), and the oval mark S100 were placed during the first phase between 33,000 and 31,000 cal BP (Reimer et al. 2013), while six animals (CHV001, 007, BIS002, CER001, MEG001, FEL001) and the star-like sign (S121) were dated to the second phase, between 25,000 and 21,000 cal BP. It is noteworthy that these bison, BIS001 and BIS002, which were dated respectively to the second and first phases of decoration, are laid one beside the other and display the same drawing conventions. Such a situation could be explained in two ways: either the conventions persisted through ~10,000 yr or BIS002 is contemporary with BIS001 and was drawn with charcoal left by people who came into the cave during the first phase (Clottes et al. 1997). Finally, one hand (MNN12) and a horse (CHV005) were dated to 29,000–28,000 cal BP. These latter results suggest the eventual existence of an intermediate period of decoration of the cave between the two main phases,

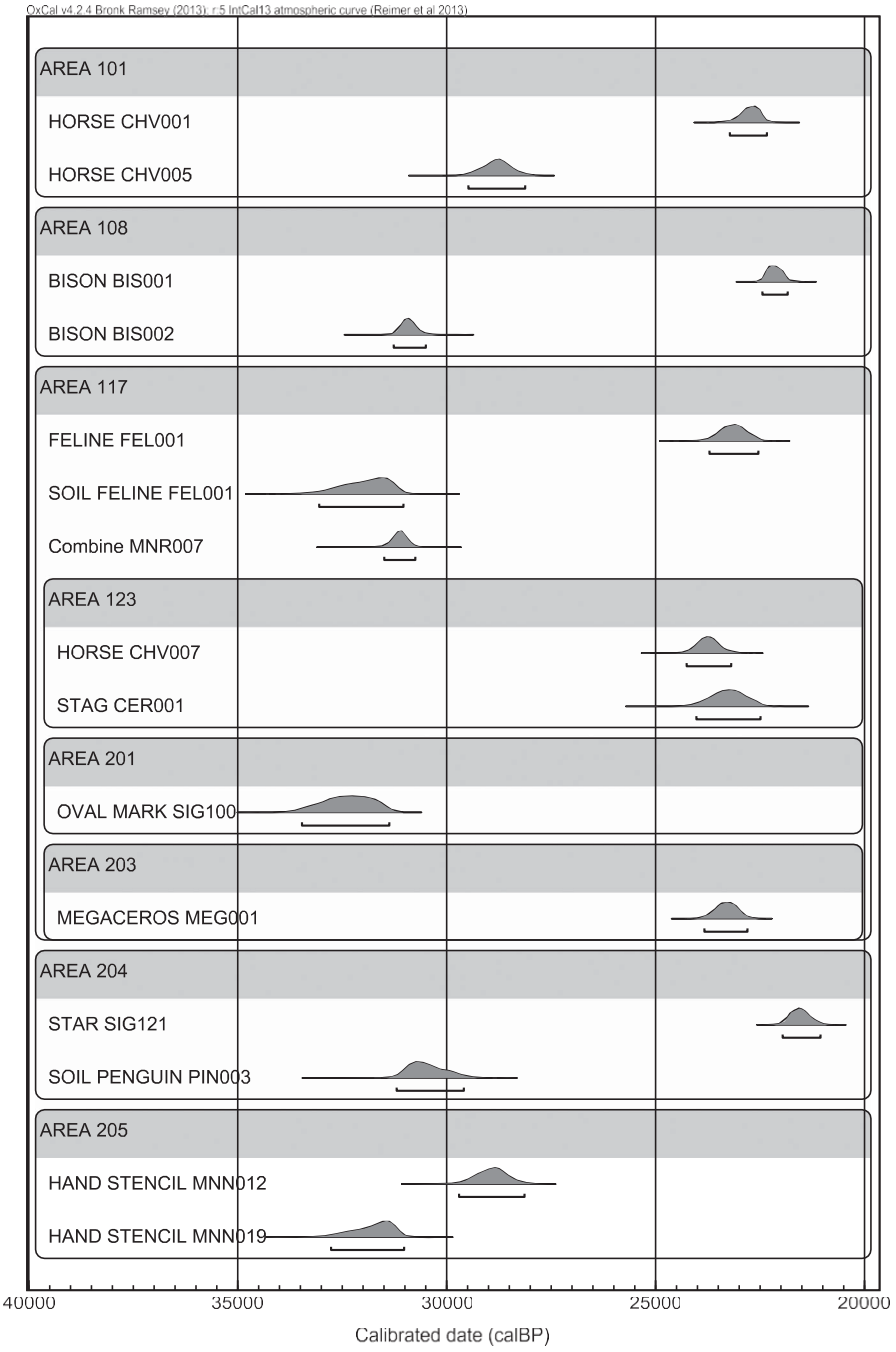

Figure 2 Calibrated ^{14}C dates obtained from 1992 to 1998 using OxCal v 4.2 and the IntCal13 calibration data (Bronk Ramsey 2009; Reimer et al. 2013; at 2-standard deviation confidence level).

although we could not exclude the possibility that these two ages had been artificially under-estimated due to contamination of the sample by modern carbon. The reliability of the result obtained on the jellyfish sign dated at ~16,000 cal BP remains questionable

considering the difficulty of dating that small amount (0.2 mg) of carbon 20 yr ago. The charcoal fragments collected on the ground surface fell within the two main occupation periods (Clottes et al. 1992a, 1992b; Clottes et Courtin 1994).

The New Sampling

In order to obtain more information on the human frequentation of the cave, the Ministry of Culture and Communication (DRAC Provence-Alpes-Côte d'Azur SRA) decided in 2011 to collect 23 new samples to be dated by ^{14}C on the Artemis AMS (LMC14, CEA, Saclay). To the extent possible, the pigment was taken in a restricted area of the representation, which was carefully described, while the full process was photographed, including the exact location of each of the samples (Vanrell and Olive 2012). The samples were collected on 12 animal drawings: four horses (CHV001, 005, 017 and 057), two jellyfish shapes (1 and 2), four bison (BIS001, 002, 004, and 005), one penguin (PIN003), and an animal shape (AIN015). Four of these samples were collected on representations (CHV001 and 005, BIS001 and 002) studied during the first dating program. Two new hand stencils (MNN001 and 009) and four other parietal marks were also sampled, as well as five charcoal specimens collected in fireplaces present on the ground surface or at the foot of the ornate wall. At the same time, two fragments of calcite (Prv1105-27 and Prv1105-30) of the flowstone deposited on the cave soil were dated by the U/Th method. These dates aimed to establish if this carbonate layer was deposited between the Paleolithic human occupations as previously suggested (Clottes et al. 2005b; Collina-Girard and Arfib 2010) or much later during the Holocene interglacial period. One of the calcite samples (Prv1105-30) was situated just above the dated charcoal (Prv1105-19).

MATERIAL AND METHODS

The parietal samples (or the ground charcoal) to be dated consist of splinters of charcoal mixed with calcite (or moonmilk) grains from the limestone wall. After removing with pliers the calcareous minerals as much as possible, the chemical pretreatment of charcoal varied in intensity according to the sample size (Valladas et al. 1999, 2001). The pretreatment involves a succession of 0.5N hydrochloric acid-base-acid (ABA) treatments, which first dissolve the remaining carbonate grains, the fulvic acids arising from the transformation of organic matter, and bacteria or other living microorganisms. The basic treatment (sodium hydroxide), gentle at first, is increased in intensity according to the fragility of the sample. As a rule, the treatment stops when the solution becomes highly colored. The coloration suggests that not only have the outer grain layers been stripped, but that a good fraction of the original charcoal has passed into the solution. If the treatment is not interrupted in time, no charcoal may be left for dating. The remaining charcoal grains are washed again with aqueous HCl (0.5N). A Fourier transform infrared (FTIR) analysis was not performed on the charcoal after this treatment. Taking into account the efficiency and the strength of the chemical attack, which usually eliminates more than 95% of the original sample, we are assuming that no residual carbonate remains in the dated charcoals. Before the combustion, the small pieces of charcoal are carefully examined under a microscope to check their integrity (absence of any visible contaminant).

Whatever remains is oxidized to carbon dioxide, then reduced to graphite and compressed into pellets for the Artemis accelerator (3MV Pelletron accelerator; Cottereau et al. 2007). These pellets usually contain somewhere between <0.5 mg to approximately 1 mg of carbon. During the processing of the Cosquer samples, blank values, which take into account the sample's chemical pretreatment, the conversion into CO_2, the graphitization, and the machine background contaminants, were estimated by measuring charcoal specimens from a Middle

Stone Age layer (Border Cave, South Africa). The $\delta^{13}C$ values of all samples were measured during the AMS analysis for the purpose of fractionation correction.

Two samples (Prv1105-3 and 19, collected respectively on CHV005 and on the ancient patina fireplace) were big enough to be divided into two parts, which were successively pretreated and ^{14}C dated to test the reproducibility of the results. The humic acid fraction (*HAF, in italics* in Table 1) of six samples resulting from the basic treatment was also dated to evaluate the contamination level of the samples. This fraction contains a large part of the dissolved charcoal and the possible contamination by extraneous carbon. Therefore, the comparison of ages obtained on the humic acid fractions (HAF) to those of the purified charcoal specimens provides information on the sample's quality and contamination (Batten et al. 1986; Valladas et al. 2001). The two flowstone samples (~250 mg per sample) were prepared and analyzed at the LSCE on the Neptune Plus Plasma multicollector inductively coupled plasma mass spectrometer (MC-ICP-MS) following the procedure described by Pons-Branchu et al. (2014) (see supplementary material 1).

RESULTS AND DISCUSSION

Information on the samples and their analysis is given in Table 1. Most of the ^{14}C ages range from 27,000 to 16,000 yr BP (~32,000 to 19,000 cal BP) and fall within the same time period as the previous results. Surprisingly, the charcoal specimen found on the Crystal Gallery ground gives a much later age, ~4000 yr BP. At that time, Cosquer Cave was only accessible by diving and the only possible explanations for this recent age are that the charcoal was severely contaminated by modern carbon or was brought into the cave by sea currents during the Holocene period.

The duplicate results obtained on the 2011 samples collected in the ancient patina fireplace (Prv1105-19: 27,290 ± 300 and 27,560 ± 310 BP) and on the horse CHV005 (Prv1105-03: 22,440 ± 130 and 22,920 ± 160 BP) are in agreement. However, for this latter sample, the HAF gives an age about 1500 yr older (24,340 ± 170 BP) than the charcoal duplicate ages. In general, we have found older dates for a given drawing sample to be more reliable after noting how much more frequent was contamination by recent carbon and consequent age reduction. Exposed pigments can be contaminated by organic materials, some of which can resist the chemical treatment meant to eliminate them. Some samples are so fragile that if the solid component is not to dissolve completely the purification has to be less rigorous. In such cases, the HAF, which consists of parts of original charcoal that were dissolved in the alkaline solution and reprecipitated, will give a more correct age. Therefore, for the horse drawing (Prv1105-03: CHV005), the oldest date obtained on the HAF (24,340 ± 170 BP) should be the most relevant, and is also in agreement with the date (24,730 ± 300 yr BP) obtained on the sample collected on the same representation in 1996 (Clottes et al. 1997). A similar situation was encountered with the sample collected in the recent patina fireplace (Prv1105-14: charcoal and humic acid fraction dated respectively to 15,730 ± 80 and 17,950 ± 380 BP) and to a less extent with the hand stencil MNN001 (Prv1105-24: charcoal and HAF dated respectively to 26,900 ± 290 and 28,060 ± 550 BP). In our opinion, the oldest dates obtained on the HAF are the most reliable.

For the ancient patina fireplace (Prv1105-14) and the fixed lamp (Prv1105-18), the HAF ages are compatible with those obtained on the associated charcoals: for the Prv1105-14, the charcoal is dated to 27,290 ± 300 BP and 27,560 ± 310 BP and the HAF at 27,090 ± 300 BP; for Prv1105-18, the charcoal and HAF are dated respectively to 27,020 ± 290 and 27,990 ± 520 BP. While this good agreement between the two sets of dates generally increases one's confidence in

Table 1 Information on the charcoal samples and ^{14}C analysis data. The acid humic fractions HAF are given in italics. The symbols *, °°, and ** respectively designate the following references: Clottes et al. (1992, 1997) and Vanrell and Olive (2012). The calibrated ages are given in the rightmost column.

Area	Lab code	Sample reference	Sample description (Sampling area)	Datable C (mg)	$\delta^{13}C$	Age (yr BP)	Error	Age (cal BP) 95% confidence
101								
Parietal	GifA92416	N°1A*	Horse CHV001 (nostrils end, under highest sea level)	1.56	−22	18,840	250	23,416–22,247
	GifA92417		Horse CHV001 (nostrils end, under highest sea level)	0.94	−13	18,820	310	23,492–22,022
	GifA92422		*HAF*	*1.24*	*−22*	*18,760*	*220*	*23,230–22,165*
	GifA13481/SacA37400	Prv1105-01**	Horse CHV001 (top of the mane, above highest sea level)	0.975	−23	25,450	190	30,198–29,040
	GifA13485/SacA37403	*Prv1105-01***	*HAF*	*0.319*	*−18*	*22,860*	*330*	*27,711–26,430*
	GifA96072		Horse CHV005°° (mane)	0.84	−23	24,730	300	29,480–28,122
	GifA13479/SacA37398	Prv1105-03**	Horse CHV005 (upper middle of the mane)	1.12	−22	22,440	130	27,155–26,350
	GifA13480/SacA37399	Prv1105-03**	Horse CHV005	1.083	−25	22,920	160	27,581–26,871
	GifA13484/SacA37402	*Prv1105-03***	*HAF*	*0.441*	*−22*	*24,340*	*170*	*28,742–27,965*
	GifA96101		Median jellyfish shape°° (left)	0.2	−8	14,050	180	17,579–16,501
	GifA14001/SacA37405	Prv1105-5**	Jellyfish shape n°2 (above the highest sea level)	0.406	−27	17,120	80	20,909–20,426
	GifA14002/SacA37406	Prv1105-06**	Jellyfish shape n°1 (the highest possible)	0.169	−15	18,910	630	24,447–21,397
Soil	GifA14153/SacA39216	Prv1105-04**	Crystal Gallery, ground (coal probably introduced and deposited by the sea)	0.07	−28	3990	90	4815–4160

103								
parietal	GifA14003/SacA37407	Prv1105-08**	Horse CHV017 (mane, under the highest sea level, figuration is fully submerged during floods)	0.451	−31	18,610	100	22,746–22,277
	GifA14154/SacA39217	Prv1105-09**	Mark IND003 (middle of the crown part, under the highest sea level, figuration submerged during floods)	0.053	no analysis			
106								
soil	Ly 5528		Fireplace*			18,400	440	23,369–21,186
108								
parietal	GifA92419	N°1C*	Bison BIS001 (mane)	0.64	−22	18,010	200	22,355–21,303
	GifA92423		*HAF*	*0.27*	*−19*	*16,390*	*260*	*20,451–19,148*
	GifA92492		Bison BIS001	1.2	−17	18,530	190	22,840–21,921
	GifA14155/SacA39218	Prv1105-10**	Bison BIS001 (in the middle of the neck)	0.552	−28	16,590	90	20,287–19,723
	GifA96069		Bison BIS002°° (withers)	1.79	−23	26,250	350	31,053–29,659
	GifA95195		Bison BIS002°° (withers)	2.04	−25	27,350	430	32,425–30,730
	GifA14157/SacA39220	Prv1105-11**	Bison BIS002 (midway between the horns and the nose, mouth height)	0.911	−24	26,240	270	30,988–29,796
	GifA14159/SacA39222	Prv1105-12**	Bison BIS004 (beginning of the fleece in vertical alignment with the visible horn)	0.637	−27	18,200	110	22,365–21,795
	GifA14160/SacA39192	Prv1105-13**	Bison BIS005 (middle of the bottom line of the right horn)	0.174	−20	20,120	510	25,530–23,084

Table 1 (*Continued*)

Area	Lab code	Sample reference	Sample description (Sampling area)	Datable C (mg)	$\delta^{13}C$	Age (yr BP)	Error	Age (cal BP) 95% confidence
soil	GifA92348		Ground* (charcoal scattered below bison BIS001)	2	−26	20,370	260	25,255–23,916
117								
parietal	GifA92418	N°1B*	Feline FEL001 (out of the drawing, near the ear)	1.52	−22	19,200	240	23,710–22,539
	GifA92409	N°1D*	Hand stencil MNR007 in front of the feline (left of the little finger)	0.86	−24	27,110	400	31,885–30,531
	GifA92424		*HAF*	*0.44*	*−22*	*26,180*	*330*	*30,997–29,633*
	GifA92491		Hand stencil MNR007	1.59	−27	27,110	350	31,650–30,651
soil	GifA92350	N°4*	Ground (scattered charcoal below FEL001)	2	−26	27,870	470	33,048–31,033
123								
parietal	GifA98186	Prv14°°	Horse CHV007	0.84	−24	19,720	210	24,256–23,191
	GifA98196	Prv14°°	*HAF*	*0.29*	*−13*	*19,740*	*340*	*24,601–22,906*
	GifA98188	Prv15°°	Stag CER001	0.25	−8	19,290	340	24,025–22,489
201								
parietal	GifA96074		Oval shape°° SIG100	2.1	−23	28,370	440	33,462–31,373
soil	GifA14161/SacA39193	Prv1105-14**	Recent patina combustion zone on a raised floor	1.474	−24	15,730	80	19,193–18,796
	GifA14224/SacA39206	Prv1105-14**	*HAF*	*0.191*	*−25*	*17,950*	*380*	*22,568–20,479*
202								
parietal	GifA14164/SacA39196	Prv1105-17**	Horse CHV057 (on the line of the neck)	1.118	−23	19,890	130	24,275–23,590
	GifA14162/SacA39194	Prv1105-15**	SIG125, differentiated line on the first pillar	0.069	−23	25,260	960	31,228–27,713

	GifA14163/SacA39195	Prv1105-16**	SIG119, phallic pillar (on the horizontal circle line, at the narrowing of the pillar)	0.44	−26	23,830	210	28,392–27,578
	GifA14165/SacA39197	Prv1105-18**	Fixed lamp (coal on a suspended floor)	1.113	−21	27,020	290	31,429–30,706
	GifA14225/SacA39207	Prv1105-18**	*HAF*	*0.234*	*−26*	*27,990*	*510*	33,266–31,085
203 parietal	GifA 95135		Megaceros°° MEG001 (middle of the back)	1.25	−25	19,340	200	23,833–22,804
	GifA14167/SacA39199	Prv1105-20**	Animal shape AIN015 (in the middle of the concavity, directly on the drawn line)	1.314	−24	25,650	250	31,607–30,990
soil	GifA14166/SacA39198	Prv1105-19**	Ancient patina fireplace (soot deposited on the ground under concretion coating)	0.998	−21	27,290	300	31,694–30,820
	GifA14227/SacA39209	Prv1105-19**	Ancient patina fireplace (soot deposited on the ground under concretion coating)	1.159	−25	27,560	310	32,240–30,961
	GifA14226/SacA39208	Prv1105-19**	*HAF*	*1.127*	*−18*	*27,090*	*300*	31,492–30,731
204 parietal	GifA96075		Star shape°° SIG121	0.87	−25	17,800	160	21,957–21,051
	GifA14168/SacA39200	Prv1105-21**	Penguin PIN003 (on the rump)	0.521	−23	18,590	110	22,757–22,216
soil	GifA14170/SacA39201	Prv1105-22**	Power hammer (in the concavity of the stone lodged on the ground below the penguins)	1.07	−26	16,200	90	19,842–19,266
	GifA92349		Ground* (charcoal below the black penguins)	2	−25	26,360	440	31,195–29,586

Table 1 (*Continued*)

Area	Lab code	Sample reference	Sample description (Sampling area)	Datable C (mg)	$\delta^{13}C$	Age (yr BP)	Error	Age (cal BP) 95% confidence
205 parietal	GifA95358		Hand stencil°° MNN012	0.63	−24	24,840	340	29,701–28,136
	GifA95372		*HAF°°*	*0.26*	*−26*	*23,150*	*620*	28,577–26,150
	GifA96073		Hand stencil°° MNN019	1.3	−21	27,740	410	32,766–31,014
	GifA14171/SacA39202	Prv1105-23**	SIG133, farandole of great well (highest part of the drawing)	0.166	−21	16,310	320	20,466–18,939
	GifA14172/SacA39203	Prv1105-24**	Hand stencil MNN001 (left end of the halo, at the level of the wrist)	1.042	−25	26,900	290	31,365–30,620
	GifA14228/SacA39210	Prv1105-24**	*HAF*	*0.212*	*−23*	*28,060*	*550*	33,404–31,106
	GifA14173/SacA39204	Prv1105-25**	Hand stencil MNN009 (right of the distal end of the atrial)	0.718	−25	26,310	270	31,029–29,868

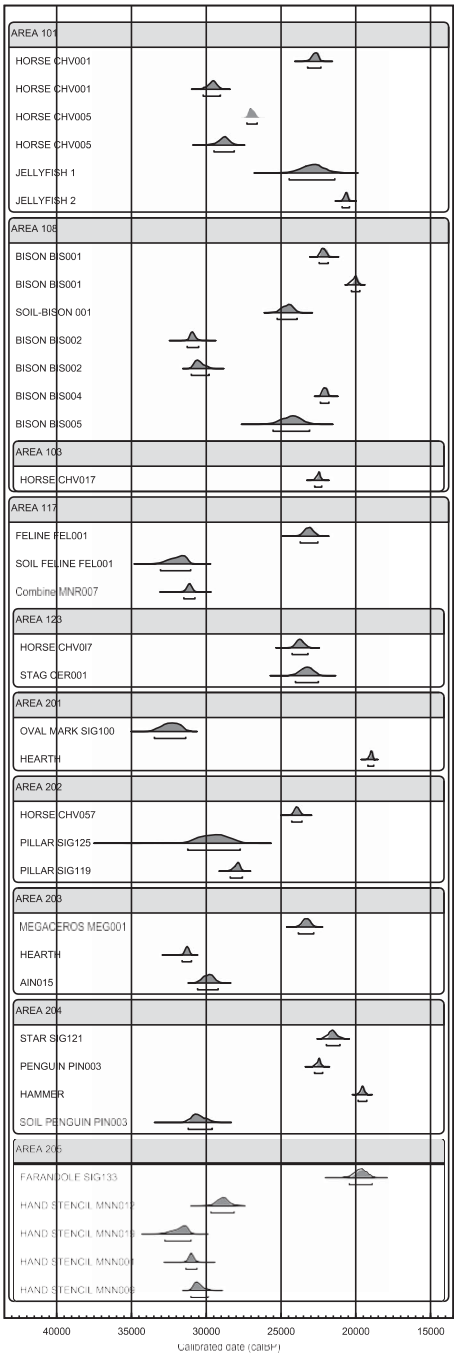

Figure 3 Calibrated ^{14}C dates obtained from 1992 to 2012 using OxCal v 4.2 and the IntCal13 calibration data (Bronk Ramsey 2009; Reimer et al. 2013; at 2-standard deviation confidence level).

the reliability of the dates, we can never exclude a remote possibility that both fractions may have been contaminated somehow. In the case of the horse CHV001 (Prv1105-01), the HAF (22,860 ± 330 BP) is ~1500 yr BP younger than the charcoal (25,450 ± 190 BP), suggesting the presence of modern carbon contamination in the pigment specimen. In this case, the most trustworthy age is the one of the purified charcoal.

Finally, we compare the sets of ages obtained in 1992–1996 and in 2012 on the four parietal representations sampled twice (CHV001 and 005, BIS001 and 002). The ages of the bison BIS002 are in good agreement. Those obtained on the horse CHV005 and the bison BIS001 sampled in 2011 are 1000 to 1500 yr younger than the previous results, and we suspect the presence of a remaining slight contamination in the second set of samples. The case of the horse CHV001 is more surprising: the 2010 date (25,450 ± 190 BP) is much older than those obtained in 1992 on the same representation (18,840 ± 250 and 18,820 ± 310 BP). There is no straightforward explanation for this age difference, but several assumptions could be proposed as the two dated samples were not taken in the same part of the drawing: reutilization of old charcoal left on the soil surface (Bednarik 1994) or a later repainting.

All the calibrated ^{14}C dates obtained using the IntCal13 curve (Reimer et al. 2013) and the OxCal v 4.2 software (Bronk Ramsey 2009) are reported in Figure 3. The 2010 results fall in the same time interval (33,000 and 20,000 cal BP) as the previous ones, but they show that prehistoric people went into the cave and made drawings not only during the two phases (33,000–30,000 and 25,000–21,000 cal BP, respectively) initially highlighted. The new dates confirm the existence of an intermediate period of decoration (~25,000 BP; 30,000–27,000 cal BP) between these two main phases. The horse CHV005, the animal shape (AIN015), the parietal marks (SIG125, 119), and the hand stencil MNN012 can be attributed to this intermediate period.

The ages obtained on the bison and the horse drawings are scattered from 32,000 to 22,000 cal BP; thus, the horses CHV017 and 007 and the bison BIS001 and 004 were dated between 25,000 and 22,000 cal BP, while the horse CHV005 and the bison BIS002 were placed between 32,000 and 28,000 cal BP. These results suggest that the stylistic conventions have persisted through several millennia, even if we cannot definitively exclude the reuse of old charcoal collected on the ground to realize the drawings by prehistoric people.

The ages obtained on the two calcite samples, 8300 ± 137 on Prv1105-30 (LSCE5695) and 4288 ± 260 yr BP on Prv1105-27 (LCE5694), show that the flowstone grew during the Holocene period, more than 10,000 yr after the second Paleolithic human frequentation. This flowstone is present on a large part of the cave soil surface and contributed to the good preservation of the underlying archaeological layers (supplemenaty material 1).

CONCLUSION

Two dating programs involving 41 samples (18 from 1992 to 1998 and 23 in 2012) have been devoted to the decorated Cosquer Cave since its discovery. The charcoal samples consist of 21 animal representations (9 between 1992 and 1998 and 12 in 2012), five hand stencils (3 and 2), seven signs (2 and 5), and eight specimens found on the soil surface (4 and 4). A total of 57 ^{14}C analyses including duplicate measurements were realized. They produce a coherent set of data, which shows that the Cosquer Cave was visited by prehistoric people from 33,000 to 20,000 cal BP. Throughout this time period, animal representations as well as hand stencils and several marks were drawn on the wall of the cavity. The oldest decoration period of Cosquer

Cave falls in the same time range as the Chauvet Cave's latest occupation dated between 31,000 and 29,000 cal BP (Clottes 2001; Geneste 2005; Quiles et al. 2016).

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REFERENCES

Arnold M, Bard E, Maurice P, Duplessy JC. 1987. ^{14}C dating with the Gif-sur-Yvette Tandetron accelerator: status report. *Nuclear Instruments and Methods in Physics Research B* 29(1–2):120–3.

Batten RJ, Gillespie R, Gowlett JAJ, Hedges REM. 1986. The AMS dating of separate fractions in archaeology. *Radiocarbon* 28(2A):698–701.

Bednarik R. 1994. About rock art dating. *International Newsletter on Rock Art* 7:16–8.

Bronk Ramsey C. 2009. Bayesian analysis of radiocarbon dates. *Radiocarbon* 51(1):337–60.

Clottes J, editor. 2001. *La Grotte Chauvet. L'art des origines*. Paris: Edition Seuil. 224 p.

Clottes J, Courtin J, editors. 1994. *La grotte Cosquer*. Paris: Edition Seuil. 197 p.

Clottes J, Beltran A, Courtin J, Cosquer H. 1992a. La grotte Cosquer (Cap Morgiou, Marseille). *Bulletin Société Préhistorique Française* 89(4):98–128.

Clottes J, Courtin J, Valladas H, Cachier H, Mercier N, Arnold M. 1992b. La grotte Cosquer datée. *Bulletin Société Préhistorique Française* 89(8):230–4.

Clottes J, Courtin J, Collina-Girard J, Arnold M, Valladas H. 1997. News from Cosquer Cave; climatic studies, recording, sampling, dates. *Antiquity* 71(272):321–6.

Clottes J, Courtin J, Vanrell L, editors. 2005a. *Cosquer redécouvert*, Paris: Edition Seuil. 255p.

Clottes J, Courtin J, Vanrell L. 2005b. Nouvelles recherches a la Grotte Cosquer (Marseille). *Munibe (Antropologia-Arkeologia)* 57:9–22.

Collina-Girard J, Arfib B. 2010. Le karst polyphasé des Calanques et la grotte Cosquer. In: Audra P, editor. Grottes et karsts de France. *Karstologia Mémoires* 19(360):242–3.

Cottereau E, Arnold M, Moreau C, Baqué D, Bavay D, Caffy I, Comby C, Dumoulin J-P, Hain S, Perron M, Salomon J, Setti V. 2007. Artemis, the new ^{14}C AMS at LMC14 in Saclay, France. *Radiocarbon* 49(2):291–9.

Geneste J-M, editor. 2005. Recherches pluri-disciplinaires dans la grotte Chauvet. *Karstologia Mémoires 11*. Lyon: Journées SPF.

Pons-Branchu E, Douville E, Roy-Barman M, Dumont E, Branchu E, Thil F, Frank N, Bordier L, Borst W. 2014. A geochemical perspective on Parisian urban history based on U-Th dating, laminae counting and yttrium and REE concentrations of recent carbonates in underground aqueducts. *Quaternary Geochronology* 24:44–53.

Quiles A, Valladas H, Bocherens H, Delqué-Količ E, Kaltnecker E, van der Plicht J, Delannoy JJ, Feruglio V, Fritz C, Monney J, Philippe M, Tosello G, Clottes J, Geneste JM. 2016. First high-precision chronological model for the decorated Upper Paleolithic cave of Chauvet-Pont d'Arc, Ardèche, France. *Proceedings of the National Academy of Sciences of the USA* 113(17):4670–5.

Reimer PJ, Bard E, Bayliss A, Beck JW, Blackwell PG, Bronk Ramsey C, Grootes PM, Guilderson TP, Haflidason H, Hajdas I, Hatté C, Heaton TJ, Hoffmann DL, Hogg AG, Hughen KA, Kaiser KF, Kromer B, Manning SW, Niu M, Reimer RW, Richards DA, Scott EM, Southon JR, Staff RA, Turney CSM, van der Plicht J. 2013. IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon* 55(4): 1869–87.

Valladas H, Tisnerat N, Cachier H, Arnold M. 1999. Datation directe des peintures préhistoriques par la méthode du carbone 14 en spectrométrie de masse par accélérateur. *Revue d'Archéométrie, Supplément 1999 & Mémoire de la Société Préhistorique Française* 26:39–44.

Valladas H, Tisnerat-Laborde N, Cachier H, Arnold M, Bernaldo de Quiros F, Cabrera-Valdes V, Clottes J, Courtin J, Fortea-Perez J, Gonzales-Sainz C, Moure-Romanillo A. 2001. Radiocarbon AMS dates for Paleolithic cave paintings. *Radiocarbon* 43(2B):977–86.

Vanrell L, Olive M. 2012. *Nouvelle campagne de datations ^{14}C, pictures and details, La Grotte Cosquer 2010–2011, Prospection thématique*. Aix-en-Provence: SRA DRAC PACA. 165 p.