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The skeletons of Lauricocha: New data on old bones

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ABSTRACT

The caves near Lake Lauricocha, Peru, were excavated between the late 1950s and mid-1960s and have since influenced the interpretation of early man in South America. Prior to the publication of this paper, the data used to interpret the age of this material was not based upon the human skeletons themselves, but were rather produced from the accompanying material, such as sediment, plant remains and animal bone. Radiocarbon dating in the 1960s was often not applied to human bones, as pre-treatment methods at that time were not as refined as at present and with conventional techniques, quite a lot of material had to be used. The development of AMS techniques requires much less material for analysis and sample preparation through collagen extraction means that radiocarbon dating of human bones is now possible and is a reliable method. As part of a wider project to analyse the DNA of the Lauricocha skeletons in order to elucidate migration patterns in Peru, we sampled 4 of the 11 skeletons for radiocarbon dating. This paper reports the results of this dating analysis.

The results indicate that the skeletons are younger than interpreted from previously determined radiocarbon data on different material. However, this does not mean that the older analyses are wrong, and we review our findings in the light of this previous work to produce a new chronology for the site.

1. Introduction

The caves of Lauricocha were discovered along the eastern side of Lake Lauricocha (3850 m a.s.l.), with cave L-2 at a height of more than 4000 m above sea level. Lake Lauricocha is located in the Central Andes of Peru, 25 km east of one of the highest mountains in South America, Cerro Yerupajá (6634 m) in the Cordillera Huayhuash, and 190 km north–north-east of Lima (see Fig. 1). The Andes can be described as topographically rugged, which greatly influences temperature and atmospheric pressure, both diminishing with altitude. However, at altitude, significant areas of land suitable for settlement and agriculture can be found. The area of Lauricocha is part of an environmental zone called Puna, which is described as a high, cold region (3900–4600 m) where grassy steppe vegetation predominates. The fundamental element for allowing settlement is the availability of water. Rainfall in the higher Andes is heavier in the summer months, favouring crop growth. However, precipitation may also be scarce as it varies according to topography (location) and according to climate cycles. In generally, water availability increases with altitude as evaporation decreases, which allows cultivation with less irrigation than in lower parts of the region (Cardich, 1987).

In prehistory, during some time the climate must have been warmer than today as traces of agriculture can be found at altitudes up to 4400 m. Whereas today tongues of glacial ice descend to 4700 m, at the end of the Pleistocene, when Lauricocha cave L-2 shows the first signs of human visitation, icesheets covered the Lauricocha region (Cardich, 1985).

Augusto Cardich excavated the caves of Lauricocha/Peru between around 1958 and 1967. During the first excavation in 1958, 11 skeletons were found in different layers in cave L-2 (see Figs. 2, 3 and 5). During a later excavation in 1967 in the rear part of the cave the site stratigraphy was investigated in more detail. The different sediment layers, showing a sequence similar to that published by Cardich (1964), were renamed (numbers 1–32) and some sediment samples taken for radiocarbon dating. Unfortunately the stratigraphy of both excavations does not seem completely consistent and hence it is quite challenging to correlate the radiocarbon ages of the sediment samples taken during the later (1967) excavation to the contexts in which the 11 skeletons were found, 4 of which are the focus of radiocarbon dating described in this paper. We have tried to put our data into a robust context using the information provided by Cardich (1964) and the information on the radiocarbon sampling and dating undertaken during the 1967 excavation. However, a key problem of the 1967 stratigraphic analysis is that whilst the sediment units were relabelled and described, no indication was provided as to which layer (1–32, from top to bottom) corresponds to which depth (Teruggi et al., 1970) or how the layers correspond to the labelling of the first excavation in 1958 (Labels A–S, from top to bottom). However, we found some information on depth of the sediment samples used for radiocarbon dating in Ziolkowksi et al. (1994).

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Fig. 1. Location of Lauricocha in Peru.
Modified from d-map, free download.

To correlate the data it is necessary to consider the material used for dating. The first dates were determined at Teledyne labs/USA (laboratory code "I-"). Here the material used is not clear (burnt bone and charcoal, or only burnt bone, or only charcoal). The data corresponding to the second excavation in 1967, charcoal (humic acid, residue) and sediment, was measured in Groningen/Netherlands (laboratory code GrN-) with the conventional counting technique. The new data, on human bones, was determined at Mannheim/Germany (MAMS-) using AMS, cf. Table 3.

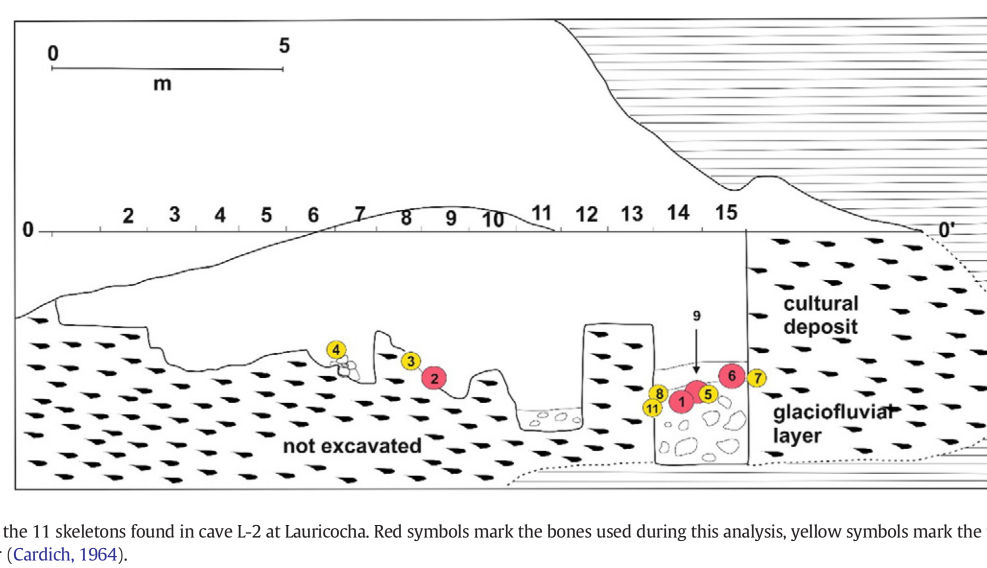

Fig. 2. Positions of the 11 skeletons found in cave L-2 at Lauricocha. Red symbols mark the bones used during this analysis, yellow symbols mark the unsampled skeletons. Figure drawn after (Cardich, 1964).

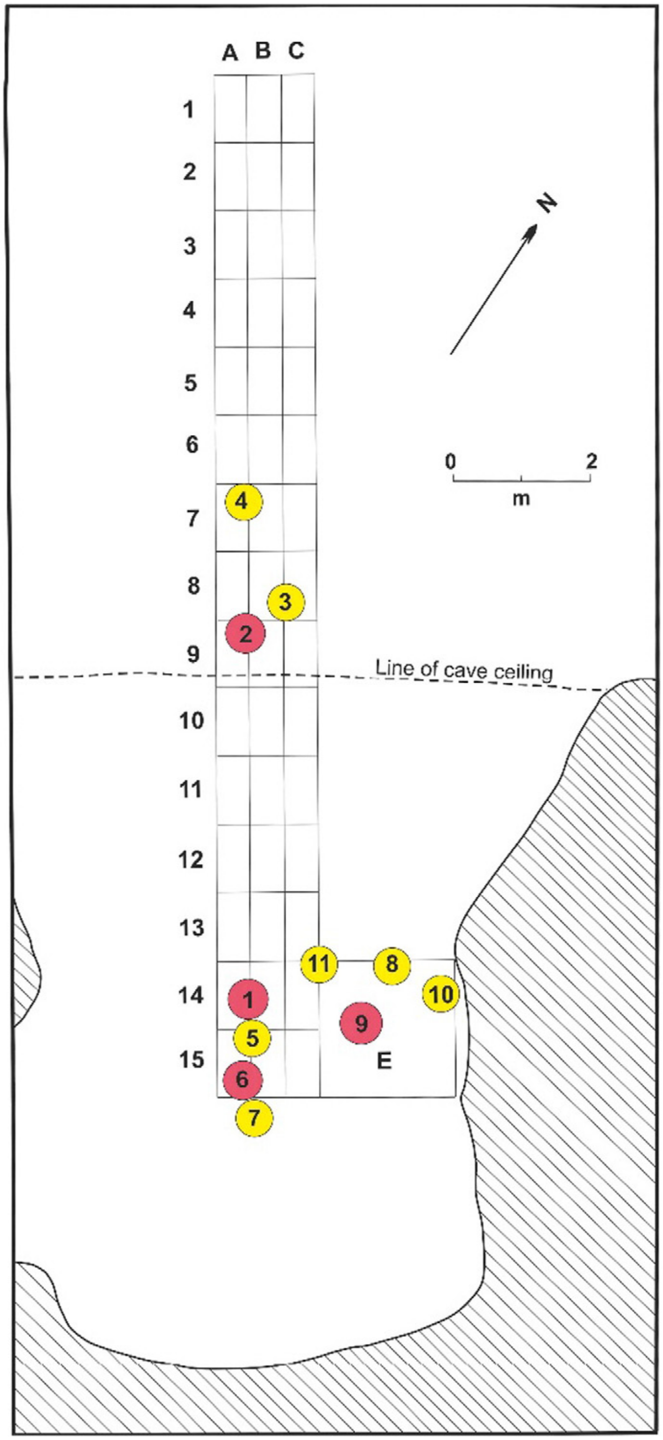

Fig. 3. Horizontal positions of the skeletons found in cave L-2 at Lauricocha. Red symbols mark the bones used for radiocarbon dating, yellow symbols mark the unsampled skeletons. Figure drawn after Cardich (1964).

By dating the human bones directly we intend to find the time when the cave was first used for burials — for details on migration analyses in context with Lauricocha refer to Fehren-Schmitz et al. (2015).

Of the 11 skeletons found at Lauricocha cave L-2, we received samples of four of them for further analysis (see Table 1 for information on individuals and Table 3 for sampled bone material): No 1, No 2, No 6 and No 9. Skeleton no 6 was of particular interest because it exhibited characteristics interpreted as evidence for artificial cranial deformation; at the time of its discovery, Augusto Cardich was of the opinion that is should be amongst the oldest skulls in Peru to show evidence for this kind of manipulation. However, new analyses by one of the team showed that the skull does not in fact show depressed areas in the frontal or occipital bones that would provide evidence for the use of deformatory devices (Elsa Tomasto-Cagigao, unpublished data). Additionally the skull has a crack in the dorsal area of the parietals that changes the direction of the bones. Therefore, the deformation must have happened post-mortem. The information provided by (Cardich, 1964) suggests that the remains of skeletons 1, 5, 9, 10 and 11 were found in small graves in the lowermost unit (Layer S), which was interpreted by Cardich as a sterile glaciofluvial layer of Pleistocene age. Both layers, R and S, correspond to the cultural phase Lauricocha I (see Fig. 5). Of these remains, skeletons 1, 5, 6, 7, 8, 9, 10 and 11 were found in the rear part of the cave (Fig. 2). The remains of the individuals no 2, 3, 4, 6 and 7 were found in a dark soil horizon of the lowermost cultural Layer R and hence we expected them to be younger than the other skeletons. None of the skeletons recorded were complete, but there was obviously no hint of a corrupt burial in the sediments (Cardich, 1964). Therefore parts of them had obviously been removed before burial. Skeleton 11, a child of roughly 2 years old, seems to have been reburied (Cardich, 1964). None of the skeletons showed signs of a violent death. Three of them (Numbers 9, 10, 11) were the remains of children; their graves seemed richer in burial objects, which included pieces of ochre, silex, calcined mammal bones, pearls and food. The use of iron oxide, which completely covered Skeleton 11, in burials had not been seen before in South America, though it is a phenomenon of the later Palaeolithic in Europe (Jacobi and Higham, 2008). All skeletons had in common that their bodies showed a certain flexion, as if they were sleeping.

Table 1
Information on the skeletons found by Cardich and our team. Bold numbers indicate the skeletons that were sampled for DNA and radiocarbon dating as part of this study. The asterisk * in the column for sex indicates that DNA analysis demonstrated that the sex determined was different to that determined the initial excavations; new morphological investigations draw the same conclusions as the DNA results. Empty cells means no information found.

Skeleton	Depth (m)	Square	Layer	Sex	Age (yrs)
1	3.30–3.40	14A, 14B	S	Female*	Adult
2	3.15	9A, 9B	Q, R	Male*	30–50
3	2.85	8B, 8C	Q		
4	2.7	7A, 7B	Q		
5	3.20–3.30	14A, 14B, 15A, 15B	S		
6	3.00–3.20	15A, 15B	Q, R	Male	60
7	3.00–3.20	South of 15A, 15B (“16”)	Q, R		Juvenile
8	3.15–3.30	E	R, S	Male	50+
9	3.40–3.60	E	S	Male	1.5–2
10	3.25–3.4	E	S	Unknown	12
11	3.40–3.60	13C, 14C, E	S	Male	2

2. Material and methods

It is not completely clear from the original studies of Cardich precisely what material was used for dating the skeletons in cave L-2 at Lauricocha apart from the bones studied here. For the first age estimates, determined around 1959, it seems that a mixture of “burnt and unburnt bone and small fragments of charcoal” was used to derive the radiocarbon result I-107 (Cardich, 1960); this is mentioned in a footnote where Cardich quotes Dr Trautmann who undertook the analyses at the Teledyne Laboratory. Cardich (1960) also mentions in the same paper that the oldest radiocarbon date (9525 ± 260 BP, Lab-No I-107) was determined on burnt and half-burnt bone as well as organic material. However, the exact location of this oldest date, e.g. depth below surface, is unknown, although (Cardich, 1964) mentioned that it originated from the first layer with cultural deposits, which therefore must correspond to Layer R (depth approx. 3,00–3,20 m below the cave floor), and immediately above the glaciofluvial Layer S. According to Trautmann (in Cardich, 1960) the sample was leached in acid to remove inorganic carbon. Apparently a sample of similar composition, but from a level above sample I-107 was also dated by the Teledyne Laboratory, but its younger age of 8140 ± 140 BP (Lab. No unknown, hence referred to as I-?) was only mentioned in two publications (Cardich, 1963, Ravines and Alvarez, 1967). This sample, too, lacks information about its exact stratigraphic position below the cave floor surface. A hint is given that this younger sample, according to its age, should coincide with the beginning of the phase Lauricocha II, which Cardich located in Layer Q, below the first ash layer P (at a depth of around 3 m below the cave floor). Clearly, these dates are difficult to interpret and the bulk analysis of a mixture of materials, as in this case, can lead to erroneous age interpretations, especially influenced by the presence of charcoal (Gillespie, 1997).

Furthermore, burnt bone consists mainly of (bone) apatite, which is known to exchange carbon, and can be similar in age to soil carbonate from nearby locations (Gillespie, 1997). Therefore, sample pre-treatment becomes a crucial factor and radiocarbon dating of the bio-apatite fraction of burnt and/or cremated bone has for a long time been abandoned by the scientific community due to contamination effects and associated erroneous results. However, recently, it has been applied again with adjusted pre-treatment methods (van Strydonck et al. 2009; Zazzo and Saliège 2011); heating causes a re-crystallization of the bio-apatite bone matrix into a more robust structure (Olsen et al. 2013). Contamination of the bone depends on the degree to which the bio-apatite is changed and how the bone reacts with its surrounding during cremation. In the 1960s, as with sample I-107, samples were not investigated in regard to their content of bio-apatite or secondary calcite and these components were not distinguished (van Strydonck et al. 2009).

The combination of these effects makes an interpretation of the age obtained for the horizon Lauricocha I (sample I-107) quite difficult. When plotted according to its depth, the sample is too old, compared to the other samples from later measurements. But this might be due to the influence of calcite in the sediment, and hence possibly also in the cremated bone (exchange during cremation). Therefore, it should be used to provide an indication for a maximum age estimate rather than a real age. Moreover from the information we have already stated on this sample it was not determined on the skeletons. The bones were too valuable and too few to be used for radiocarbon dating, because the skeletons were not complete, as mentioned previously. Apart from this, in the 1960s bones in general were not considered to be a reliable material for dating (Olsson, 2009). Hence if the burnt animal bones were used these might be a lot older than the first humans to be buried in the cave. Hunters might have used it for shelter long before they used it for burial place. Furthermore, information on the species of the animal bone analysed is not given in the original publications. The new analyses of the human bone material (MAMS 14389, MAMS 14390, MAMS 14391, MAMS 14731 in Table 3) seem to confirm this, as the human bones are younger than the animal bones and organic material of samples I-107 and I-?.

The samples of the later excavation in 1967 were dated at Groningen (Vogel and Lerman, 1969) and consisted of sediments and ashes. The fractions used were humic acids and residue, original material mentioned as "sediment", residue explained as "charcoal, etc.". These non-bone samples were taken from the layers above the glaciofluvial layer. From three of these samples, humic substances were also dated in 1967. These are defined as alkali-soluble, (but acid insoluble) products of organic matter humification processes (Gillespie, 1997). Dates on the humic acid fraction that are younger point to a residue age being a minimum age estimate. *Vice versa*, incomplete removal will lead to maximum age estimates. If ages on humic acids are significantly older, they seem to originate from disturbed, fine-grained, calcareous sediments from semi-arid regions as pointed out by Gillespie (1997).

Cardich (1964) mentions that no skeleton was found above Layer P, although later in the same publication he mentioned that Skeleton 4 is found at a depth of 2.70 m below the cave floor surface. However this might be explained by the uneven nature of the cave floor, with excavators drawing a baseline that did not always correspond to the actual surface at some points, like the column in which skeletons 2–4 were found (compare Fig. 2). Besides the depths below "surface" or "baseline" do not always correspond with the thicknesses of the different sediment layers given in the same publication. Again, this leads to difficultly in the interpretation of individuals 2, 3, and 4 that were found close to the cave entrance. In Fig. 2, re-drawn after (Cardich, 1964), it appears as if just above Skeleton 4, the surface coincides with the reference line he uses. Given this conundrum, we chose to place the depth of Skeleton 4 between the beginning of layer P and the end of Layer Q. These layers are usually only several centimetres thick and therefore any error in placing the position of the skeleton and hence its context can have significant implications for archaeological interpretation. However, the first description of the layer in which a skeleton was found will be referred to here. This allows us to directly link the age to the stratigraphy in which the bone samples were found as marked in Cardich (1964). The sediment layers were naturally deposited, including debris from the cave ceiling, and are rich in Carbonates. Other carbonate deposits had also been sampled (compare Table 3) but as they are not specified (stalagmite, shell, secondary carbonates to name but a few possibilities) were excluded from the interpretation. Their data points to a geological age. The thickest layer is a glaciofluvial layer, approximately 180 cm thick, which includes some large stones some of which had been used *in situ* to enclose the children's graves (skeletons 9–11).

The amount of bone needed to extract enough collagen for a reliable age determination using AMS is in the range of 0.5–1 g and collagen preservation in all our samples was quite good allowing for reliable measurements. Bone sample preparation techniques used by the Mannheim laboratory are described fully by (Kromer et al., 2013), but are described briefly as follows. The bone is decalcified with 4% HCl, with humic acids removed by a base step (0.4% NaOH) and another acid step. Collagen is gelatinized in acid of pH 3 at 60 °C for 20 h. Then the samples are processed using an Eezi™ Filter and ultra-filtration (Vivaspin Turbo 15, 30 kDa) and the collagen is finally freeze-dried. The sample is then combusted using an Elemental analyser (Elementar Microcube) and graphitized using iron as a catalyst. Details for bone pre-treatment can be found follow (Bronk Ramsey et al., 2004; Higham et al., 2006). Graphitization as well as measurement by the Mannheim laboratory are described by Kromer et al. (2013) and Lindauer and Kromer (2013). The C/N ratio of the collagen extracted was good (3.4–3.5), providing a measurement of the quality of the collagen. To detect any contamination during the sample preparation, 2 modern bone samples (internal laboratory standards, one calf, 6 month old, from the butcher, one pig bone buried in a garden of known age and burial time, see Table 3) were prepared alongside the skeletons. Using the same protocols a sample of an old mammoth (Latton Mammoth, should contain no ^{14}C) was prepared to detect modern contamination caused by handling and chemicals. The samples were graphitized using an elemental analyser and measured with the MICADAS (Kromer et al., 2013; Lindauer and Kromer, 2013).

3. Results

The modern bones used for comparison confirmed their expected age. MAMS 14536 was dated as 2004–2009 and died in 2009, MAMS 14537 died between 1985 and 1986 and was dated to 1983–1985. The calibration also showed some probability for data in 1950 in both cases, but from the information on the samples this probability was neglected. The mammoth bone, being at the limit of detection, showed the same result as the measurement blank used (see Table 2). This means that we can exclude the possibility of contamination during sample preparation and combustion. The data is given in Table 3 and the ^{14}C-ages (calibrated) are plotted in Fig. 5 according to the approximate depth from which they were taken. The samples were calibrated using

Table 2
Samples prepared together with the Lauricocha bones as process blanks to detect contamination introduced during sample preparation. Fm denotes fraction modern.

Labcode	Info	Remarks	C-content [%]	C/N ratio	% collagen	Fm		cal age	$\delta^{13}C$
							±	2 sigma	‰
MAMS 14536	Butcher's cow	Died 2009 aged 6 months	34.85	3.2	11.7	1.0654	0.0027	2004–2009 AD	−25
MAMS 14537	Garden pig	Died ca. 1985–1996	32.2	3.2	13.9	1.1728	0.0028	1983–1985 AD	−25
MAMS 11181	Latton Mammoth	Beyond ^{14}C (>50,000)	21	3.2	7.5	0.22	0.04	51,000–44,639 BC	−23.4

Oxcal in combination with Intcal13 (Reimer et al., 2013). The $\delta^{13}C$-values measured in Mannheim (MAMS-notation) should not be compared to measurements from an IRMS, as they are determined using the AMS. In Table 3 we also give the Fm (Fraction modern) values for anyone who wants to recalibrate the data and prefers using Fm.

In this context we should highlight the problem of reporting radiocarbon ages. The old (previous) dates are usually reported as "BP", which means "before present" and refers to 1950. Unfortunately, nowadays one has to keep in mind that when converting to an age "BC" or "AD" during these earlier times, only the number 1950 was subtracted from the age BP, a point very well explained in the introductory chapters of Ziolkowksi et al. (1994). From modern studies, it is clear that using this approach will produce erroneous values and although calibration curves were beginning to be used at that time, their application was not yet routine. Radiocarbon scientists noticed that there were some discrepancies between tree-ring data and corresponding radiocarbon data calculated only by focusing on radioactive decay, to name but one of the problems. This made the use of a calibration curve necessary (see Olsson, 2009, for more details on the history of radiocarbon analysis). In this paper, we report the ^{14}C-ages BP and calibrate them using the latest calibration available (IntCal13). We did not use an age correction for the Southern Hemisphere, because Lauricocha lies at 10°S, which marks a line where climatic changes have already occurred in the past (especially the position of the Inter-Tropical-Convergence-Zone ITCZ) making a correction unnecessary (Carré et al., 2011; Hogg et al., 2013, Thompson, Mosley-Thompson et al., 2013). If the exact position of the ITCZ at the time period of interest becomes known, the data can be recalculated if necessary.

The charcoal or the wood from which it is derived can also be older than the timing of the first human beings to use the cave, but it is not to be expected that the charcoal age is several thousand years older. The data derived from charcoal and the samples referred to as sediment (GrN-5582 and GrN-5583) are too vague to be able to model them properly; the bones are not placed in the layer corresponding to their age but buried in the sediment below, and is in unclear how deep they are below the layer relevant to their culture.

Fig. 5 illustrates the depth of the radiocarbon samples alongside the stratigraphy with the ages plotted aside (without error) together with cultural horizons. It should be noted that only the depth and stratigraphy is presented with information on horizontal position not used or given.

Even if the detailed stratigraphic position of the radiocarbon samples of sediment is not known, the information provided from the entire dataset can be used to analyse the results and to derive enough possibilities for interpreting the data properly.

As can be seen from Fig. 5, the ages of the sediments are in stratigraphic order. The oldest ages from Teledyne could be influenced by the carbonates of the cave, for example sediment as well as debris from the cave ceiling. The bones are interesting to interpret as they also give a hint on the burial practices of the different ages. The main differences are the grave goods for the children, and the orientation of Skeleton 6, though all were buried in a sleeping position. All the adult graves are very simple. Therefore it seems that the burial practices did not change a lot over time for the graves of adults (apart from Skeleton 6, the youngest of the four we sampled), but for children it changed from simple grave goods (stones, ochre) to complex coverage with material (iron oxide in case of Skeleton 11).

Table 3
Data of the Radiocarbon samples, calibrated with Intcal13. The depths are mean values of the values given (e.g. 3,00–3,20 m gives 3,10 m). "*Residue*" and "*humic*" refer to sediment samples, where residue was described as "charcoal, etc.". "Sed" refers to samples from the sediment without further information. The question mark next to the information of GrN-5677 and GrN-5673 refers to the information that Layer R which should correspond to Layer 32 is not part of Lauricocha II but most probably of Lauricocha I. Note: *n.a.* refers to data that is not available; The italic $\delta^{13}C$-value of GrN-5589 could be found in the literature. Human Bone $\delta^{13}C$-values from AMS and not comparable to IRMS analysis. The carbonate data GrN-5515 and GrN-5516 is not used in the plots, but mentioned here for the sake of completeness. The remaining Groningen data was used as given by Prof. Dr. Harro Meijer. Fm values included for future calibration efforts.

Labcode	Depth (cm)	Info	Remarks	C14 age		cal Age	δ13C	C-content [%]	C/N ratio	% collagen	Fm	
	Mean				±	2 sigma						±
GrN-5487	90	Cave L-2 Layer 12 res	Associated with ceramics (Lau V)	1080	90	718–1157 AD	−23.8				0.8763	0.0096
GrN-5560	90	Cave L-2 Layer 12 humic	Associated with ceramics (Lau V)	1500	280	160 BC-1120 AD	−24.0				0.8423	0029
GrN-5582	120	Cave L-2 Layer 14 Sed	Associated with ceramics (Lau V)	1640	70	244–565 AD	−23.4				0.8183	0.0069
GrN-5583	150	Cave L-2 Layer 18 sed	Associated with ceramics (Lau V)	1570	60	354–613 AD	−23.4				0.8271	0.0061
GrN-5493	225	Cave L-2 Layer 24 res	Lauricocha II	4260	250	3627–2206 BC	22.9				0.5906	0018
GrN-5559	225	Cave L-2 Layer 24 humic	Lauricocha II	4620	350	4230–2473 BC	−23.1				0.5646	0.0244
GrN-5519	275	Cave L-2 Layer 28 res	Assoc. Lauricocha II	4650	130	3695–3018 BC	−23.4				0.5604	*n.a.*
I-?	~305	Cave L-2 Layer P Lauricocha II	Assoc. Lau II, burnt bone and charcoal?	8140	140	7486–6700 BC	*n.a.*				*n.a.*	*n.a.*
GrN-5589	305	Cave L-2 Layer 31 humic	Assoc. Lauricocha II	4660	90	3641–3106 BC	*−23.5*				0.5598	0.0062
GrN-5518	305	Cave L-2 Layer 31 res	Assoc. Lauricocha II	5170	140	4326–3696 BC	−23.6				0.5267	0.0093
GrN-5677	310	Cave L-2 Layer 32 humic	*Assoc. Lauricocha II?*	5720	110	4798–4349 BC	−23.7				*n.a.*	*n.a.*
GrN-5673	310	Cave L-2 Layer 32 res	*Assoc. Lauricocha II?*	5830	120	4997–4403 BC	−23.9				*n.a.*	*n.a.*
MAMS 14389	310	LAU 3, Skeleton 6	Metatarsus	3340	22	1690–1534 BC	−22.2	41.7	3.4	2.8	0.66	0.0018
I-107	~315	Layer R	Burnt & unburnt bone & charcoal	9525	260	9755–8249 BC	*n.a.*				*n.a.*	*n.a.*
MAMS 14390	315	LAU 4, Skeleton 2	Metatarsus	5160	27	4041–3825 BC	−27.2	39.1	3.4	4.2	0.5261	0.0017
MAMS 14731	330	LAU 5, Skeleton 1	Metatarsus I, right	7760	31	6646–6504 BC	−15.3	39.1	3.5	1.3	0.3753	0.0014
MAMS 14391	340	Lau 1, Skeleton 9	Pars petrosa	7870	30	6821–6640 BC	−27.2	25.7	3.4	6.6	0.3808	0.0015
GrN-5515	90	Layer 12 carbonates	Associated with ceramics (Lau V)	24,100	400		2.5				0.0498	0.0025
GrN-5516	225	Layer 24 carbonates	Assoc. Lauricocha II	28,350	440		2.2				00.293	0.0016

It is difficult to interpret the age of all 11 human remains when only 4 of them have been dated. In this context it would be beneficial to date Skeleton 11, which was the lowermost body, Skeleton 8 found between Layer S and R and the human bones of Skeleton 4, which was uppermost in the stratigraphy. The information on the chronology of the cultural periods Lauricocha I-V follows that used in (Muelle, 1959). Here Lauricocha I refers to the time period between 9500 and 8000 BP, Lauricocha II 8000–5000 BP, and Lauricocha III 5000–4000 BP; these are all pre-ceramic cultures. Lauricocha IV covers the period 4000–2000 BP and Lauricocha V 2500 BP until the Inca culture.

As can be seen from the calibration plot (Fig. 4) and the stratigraphic plot (Fig. 5) the samples and ages (plotted according to their depths) show a huge gap between the end of phase Lauricocha II and the beginning of phase Lauricocha V. As expected, skeletons 1 (MAMS 14731) and 9 (MAMS 14391) show the same age and are significantly older than the other two skeletons dated, skeletons 2 (MAMS 14390) and 6 (MAMS 14389). It can be interpreted that skeleton 2 (MAMS 14390) most likely belongs to the cultural phase Lauricocha II, whereas Skeleton 6 (MAMS 14389) neither belongs to phase Lauricocha II nor V, but lies somewhere in-between according to its age, probably being a representative of the cultural phase Lauricocha IV. This burial is the only one showing an orientation of west–east as well as the only one with volcanic stone tools.

In this study, a more detailed sampling programme focused on the second excavation (1967) would have been desirable. The skeletons were buried which means they are younger than the surrounding sediments. This point is interesting for skeletons 1 (MAMS 14391) and 9 (MAMS 14371) as they are older than the oldest samples from Groningen, which were taken from Layer 32, said to correspond to Cardich's layer R (Ziolkowksi et al., 1994). The Teledyne sample I-107 indeed points to a use of the cave as a shelter by hunters long before it was used to bury people. The other Teledyne sample, I-?, remains problematic and taking into account the uncertainty about the material used for dating and its exact stratigraphic position, it cannot be interpreted further.

4. Conclusions

This work shows how important it is to review and include original archaeological research in new investigations of both sites and individual artefacts; it helps to link contexts, and provides a solid basis for the robust analysis and interpretation of results.

The oldest radiocarbon age I-107 (9525 $\pm$ 260 BP) of Lauricocha cave L-2 has always been used to denote the time when people first lived or travelled through this area. From our radiocarbon analysis of the human bones themselves, we conclude that burials in the cave occurred at a later time than originally assumed. Nevertheless it does not exclude the earlier use of the cave, perhaps for shelter, but it demonstrates that burials did not take place before around 8000 BP. The use of the cave by hunters before the first burials, is interpreted from the radiocarbon date of sample I-107 and its stratigraphic context.

The Groningen radiocarbon dates are in stratigraphic order and consistent. The ages we derived for the human bone are consistent when taking into account that burials are intrusive, hence disturbing deeper layers, for the placement of the body. We could show that 2 of the 4 individuals (MAMS 14731, Skeleton 1, and MAMS 14391, Skeleton 9) were buried at approximately the same time, around 6700 BC.

The work that has been previously undertaken at Lauricocha accords with our new analyses on the bones and the associated data.

Only the data points associated with samples I-107 and I-? are difficult to interpret and compare to our results as it is not exactly known whether the original data was measured on mixed material ("burnt bone, half-burnt bone and charcoal") or a single material of unknown origin.

Considering the complete dataset, this study shows a number of common problems typically encountered during sampling and data interpretation. For example, it would be beneficial to determine the age of skeletons 3 or 4, 8, and especially 11. Skeletons 3 and 4 represent the uppermost burials and hence might be the last buried individuals. Skeleton 8 is buried between two layers, Layer R and S, which leads to the question why it was buried between two strata and when. Skeleton 11, a child of around two years, is the deepest burial in the cave and the

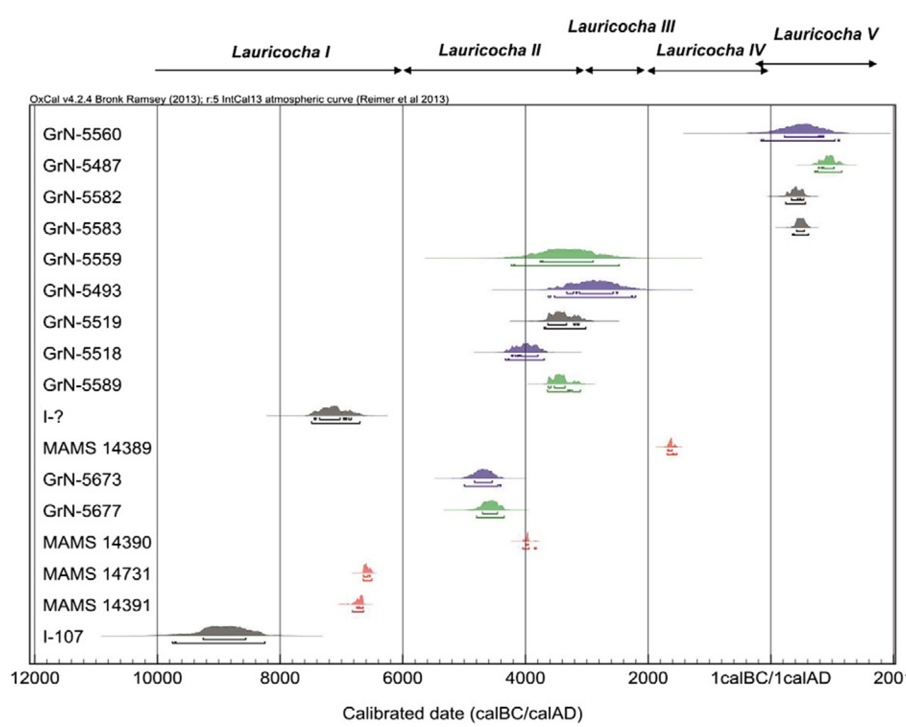

Fig. 4. Calibrated radiocarbon dates (IntCal13 with Oxcal). Samples are plotted according to their stratigraphic depth (top = close to surface). The carbonate samples dated at Groningen with ages above 20,000 years are not included. *Green* colour marks the data on humic acids whereas the blue colour represents the residue fraction of the same material. Black colour refers to sediments samples and the quite uncertain Teledyne. In red, are the skeletons with MAMS-Numbers. Calibrations were done using Oxcal with Intcal13.

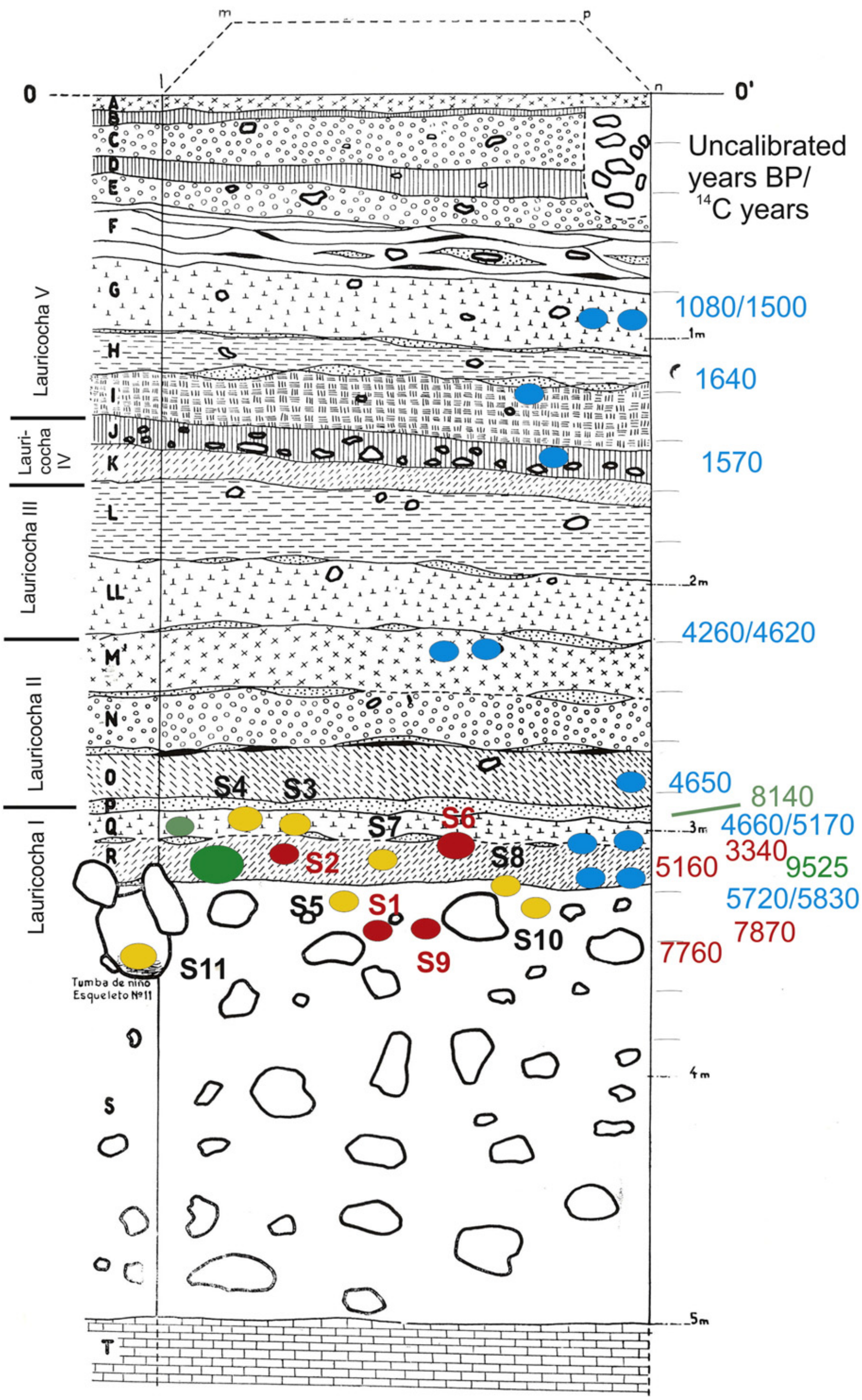

Fig. 5. Radiocarbon dates plotted according to their stratigraphic position, together with undated bone (yellow dots). The red dots are the bones dated for this publication, the blue dots represent the formerly derived ages from Groningen. The skeletons are marked with "S" and the number of the skeleton.
Graph taken from (Cardich, 1964) and information reconstructed by S. Lindauer.

first to show a complete cover with iron oxide. Also it would be helpful to re-excavate and re-sample the cave stratigraphy to clarify the character of Lauricocha phases I–V properly. In addition to the use of radiocarbon dating, it would be desirable to use OSL-dating (Optically stimulated Luminescence) upon suitable layers of sediment and apply TL-dating (Thermoluminescence) when ceramics are identified.

Finally, more than 50 years after the initial excavations, Lauricocha cave remains an important site for the study of early human occupation in Peru. Many research questions remain to be answered and clearly more work could be undertaken on the sedimentary sequence, human remains and artefacts. It is hoped that this paper will galvanise interest in the site and contribute to the ongoing study of early human occupation of the Americas.

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