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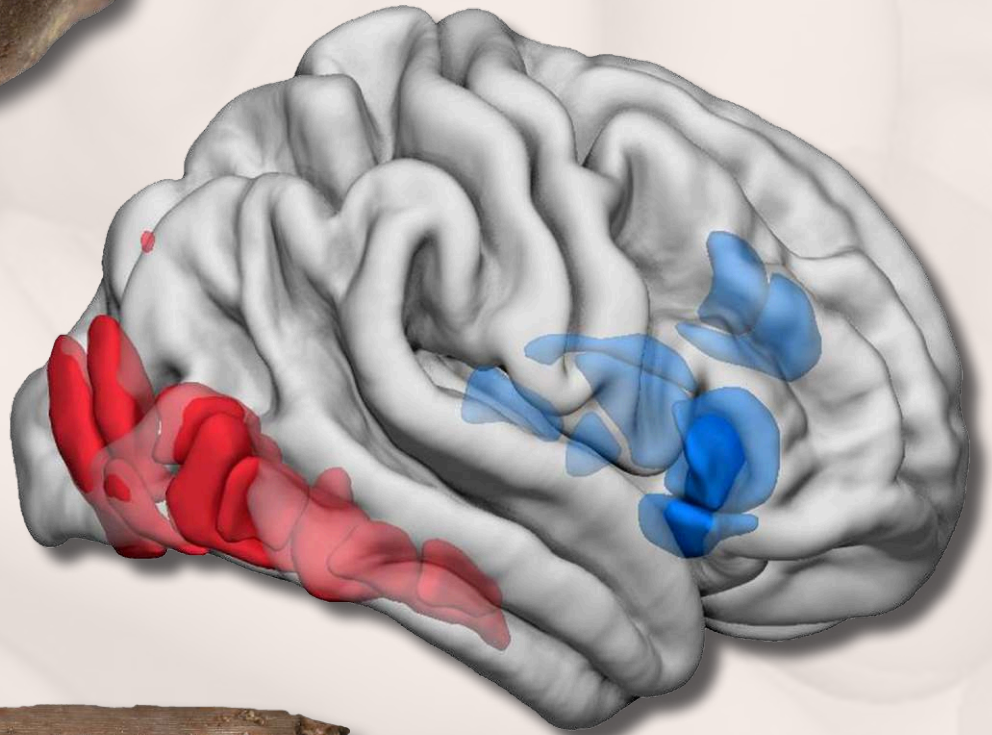
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New taphonomic approach applied to the Late Pleistocene bone remains from Pikimachay Cave, Ayacucho Basin, Peru: possible implications for the debate on human colonisation of western South America

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Abstract – The Pikimachay cave in south-eastern Peru had an important role in archaeological discussions concerning the first peopling of South America, and the Southern Andes in particular. The excavations by Richard MacNeish in 1969-1970 identified a sequence of possible but controversial Late Pleistocene human occupations up to historical times. As a part of a research programme aiming to re-assess the Late Pleistocene remains from this site, we made taphonomic observations on a sample of bones (n=40) from the lower strata (layers *h* to *k*) as follows: *h* (n=17), *hl* (n=6), *i* (n=4), *il* (n=7), *j* (n=5), and *k* (n=1). The conventional uncalibrated radiocarbon dates initially obtained suggest that these layers span a period of ~14.0 to 25.0 thousand years before present (kybp). Each bone was thoroughly examined to determine the nature of modifications to them, and to describe alterations and the general condition of the specimens in order to identify possible anthropic intervention. For this purpose, we examined the surface modifications indicating fresh or post-depositional fractures, the different kinds of marks, weathering, and the presence of manganese staining. We concluded that several bones (n=8) from layer *h* showed various human-made modifications. We can therefore suggest that this new information justifies the assumption that the bones and lithic materials from layer *h* would have been produced during the Early Holocene/Late Pleistocene between ~9.0/10.0 and ~14.1, probably at ~14.1 kybp; an assumption that can also be considered for the stone remains from the underlying strata *hl* that yielded a similar date. The bone remains from strata *j* to *k* do not show any human modifications. Furthermore, if the reported chronology and its association with the anthropic remains are true,

the Pikimachay cave could still be relevant to the debate over the human colonisation of western South America that occurred within a similar timeframe during the post-glacial era.

Keywords – archaeology, palaeontology, taphonomy, human colonisation, Late Pleistocene

Résumé – La grotte de Pikimachay dans le sud-est du Pérou a joué un rôle important dans les discussions concernant le premier peuplement de l'archéologie sud-américaine, et en particulier dans les Andes du Sud. Les fouilles effectuées par Richard MacNeish en 1969-1970 ont permis l'identification d'une séquence d'occupations humaines possibles et controversées du Pléistocène tardif aux temps historiques. Dans le cadre d'un programme de recherche visant à réévaluer les vestiges du Pléistocène supérieur de ce site, nous avons effectué des observations taphonomiques sur un échantillon osseux (n=40) appartenant à ses strates inférieures (couches *h* à *k*) comme suit : *h* (n=17), *hl* (n=6), *i* (n=4), *il* (n=7), *j* (n=5) et *k* (n=1). Les datations au radiocarbone conventionnelles non calibrées initialement obtenues suggèrent que ces couches couvrent une période d'environ 14 à 25 000 ans avant le présent (kybp). Chaque os a été minutieusement étudié pour connaître la nature de ses modifications, décrire l'état général des spécimens et les altérations, dans le but d'identifier une éventuelle intervention anthropique. À cette fin, nous avons considéré les modifications de surface enregistrant des fractures fraîches et post-dépositionnelles, différents types de marques, l'altération et la présence de taches de manganèse. Nous avons conclu

que divers os ($n=8$) de la couche *h* étaient affectés par diverses modifications d'origine humaine. On peut donc supposer que ces nouvelles informations justifient l'hypothèse selon laquelle les os et les matériaux lithiques de la couche *h* auraient été produits au cours de l'Holocène inférieur/Pléistocène terminal entre $\sim 9,0/10,0$ et $\sim 14,1$, probablement à $\sim 14,1$ kybp ; un fait qui peut être considéré pour les restes de pierre des strates sous-jacentes *h1* qui ont donné une date similaire. Les restes osseux des strates *j* à *k* ne présentent pas de modifications humaines. Ensuite, si la chronologie rapportée et son association avec les restes anthropiques sont vraies, Pikimachay pourrait encore être pertinent en ce qui concerne la discussion sur la question de la colonisation humaine dans l'ouest de l'Amérique du Sud à une époque acceptable pendant la période postglaciaire.

Mots clés – archéologie, paléontologie, taphonomie, colonisation humaine, Pléistocène supérieur

Introduction

The Ayacucho Basin in south-eastern Peru has played an important part in the history of South American archaeology. Between 1966 and 1973, under the patronage of the Robert S. Peabody Foundation for Archaeology headed by Richard MacNeish, an international team of archaeologists carried out the “Ayacucho Archaeological-Botanical Project”. Several sites were excavated under this landmark project in South American archaeology, yielding a regional sequence that spans human occupation from the Late Pleistocene to

Inca times (MacNeish, 1969; MacNeish et al., 1970a). The Pikimachay cave was one of the main sites that provided evidence to support discussions on the earliest human population of the Southern Andes (MacNeish, 1969, 1971, 1979; MacNeish et al., 1970b, 1980, 1981, 1983). However, due to the nature of the finds and the way in which they were reported (Dillehay, 1985), the role of the site as regards this topic has remained controversial (Lynch, 1974, 1990, 1992). For this reason, and based on the new approaches developed in archaeology in general, and in the Central and South-Central Andes in particular (e.g. Lavallée et al. 1995; Rodríguez-Loredo, 2012; Dillehay, 2014; Rademaker et al., 2014; Capriles et al., 2016; Jodry and Santoro, 2017; Borrero and Santoro, 2022), we carried out a detailed review of the legacy collection resulting from the “Ayacucho Archaeological-Botanical Project” and of new fieldwork in the area (León and Yataco Capcha, 2008; Yataco Capcha, 2011, 2020; Yataco Capcha and Nami, 2016, 2022; Giesso et al., 2020; Yataco Capcha et al., 2021). This paper sets out the taphonomic observations made as part of our research on a sample of bones ($n=40$) exhumed from the Late Pleistocene levels of Pikimachay, and which had been previously reported by MacNeish and Yataco Capcha (MacNeish, 1979; MacNeish et al., 1980; Yataco Capcha, 2011, 2020).

General background

The Ayacucho Basin is located in the south-central part of the Central Andes (figure 1). The Marcahuilca Cordillera connects with the eastern Cordillera in the north-east.

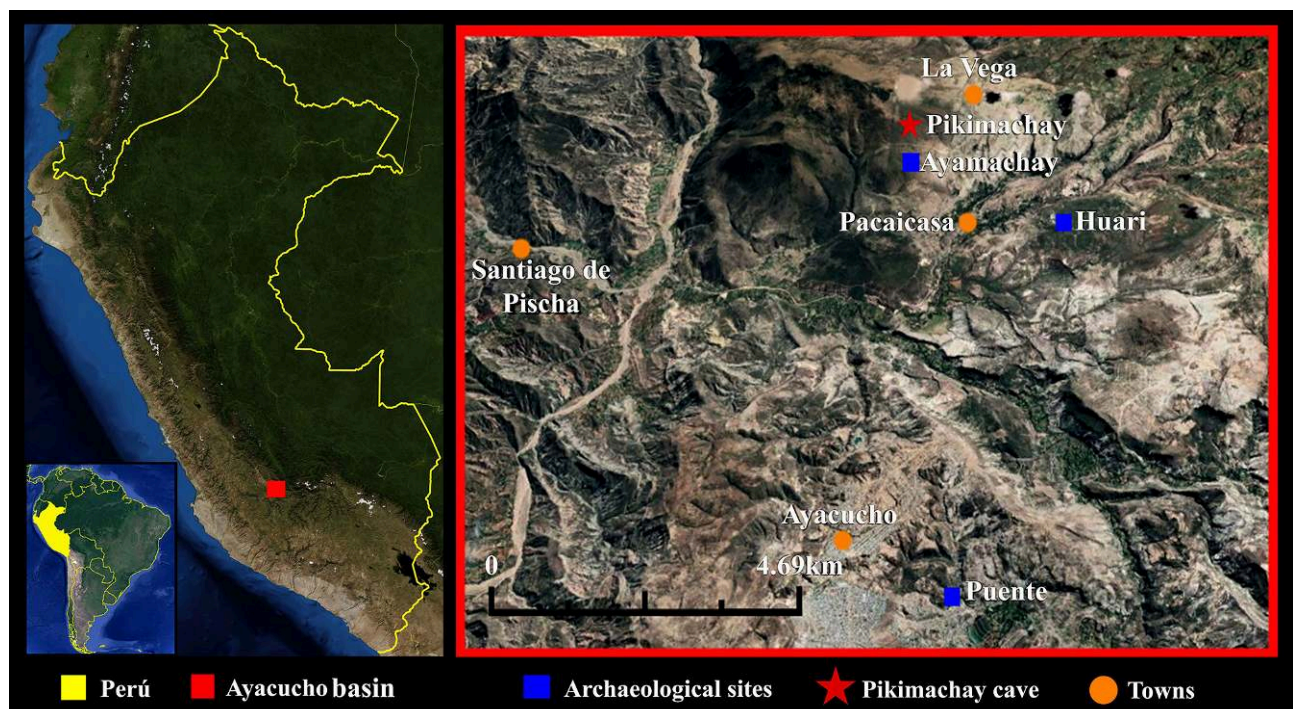


Figure 1. Map of the Ayacucho Basin showing the main sites excavated under the MacNeish Ayacucho Archaeological-Botanical Project in south-eastern Peru (CAD: J. Yataco Capcha) / Carte de localisation du bassin d'Ayacucho et des principaux sites issus du “projet archéologique et botanique d'Ayacucho” de MacNeish dans le sud-est du Pérou (DAO : J. Yataco Capcha)

Vinchos is a continental watershed that flows across the western Cordillera's upper area, whose average heights range from 2,500 to 4,500 m above sea level (m.a.s.l.) (Morche et al., 1995:7). The landscape was modelled by glacial action that produced moraines, erosive processes and glacial-fluvial deposits, but also by various geotectonic and geodynamic processes (Yataco Capcha, 2020:39-47).

The region of Ayacucho is characterised by a temperate, moderately rainy climate, with temperatures averaging 13 to 15 °C. It is located in the inter-Andean area, consisting of a depression cut across by numerous watercourses, and sheer, rugged, steeply sloping ravines. The local vegetation growing around the Pikimachay cave is mainly composed of shrubby species such as *Opuntia tunicata*, *Cylindropuntia tunicata*, *Opuntia exaltata deformis*, as well as *Agave sisalana*, molle (*Schinus molle*) and adropongo (*Andropogon*). In the irrigated areas, potato (*Solanum tuberosum*), oca (*Oxalis tuberosa*), olluco (*Ollucus tuberosum*), mashua (*Tropacolum tuberosum*), corn (*Zea mayz*), broad bean (*Vicia faba*), pea (*Pisum sativum*), quinoa (*Chenopodium quinoa*) and vegetables such as lettuce (*Lactuca sativa*), carrot (*Daucus carota*) and cabbage (*Brassica oleracea* var. *capitata*) are found (ONERN, 1976).

Regarding modern fauna, it should be noted that during the Ayacucho Project, Kent Flannery and Elizabeth Wing performed a survey of the species found in the vicinity of the shelter. An unpublished report (Flannery and Wing, n.d.) resulting from the fieldwork is currently held by the Robert S. Peabody Institute of Archaeology. Conducting specific studies to identify birds and mammals in the Ayacucho

Basin, they identified birds including *Nothoprocta pentlandi* (tinamou), *Nothoprocta ornata* (tinamou), *Plegadis ridgwayi* (Ridgway's ibis), *Chloephaga melanoptera* (Andean goose), *Anas flavirostris oxyptera* (sharp-winged teal), *Anas versicolor puna* (puna teal), *Buteogallus urubitinga* (great black hawk), *Thinocorus orbignyianus ingae* (Pucopuco de altura), *Columba maculosa* (spot-winged pigeon), *Zenaidura auriculata* (white-tailed dove), *Metriopelia melanoptera* (black-winged dove) and *Colaptes rupicola puna* (puna flicker) and mammals such as *Didelphis albiventris* (white-eared opossum), *Oryzomys* sp. (rice rat), *Akodon boliviensis* (grass mouse), *Calomys lepidus* (vesper mouse), *Calomys sorellus* (vesper mouse), *Phyllotis darwini* (Darwin's leaf-eared mouse), *Phyllotis pictus* (leaf-eared mouse), *Phyllotis sublimus* (leaf-eared mouse), *Cavia porcellus* (domestic guinea pig), *Cavia cf. tschudii* (wild guinea pig), *Lagidium peruanum* (mountain viscacha), *Dusicyon culpaeus* (andean fox), *Canis familiaris* (domestic dog), *Mustela cf. frenata* (weasel), *Conepatus rex* (hog-nosed skunk), *Felis concolor* (mountain lion), *Felis* sp. (wild cat), *Lama guanicoe* (guanaco), *Lama glama* (domestic llama), *Vicugna (vicuña)*, *Odocoileus virginianus* (white-tailed deer) and *Hippocamelus antisensis* (huemul or North Andean deer). Table 1 provides a summary of the species identified according to their altitudinal distribution, taken from Flannery and Wing (n.d.).

Geologically, Pikimachay is located in the Molinoyoc formation (figure 2), consisting of a sequence of dark lava masses that arose from a series of volcanoes. This is an area with five volcanic cones made up of lava, slag and ash spills,

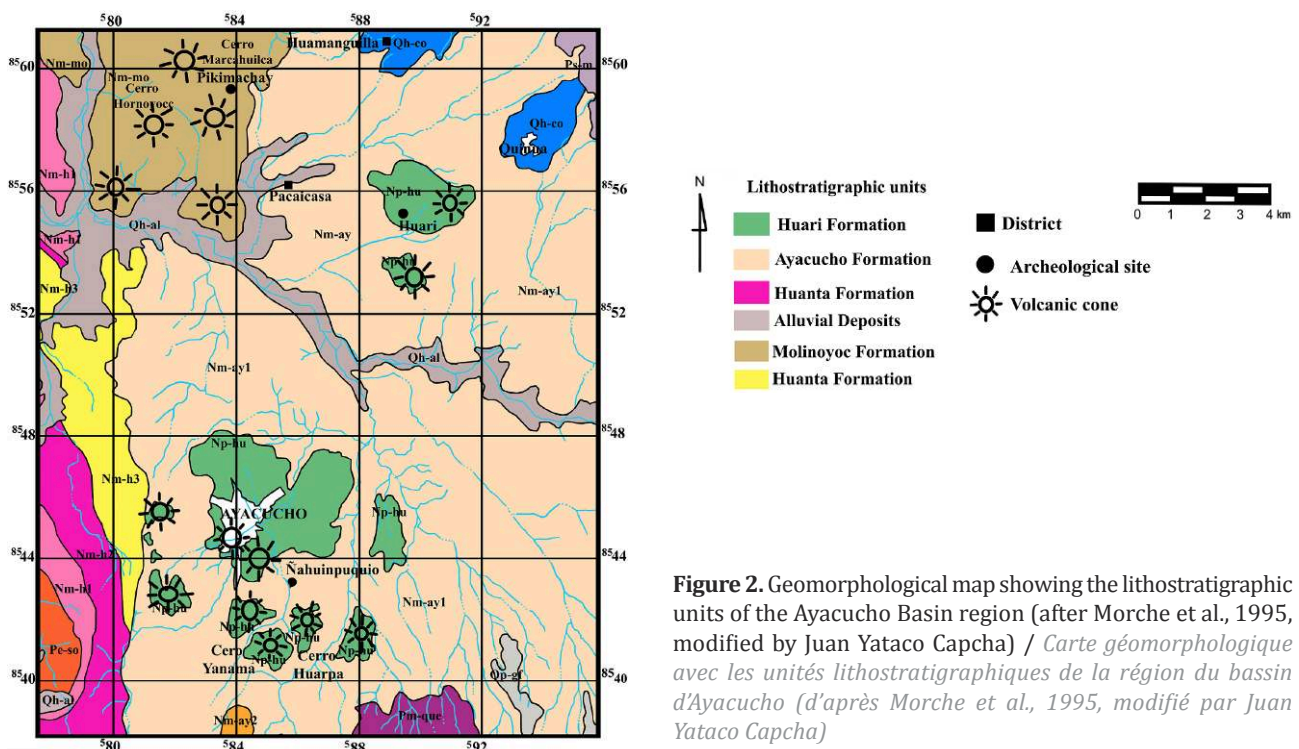


Figure 2. Geomorphological map showing the lithostratigraphic units of the Ayacucho Basin region (after Morche et al., 1995, modified by Juan Yataco Capcha) / Carte géomorphologique avec les unités lithostratigraphiques de la région du bassin d'Ayacucho (d'après Morche et al., 1995, modifié par Juan Yataco Capcha)

The Systematic of the Ayacucho Fauna. Animals																						
Project terms	2000 2250		2500 2750		3000		3250		3500		3750		4000		4250		4500		4750		5000	
	Mantaro Desert	Thorn Scrub river side facies		dry facies		Humid Woodland		Low Puna		High Puna												
BIRDS											←-----		<i>Notropocta pentlandi</i> (tinamou)									
											←-----		<i>Nothoprocta ornata</i> (tinamou)									
											←-----		<i>Plegadis ridgwayi</i> (Ridgway's ibis)		----->							
											←-----		<i>Chloephaga melanoptera</i> (Andean goose)		----->							
											←-----		<i>Anas flavirostris oxyptera</i> (sharp-winged teal)		----->							
											←-----		<i>Anas versicolor puna</i> (puna teal)		----->							
											←-----		<i>Buteogallus urubitinga</i> (great black hawk)		----->							
											←-----		<i>Thinocorus orbignyianus ingae</i> (Puco-Puco)		----->							
											←-----		<i>Columba maculosa</i> (spot-winged pigeon)		----->							
											←-----		<i>Zenaidura auriculata</i> (white-tailed dove)		----->							
											←-----		<i>Metriopelia melanoptera</i> (black-winged dove)		----->							
											←-----		<i>Colaptes rupicola puna</i> (puna flicker)		----->							
MAMMALS											←-----		<i>Didelphis albiventris</i> (white-eared opossum)		----->							
											←-----		<i>Oryzomys</i> sp. (rice rat)		----->							
											←-----		<i>Akodon boliviensis</i> (grass mouse)		----->							
											←-----		<i>Calomys lepidus</i> (vesper mouse)		----->							
											←-----		<i>Calomys sorellus</i> (vesper mouse)		----->							
											←-----		<i>Phyllotis darwini</i> (Darwin's leaf-eared mouse)		----->							
											←-----		<i>Phyllotis pictus</i> (leaf-eared mouse)		----->							
											←-----		<i>Phyllotis sublimus</i> (leaf-eared mouse)		----->							
											←-----		<i>Cavia porcellus</i> (domestic guinea pig)		----->							
											←-----		<i>Cavia</i> cf. <i>Tschudii</i> (wild guinea pig)		----->							
											←-----		<i>Legidium peruanum</i> (mountain viscacha)		----->							
											←-----		<i>Canis familiaris</i> (domestic dog)		----->							
											←-----		<i>Dusicyon culpaeus</i> (andean fox)		----->							
											←-----		<i>Mustela</i> cf. <i>Frenata</i> (weasel)		----->							
											←-----		<i>Conepatus rex</i> (hog-nosed skunk)		----->							
											←-----		<i>Felis concolor</i> (mountain lion)		----->							
											←-----		<i>Felis</i> sp. (wild cat)		----->							
											←-----		<i>Lama guanicoe</i> (guanaco)		----->							
											←-----		<i>Vicugna vicugna</i> (vicuña)		----->							
											←-----		<i>Odocoileus virginianus</i> (white-tailed deer)		----->							
										←-----		<i>Hippocamelus antisensis</i> (huemul deer)		----->								
										←-----		<i>Lama glama</i> (domestic llama)		----->								

projection of the relationship between current plants and animals with height → secure -----> probable

Table 1. Ecological zones and distribution of animals in the Ayacucho Basin (after Flannery and Wing, n.d., modified by Juan Yataco Capcha) / Zones environnementales et répartition des animaux sur le bassin d'Ayacucho (d'après Flannery et Wing, n.d., modifié par Juan Yataco Capcha)

reaching altitudes of approximately 3,400 m.a.s.l. Around Pacaicasa town, there is evidence of whitish breccias and tuffs, coloured lava streams ranging from grey to dark grey, with plagioclase and lapilli strata. On the southern side, the Molinoyoc formation is covered and surrounded by an irregular strip formed by widely distributed alluvial deposits of pebbles, stones, and medium-sized blocks with partially rounded angles in a matrix of fine gravel and silty sand (Morche et al., 1995:35). The Ayacucho formation, a unit formed by an explosive volcanic phase during the Miocene, extends towards eastwards, passing just in front of the Pikimachay cave. It is composed of lapilli tuffs (igneous rocks and volcanic deposits with some crystallization) interspersed with reworked tuffs, lithic clasts (andesite, granite), pumice and lagoon sediments that include greenish silty argillite, diatomite and pinkish siltstone (Morche et al., 1995:37-38).

Excavation and stratigraphy

Inside Pikimachay cave (figure 3A), three excavations named the North, Central and South trenches were carried out separately, following the same recording and stratigraphic procedure (MacNeish, 1979; MacNeish et al., 1981, 1983). During the first field season, between June and September 1969, the team excavated the central and northern sectors. The main excavation was carried out in the southern portion during the second field season in 1970 (figure 3B). The grids were planned with reference to the cave's axis and labelled according to the north-south cardinal axis (figure 3C). As shown by the historical images in figure 4A-H, the digging was carefully performed with trowels and brushes, and the finds were documented in their place of discovery by various methods, carefully mapped, and recorded from their Datum Point (MacNeish, 1979: figure 11-9). Finally,

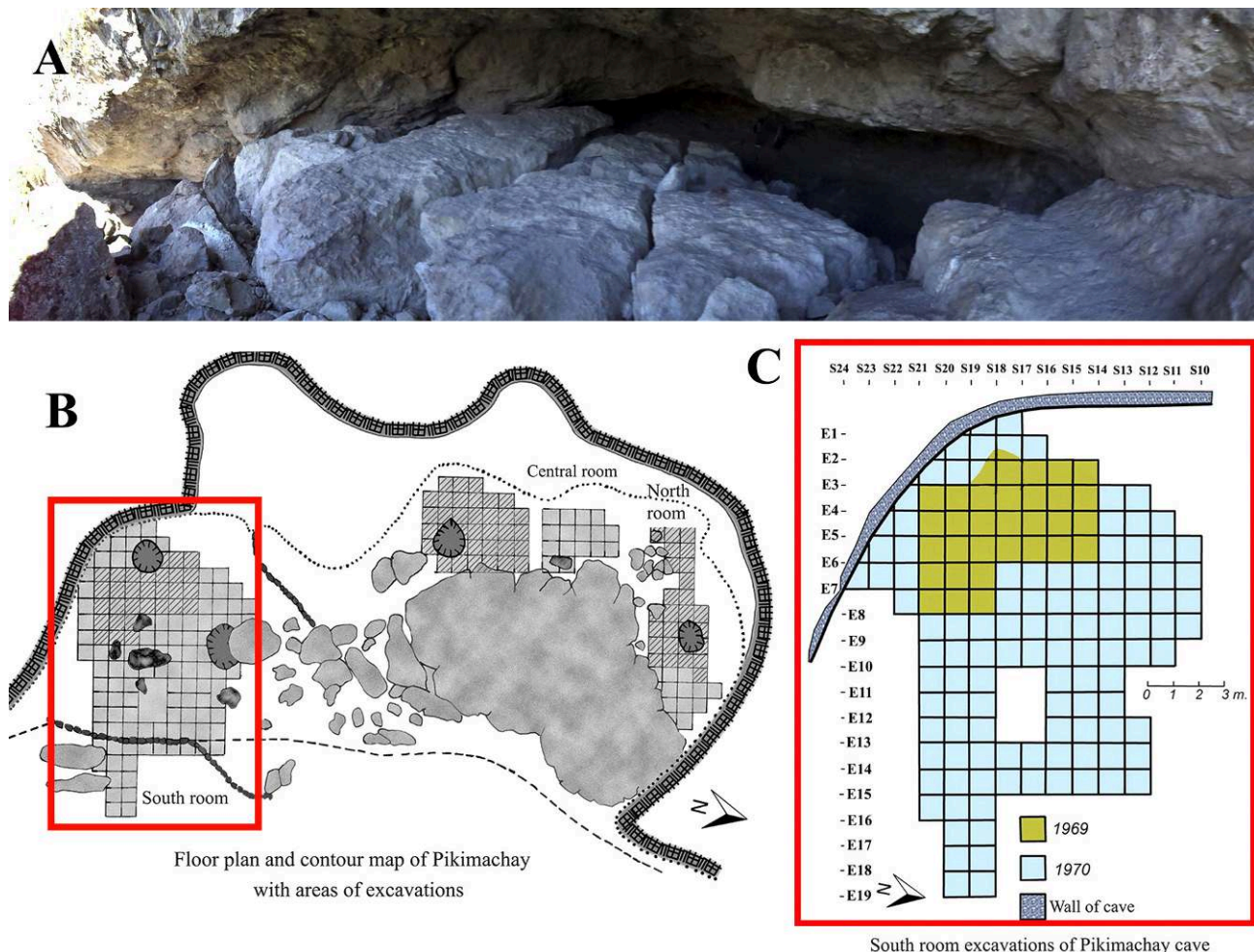


Figure 3. A: photograph of Pikimachay cave showing the large rockfalls located at the entrance. B: floor plan of the site and locations of the excavated sectors. The red rectangle denotes the south sector of the excavation illustrated in C. C: colour-coded grids excavated in the 1969 and 1970 field seasons (after MacNeish et al., 1981: figures 2-8 and figures 2-38/39, modified by Juan Yataco Capcha) / A : photographie de la grotte Pikimachay montrant les grandes chutes de pierres situées à l'entrée. B : Plan d'étage du site et localisation des secteurs fouillés. Le rectangle rouge indique le secteur sud de l'excavation qui est illustré en C. C : et montre des grilles codées par couleur excavées au cours des saisons de terrain 1969 et 1970 (d'après MacNeish et al., 1981 : figures 2-8 et figures 2-38/39, modifié par Juan Yataco Capcha)

the sediments removed were carefully screened. Figure 4E-H shows the finds left in place during the excavation of the lower layers of the cave.

In some places, the Pikimachay sedimentary fill shows a 4 m depth of deposition between ~0.5 and 25.0 kybp. MacNeish (1969, 1979, among others) used the term “zones” for the layers of the stratigraphic sequence, which he labelled differently according to the excavation sectors (figure 3B). Because the materials reported in this paper come from the southern part, we will only describe the strata there. The sedimentary deposit in that area consists of 16 layers, coded *a* to *k*. Several features are of note in the sequence of these layers. The blocks that fell when the cave’s ceiling collapsed made a clear cut in the stratigraphy (MacNeish et al., 1981). This event formed the *g* stratum, ~1.5 m thick and composed of plant remains possibly deposited by rodents, and blocks of various sizes. These are mostly present in the north-central sector, with some in the southern sector of the cave (figure 3A-B). Since these fallen rocks overlie an occupation level with projectile points dated to ~10-9 kybp (MacNeish, 1979:29-40; MacNeish et al., 1981:51-54), the rockfall was possibly caused by a catastrophic episode during the Late Pleistocene/Early Holocene, and covered the seven earliest strata (MacNeish, 1969, 1979). The stratigraphy overlying this debris is confusing and shows disturbances and intrusions due to modern human action, such

as holes for looting or corral construction, and to animal activity (MacNeish, 1979:4). Due to the thickness of the *g* stratum, some significant discontinuities (Dott, 1983) may have occurred, mainly above the blocks. However, the underlying strata show moderately uniform horizontal deposition, forming a ≥ 1.5 m thick deposit. As the lower strata are the main focus of our investigation, we will continue with their description.

The authors visited Pikimachay again on several occasions to observe and document the exposed sections. They also made other observations that might complement those of MacNeish. As part of this endeavour, we conducted extensive stratigraphic observations and took several photographs, also organising geological reconnaissance explorations in the field and identifying raw material quarries. In addition, we conducted a palaeomagnetic sampling in the northern part of the cave, and obtained a new radiocarbon date. A future paper will report on the results of this study. The stratigraphy was formed by sediments of exogenous and endogenous origin displaced by wind and rain (Waters, 1992; Ones, 2003). They mainly consist of silt and fine material from regional volcanic rocks, later consolidated by humidity and drought. At these levels, we observed graded laminar strata of consolidated volcanic tuff interspersed with silt deposits (Dott and Howard, 1962; Dott, 1963).

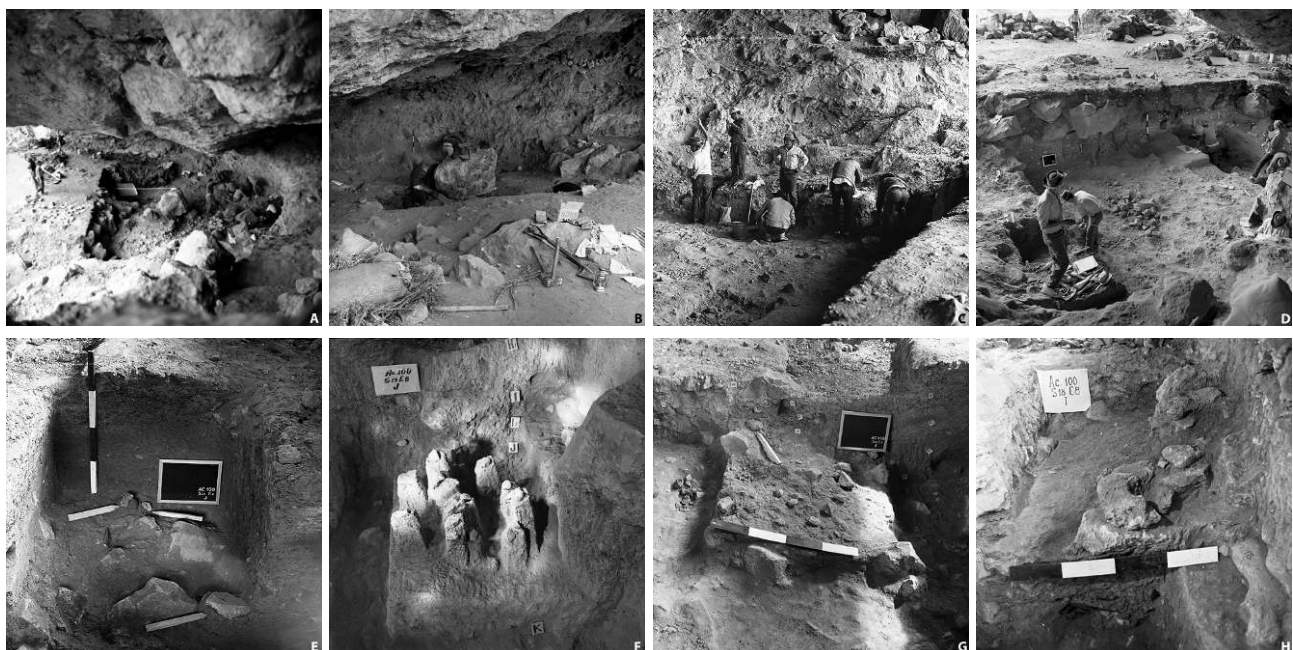


Figure 4. A-D: stages of the excavation conducted in the south sector of Pikimachay by MacNeish et al., 1970a. E-G: square excavations (S20E4, S19E8, S20E7) on level *j* and the associations with geofacts. H: this limb bone of an extinct ground sloth, shown here in the place where it was found, was submitted for Carbon-14 analysis (MacNeish, 1971). Note the uniformity of the layers underneath the large blocks of rock, which overlay and seal the lower strata in D (photographs scanned by Marla Taylor; Copyright Robert S. Peabody Institute of Archaeology, Phillips Academic, Andover, Massachusetts, USA) / A-D : étapes de la fouille réalisée dans le secteur sud de Pikimachay par MacNeish et al., 1970a. E-G : les fouilles carrées (S20E4, S19E8, S20E7) au niveau *j* et les associations avec des géofacts. H : L'os du membre d'un paresseux terrestre éteint à son emplacement de découverte a été soumis à une analyse carbone 14 (MacNeish, 1971). Notez l'uniformité des couches sous les gros blocs de roche qui recouvrent et scellent les couches inférieures en D (Photographies numérisées par Marla Taylor. Copyright Robert S. Peabody Institute of Archaeology, Phillips Academic, Andover, Massachusetts, USA)

Before the cave's ceiling collapsed, the last sediments deposited had formed the lower portion of layers *g*, small level *h*, then *h* and *hl*. Because the bones analysed belong to layers *h* to *k*, we will describe them in detail in this section. The small layer *h* is ~20 cm thick and consists of an accumulation of a soft reddish-brown dusty material. It forms a small triangular surface of 21.75 m² measuring approximately 6 × 6 m at the northern end of the excavation. The most extensive stratum below the rockfall, with an area of 119.13 m², is *h*, made up of slightly compacted reddish-orange sediment. Its thickness varies from 5 to 10 cm along the cave wall to more than 30 cm near the cave mouth. Below is *hl*, a highly compact yellowish level with a maximum thickness of ~40-50 cm, and an average thickness ranging from 25 to 35 cm. It occupies a surface area of 122 m², of which only 104 m² have been excavated. The sediment in *h* is highly acidic, unlike *hl*, which is neutral (MacNeish et al., 1981:49). With a surface area of 50 to 60 m², it reaches a maximum thickness of 30 cm. Measuring ~7-8 m from east to west, *il* is a compacted reddish-brown stratum with a maximum thickness of ~30 cm. The excavation here covered 20.5 m², leaving an unexcavated surface of 3.13 m². Extending between 8 and 14 m from east to west, this dark reddish-grey sediment reaches a maximum thickness of 40 cm. It covers an approximate area of 50 to 65 m², of which only 33.42 m² is exposed. Finally, layer *k* over the bedrock is brownish-grey with a maximum thickness of 30 cm. The surface area is 10 m long × 4 m wide, of which 27.71 m² has been excavated (Yataco Capcha and Nami, 2022).

To summarise, the sedimentary deposit about 4 m in depth contains two critical features. A turning point was the event that caused the collapse of the cave's roof, evidenced by a significant number of blocks sealing the oldest strata. The layers overlying the fallen rocks were not uniformly deposited and have been disturbed by different animal and human agents (MacNeish et al., 1981, 1983); the underlying strata show reasonably uniform horizontal deposition, disturbed only by fallen roof blocks in some places in *h* and *hl* (MacNeish, 1979; MacNeish et al., 1981). The other notable feature is that layers *h* to *k* have a highly compacted, almost lithified structure, practically reaching a cemented stage (MacNeish, 1979:19-41) in the sedimentary rock formation process (Blatt et al., 1980; Tarbuck and Lutgens, 1999; Yataco Capcha, Nami, and Toledo several pers. obs.). As the layers thickened, this part of the stratigraphy became harder (MacNeish, 1979:18), so much so that chisels were used for the excavation; their distinctive marks are still visible in the remaining sections. Hard layers of this sort seem to be present in other sites, such as the Puente rock shelter (MacNeish, 1981; MacNeish et al., 1983; Yataco Capcha et al., 2021), where chisels were also used during excavations (MacNeish, 1969:37). These highly compacted strata may have acted as a matrix, sealing in the embedded artefacts (Yataco Capcha and Nami, 2022).

Below, we will describe and discuss the remains from these lower levels, claimed to be vestiges of the earliest

human occupations at Pikimachay. Lithic materials of the Ayacucho and Pacaicasa Complexes were reported as identified in layers *h-hl* and *i* to *k*, respectively. Currently available radiocarbon data suggest that the record from *h-hl* has a Terminal Pleistocene age of ~14.1 kybp. Therefore, we will first provide a summary of the chronology and the attempts we made to date the new material.

Chronology

Most Pikimachay dates were obtained with old conventional radiocarbon techniques applied to bone, a material that has been suspect for many years because of the inaccurate ages often derived (e.g. Hassan et al., 1977; Zazzo and Saliège, 2011; Politis, et al. 2019; among many others). Despite this, the dates still provided an exploratory chronological framework for the stratigraphy containing the sample investigated, until new data became available (Yataco Capcha and Nami, 2022), as was the case recently for other South American sites (Carlini et al., 2022). It is worth mentioning that Carlini and colleagues (2022) reported a similar problem when trying to obtain updated dates for glyptodontids collected from Muaco and Taima-Taima, two Late Pleistocene sites in north-western Venezuela.

Five conventional radiocarbon assays performed on bone samples were processed by Teledyne Isotopes, New Jersey, USA. Table 2 shows the data concerning taxonomic determinations by R. Hoffstetter, grids and stratigraphic provenance, excavation depths, laboratory methodology and calibrated and uncalibrated results. Due to the lack of calibration curves at the time, they were reported as calendar years BC (MacNeish et al., 1981). However, the original dates were available online (Ziólkowski et al., 1994; see also MacNeish et al., 1970b:975-977; 1981:208-209). We calculated the dates using the OxCal v4.4 program and the SHCal20 southern hemisphere calibration curve, showing the calendar-calibrated ranges at the 95.4% probability level (Hogg et al., 2020). Figure 5A shows the conventional radiocarbon dates and calibration results. The plot of the *h* sample is remarkable as it exhibits a calibration curve with certain alterations.

According to the dates obtained and the overlapping of the calibrated results, layers *h* to *k* thus belong to the Early Holocene/Post-Last Glacial Maximum during the Late Pleistocene. This is in a period spanning ~9.0/10.0 to 25.0 kybp (figure 5B). Moreover, the chronological data suggest that there are no significant unconformities in the lower layers, mainly between *h* and *i*. This 1.5-metre-thick deposit spans ~1.0 kybp. In a nutshell, the available radiocarbon information supports the hypothesis of chronological and stratigraphic unconformities in the deposit (MacNeish et al., 1981:43-49, 51-52, 1983:136-152) overlying the rockfalls, a situation that apparently did not occur in the lower strata.

The Pikimachay dates were obtained with old conventional radiocarbon techniques and some show widely ranging standard deviations. Because of this, two bone specimens exhumed from layer *h* and held by the Peabody Museum

of Archaeology were submitted for standard radiocarbon dating by accelerator mass spectrometry (AMS) at Beta Analytic Inc. (Florida, USA). For that purpose, we selected two relatively large bones that appeared to offer suitable dating material. The documentation and submission process to the laboratory was undertaken by Marla Taylor (curator of

collections and work duty supervisor) at the Robert S. Peabody Institute of Archaeology. She submitted the bones for identification to Susan de France at the Department of Anthropology (University of Florida). From the results, she concluded that one of the specimens corresponds to the Camelidae family (Pers. Com. Marla Taylor; figure 8D).

MATERIAL DATED							
Grid	Layer	Depth (m)	Lab. Id.	Date (yr BP)	Calibrated range (yr BP) (95.4%)	Laboratory comment	Archaeological comment
Bone, identified as fragment of humerus of <i>Megatheriidae</i> or <i>Scelidotherium</i> *							
S19.1E3	<i>h</i>	2.67	I-1464**	14,150 ± 180	16,663-17,781	Fraction: collagen; dated in 1969. The gas was counted for three separate periods of 2800, 1300 and 1200 minutes each, corresponding to ages of 14180, 14150, and 14080 years BP.	-
Bone, identified as bones of <i>Megatheriidae</i> and carbon (burned bone?)							
S21.7E7.72 S20.25E6.75	<i>i</i>	3.37	UCLA-1653C	14,700 ± 1400	14,179-22,021	Fraction: collagen	Sample composed of two pieces of bone from S21.7E7.72 and a piece of carbon or burned bone from S20.25E6.75
Bone, identified as bones of <i>Megatheriidae</i>							
S20.5E7.24 S20.3E7.6	<i>il</i>	3.40/3.44	UCLA-1653B	16,050 ± 1,200	16,839-22,960	Fraction: collagen	Sample composed of two bone slivers from S20.5E7.24 and a nearby long-bone fragment from S20.3E7.6
Bone, identified as sloth bones (<i>Megatheriidae</i>)							
S22E9 S20.15E7.4 S20.2E8.98 S20.25E8.88	<i>j</i>	3.52/3.73	UCLA-1653A	19,600 ± 3,000	17,385-43,148	Fraction: collagen	Sample composed of four pieces of sloth bone from square S22E9, a rib from S20.15E7.4, a vertebra from S20.2E8.98 and a vertebra from S20.25E8.88
Bone, identified as sloth bones (<i>Megatheriidae</i>)							
S21.6E9.55	<i>j</i>	3.52/3.73	I-5851	20,200 ± 1,050	22,297-26,981	Fraction: collagen	Sample composed of remaining fragments of the bones dated by UCLA-1653A, combined with a fragment of long bone from S21.6E9.55 at a depth 3.52 m and a spine of sloth vertebra from S18.58E63 at a depth of 3.73 m

Table 2. List of radiocarbon dates obtained for the lower levels of Pikimachay. * Determined by R. Hoffstetter; ** processed by Teledyne Isotopes, New Jersey, USA (Ziólkowski et al., 1994:323), but mistakenly reported as UCLA-1464 (MacNeish, 1969:23; MacNeish et al., 1981:22-23) / *Liste des datations radiocarbone obtenues aux niveaux inférieurs de Pikimachay. * déterminée par R. Hoffstetter, ** traitée par Teledyne Isotopes, New Jersey, USA (Ziólkowski et al., 1994:323), mais rapportée par erreur comme UCLA-1464 (MacNeish, 1969:23 ; MacNeish et al., 1981:22-23)*

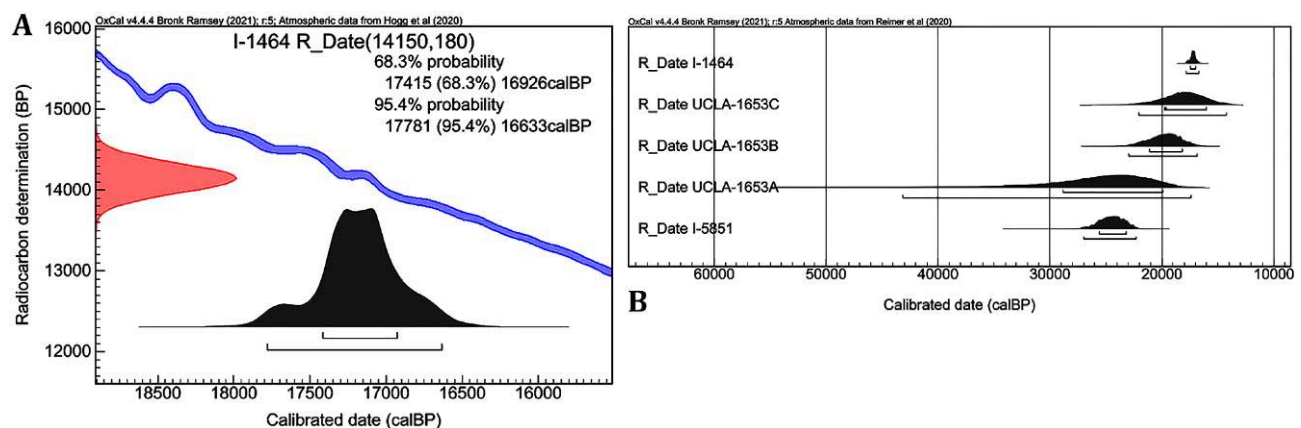


Figure 5. Plots of the calibrated ages of the samples obtained from the Late Pleistocene levels in Pikimachay cave. All the samples were processed using the ShCal20 curve for the southern hemisphere (Hogg et al., 2020). A: conventional date of 14,150 ± 180 14C yr BP (I-1464) for layer *h*, as well as the 95.4% and 68.2% of probability for the calibrated age ranges. B: calibrated ages for all the samples together / *Graphiques des âges calibrés des échantillons obtenus à partir des niveaux du Pléistocène supérieur de Pikimachay. Tous ont été traités à l'aide de la courbe ShCal20 pour l'hémisphère sud (Hogg et al., 2020). A : date conventionnelle de 14 150 ± 180 14C an BP (I-1464) pour la couche *h*, ainsi que les 95,4 % et 68,2 % de probabilité pour les tranches d'âge calibrées. B : âges calibrés pour la totalité des échantillons*

She then sent them to Beta Analytic Inc. for sampling and processing. According to the laboratory report, during the demineralization process the bone slowly dissolved in the acid baths, and consequently the samples failed to yield a separable collagen fraction and cannot be dated. Given the lack of collagen we cannot report collagen yield ranges, C/N values and ratio. According to the laboratory, this is typically caused by the bone being exposed to leaching by water, bleaching by the sun, or burial in acidic sediments. There are of course other processes that may have caused depletion or removal of the collagen, such as cooking or boiling the bones or microbial activity.

Taphonomic background of the Late Pleistocene remains from Pikimachay Cave

To contextualize the study sample, this section provides a short review of our recent analyses of the remains exhumed in the lower levels of Pikimachay. They are held by the *Museo de Arqueología y Antropología de la Universidad Nacional Mayor de San Marcos* (MAA-UNMSM), Lima, Peru. A few pieces are at the *Museo Nacional de Arqueología, Antropología e Historia del Perú* (MNAHP) and a group of bones and MacNeish's excavation field notes and documentation are at the Robert S. Peabody Institute of Archaeology (RSPIA), Andover, Massachusetts, USA. As also mentioned above, the authors returned to the Pikimachay cave on several occasions and made different kinds of observations.

It should be remembered that since the first reports (MacNeish, 1969, 1971, 1979), many questions and doubts have been raised over the evidence for the oldest occupations of Pikimachay (Lynch 1974, 1990, 1992). One of the main difficulties regarding the hypothetical palaeo-American evidence was that, in the final reports, the finds were not described with precision, and the stone remains as well as the raw material identifications were not clearly defined and described (Dillehay, 1985). In order to elucidate the questions and doubts over the possible evidence of Late Pleistocene occupations at Pikimachay (Lynch, 1974, 1990, 1992), we re-investigated the collections of finds from the aforementioned layers, mainly focusing our attention on analyses of the lithic materials (Yataco Capcha and Nami, 2022). Based on careful examination of the stone remains from Pikimachay, we concluded that the lithic artefacts from *h-h1* are human-made and showed morpho-technological homogeneity. They resulted from a series of re-occupations of the cave over a certain period, which are not distinguishable from each other. The stone artefacts show clear evidence of having been detached from cores, unambiguous shaping of instruments and the presence of bifacial flaking (Yataco Capcha and Nami, 2022: figures 9-12, 14-15). A highly significant point is that for tool-making, knappers would make a careful selection of materials from several exotic sources. Here, however, the lithic materials from *i* through to *k* are, rather, a by-product of natural action (Peacock, 1991; Raynal et al., 1995), mainly chunks fallen

from the cave walls and roof (Yataco Capcha and Nami, 2022: figure 16). Most of them show no flaking, and only some have what look like flake scars. However, they are isolated and lack any attributes that could indicate their human origin, such as initiation or continuity of flake distribution. We therefore considered them to be geofacts or "naturefacts". Having said that, based on the analysis presented above, the lithic artefacts from *h-h1* may suggest the presence of foragers who inhabited Pikimachay during the Late Pleistocene. On the other hand, the stones from the layers beneath are simple chunks and "naturefacts" or geofacts. Therefore, they do not represent enough evidence to support a discussion on earlier human occupation (Yataco Capcha and Nami, 2022).

A large number of entire and fragmented bones from various extinct and extant animals were associated with the stone remains (MacNeish, 1969, 1971, 1979; MacNeish et al., 1980:309-314). The extinct fauna remains were examined by palaeontologists Bryan Patterson and David Webb (Wing, n.d.). Following their identifications, and in order to contextualise our specific study, we will first outline the finds and observations made in layers *h* to *j*. These show evidence of the following animals: *h*: rodents, and skunk; *h* to *i1*: horse; *h* to *k*: ground sloth; *i1*: mastodon, and possibly camelid; *h*: cougar; *h1*: perhaps sabre-toothed tiger; *i1*: feline; and *j*: cervid. Although lacking a detailed palaeontological study, MacNeish (1979) pointed out that some of the fossil bones mentioned above correspond to the following species: *Scelidotherium tarijensis*, *Megatherium tarijensis*, *Equus (Amerhippus) andium*. Furthermore, in an old unpublished report, Wing (n.d.) identified the following species: *Eremotherium*, Mylodontidae, and *Mastodon*.

The bones of extinct fauna and the stone tools exhumed in layers *h* and *h1* suggest that they were coeval and, in some cases, related to each other (MacNeish, 1969, 1971, 1979; MacNeish et al., 1970b). The sample of osseous remains found in the MAA-UNMSM and at the RSPIA, discriminated by layers, are described and illustrated in figures 6-7 and figures S1-S9 in the Supplementary Information. In addition to the lithic analysis (Yataco Capcha, 2011, 2020, Yataco Capcha and Nami, 2022), detailed macroscopy and microscopy of the most significant bone remains has been performed (Yataco Capcha, 2011, 2020). These focused mainly of those remains showing various kinds of marks and alterations that were previously considered as signs of human actions, and unpublished bones that were provisionally classified by MacNeish (MacNeish et al., 1970b:975-977, 1971:36-46; 1979, 1980; Yataco Capcha, 2011, 2020). From the sample (n=40) analysed here, the former only reported 15 bones (MacNeish, 1979; MacNeish et al., 1980). The remaining 25 bones were found in the MAA-UMSNM and Robert S. Peabody Institute of Archaeology collections, but were not published by MacNeish in his reports. These remains, mainly from layer *h*, are contained in bags labelled with interpretations pointing to specific anthropic actions, such as "cut split bone", "polished scratched slot", or "polished bones of small animals".

However, this sample was further preliminarily described and reported in published and unpublished literature (Yataco Capcha, 2011, 2020).

The last review proposed some preliminary and tentative interpretations (Yataco Capcha, 2011, 2020). However, bearing in mind the complexity of natural and cultural modifications acting on the bones after their deposition, and that their marks, fractures and alterations may be due to different causes (Yataco Capcha and Nami, 2022), it was essential to perform a new specialised taphonomic study to gain a better understanding of their origins and characteristics. This kind of observation helps to shed light on the precise nature of the alterations that affected the bones from the lower levels of Pikimachay.

Materials and methods

For this research, we considered it was necessary to analyse the bones from a taphonomic perspective. This is a discipline that identifies and explains the processes affecting individuals after their death and helps to differentiate human from non-human agents (Fernández-Jalvo and Andrews, 2016). The resulting information is in turn useful for reconstructing human diets and the palaeoecological conditions of the deposition of assemblages (Lyman, 1994). Much has been discussed regarding agents, descriptions of modifications, their classification and the use of taphonomic insights to interpret bone assemblages (see Fernández-Jalvo and Andrews, 2016 for an updated review). In this case, the analysis supported a review of a historical collection with up-to-date taphonomic procedures, as done for other classic collections (Chichkoyan, 2019). For the purpose of analysing bones from the different Pikimachay levels, the following agents shown in table 3 were considered:

The sample examined was organised by minimal number of individuals (MNI) and number of identified specimens (NISP) following the method proposed by Lyman (1994).

According to this categorisation, the total NISP equals 51, and MNI equals 40. The sample is divided by layers as follows: *h* (NISP=17, MNI=17); *h1* (NISP=6, MNI=6); *i* (NISP=4, MNI=4); *i1* (NISP=17, MNI=7); *j* (NISP=5, MNI=5); and *k* (NISP=2, MNI=1). Each bone was carefully studied to determine the nature of its modification from a taphonomic viewpoint. For these purposes, the analysis was performed to describe the general condition of the specimens studied, and to identify possible anthropic interventions.

To organise the study, each specimen was given a number followed by its catalogue identification (e.g. #1. Ac100 204-2-15). Bones previously reported by MacNeish (e.g. MacNeish, 1979; MacNeish et al., 1980) and the additional bones found later in the collections analysed have been carefully recorded with standard photography techniques. The details of the marks were observed with two different microscopes: a Zeiss Stemi 2000-C, and a Veho Discovery VMS-001 USB up to 50x and 230x. These data have been reported in published and unpublished literature (Yataco Capcha, 2011:figures 9, 11-12; 2020:figures 11, 13, 18, 21, 28-30, 40-47). We performed our new taphonomic observations considering this detailed documentation, from which photographs are shown in figures 6-8 and figures S1-S9 in the Supplementary Information. In these figures, upper-case letters indicate each specimen analysed and lower-case letters indicate the microphotographs of areas with significant alterations. Table 4 shows the provenance of each specimen and its identification number, taxonomy, element, NISP, NMI, and the comparative interpretations of the bone marks described by MacNeish and Yataco Capcha.

The following are overall results; the individual observations of each piece, considering their provenance in the stratigraphic sequence, are detailed in the Supplementary Information. A brief discussion concerning initial interpretations and subsequent reviews follows the account of their examination.

SURFACE MODIFICATION	MAIN CHARACTERISTICS	BIBLIOGRAPHY
Fresh fractures	Borders will tend to be smooth, rounded, or curved	Lyman, 1994; Fernández-Jalvo and Andrews, 2016
Cut marks	Elongated/straight and narrow linear incisions, with V-shaped walls and internal microstriations	Lyman, 1994; Dominguez-Rodrigo et al., 2009
Rodents	Parallel, broad, flat-bottomed marks occurring in regular rows	Fernández-Jalvo and Andrews, 2016
Post-depositional fracture	Borders will tend to be irregular and rough, with straight angles	Lyman, 1994; Fernández-Jalvo and Andrews, 2016
Trampling	Randomly oriented and shallow lines and scratches	Lyman, 1994; Dominguez-Rodrigo et al., 2009
Weathering	Cracking, exfoliation, flaking, splintering or decomposition of bones subject to atmospheric conditions. Six weathering stages are generally used	Behrensmeier, 1978; Fernández-Jalvo and Andrews, 2016
Manganese staining	Black differential coverage of bone surface given its exposition to manganese-oxidizing bacteria contained in different types of burial conditions	López-González et al., 2006; Fernández-Jalvo and Andrews, 2016

Table 3. Main taphonomic agents considered in this study / *Principaux agents taphonomiques considérés dans ce travail*

LAYER	#	NOMECLATURE	FIGURE	TAXONOMY	ANATOMICAL ELEMENT	NISP	MNI	MACNEISH	Yataco Capcha	THIS PAPER	REFERENCES
h	1	Ac100 204-5-15	6A	artiodactyl	metapodium	1	1	not published, but found in UNMSM labelled as “cut split bone”	cut marks	cut marks + fresh fracture	Yataco Capcha, 2011, 2020
	2	Ac100 276-VI-H7	6B	indeterminate	indeterminate	1	1				
	3	Ac100 216-2-H3	S1A	ungulate	indeterminate	1	1	not published	cut marks + charred	rodent gnawing + manganese	
	4	Ac100 231-VII-H8	7A	indeterminate	indeterminate	1	1	not published, but found in UNMSM labelled as “small animals polished bones”	cut marks	cut marks + fresh fracture	MacNeish et al., 1980; Yataco Capcha, 2011, 2020
	5	Ac100 264-11-h	7B	perissodactyl	metapodial	1	1	fossil bone point	fossil bone point with polished marks	fossil bone point with polished marks	
	6	Ac100 163-VIII-H3	S1B	cervidae	cubit	1	1	not published	Cut marks indicating defleshing	rodent gnawing	Yataco Capcha, 2011, 2020
	7	Ac100 152-?-H3	8A	camelidae	phalange	1	1	cut camelid phalange	cut camelid phalange + cut marks	longitudinally fresh fracture + cut marks?	MacNeish et al. 1980, p. 314; Yataco Capcha, 2011, 2020
	8	Ac100 257-III-H3	S2A	mylodontidae	indeterminate	1	1	sloth rib deflesher	sloth rib deflesher	spiral fracture not necessarily done by humans	MacNeish, 1979; MacNeish, et al., 1980; Yataco Capcha, 2011, 2020
	9	Ac100 214-I-H2	S2B	indeterminate		1	1	not published, but found in UNMSM labelled as “cut split bone”	cut marks	trampling marks	Yataco Capcha, 2011, 2020
	10	Ac100-207-11-H1	S2C			1	1	not published, but found in UNMSM labelled as “polished bones of small animals “		manganese + post-depositional straight mark (trampling mark)	
	11	Ac100 153-2-H1	8B	indeterminate	diaphysis	1	1	not published, but found in UNMSM labelled as “polished bones of small animals “	cut marks	fresh longitudinal and helicoidal fractures + notch? + trampling (no cut marks)	
	12	Ac100 205-II-H1	S3A	mylodontidae	indeterminate	1	1	not published, but found in UNMSM labelled as “polished scratched slot”	cut marks + charred	fresh fracture + manganese (no cut marks)	MacNeish et al., 1980; Yataco Capcha, 2011, 2020
	13	Ac100 159-II-III	S3B		rib???	1	1			trampling marks + manganese	
	14	Ac100 258-IV-H4	8C	ungulate	indeterminate	1	1	fossil bone point	fossil bone point indicating defleshing	fossil bone point	MacNeish et al., 1980; Yataco Capcha, 2011, 2020
	15	Ac100 256-IV-H11	S3C	cervid	antler	1	1	Antler punch	antler punch	current observations can only confirm a spiral fracture and a pointed end	MacNeish 1979; MacNeish, et al., 1980; Yataco Capcha, 2011, 2020
	16	Ac100 346-III-1, S13E9	8D	camelidae	diaphysis	1	1	not published	-	longitudinally fresh fracture + notch?	-
	17	Ac100 II, S20E6	S3D	indeterminate	indeterminate	1	1	not published	-	spiral fracture not necessarily done by humans	-
hl	18	Ac100 327-V	S4A	rodent	scapula	1	1	according Yataco Capcha, from Area 6 (MacNeish, 1979)	no human intervention	no human intervention	MacNeish, 1979; Yataco Capcha, 2011, 2020
	19	Ac100 338-V-8	S4B	mylodontidae	phalange	1	1	according Yataco Capcha, from Area 4 (MacNeish, 1979)			
	20	Ac100 347-VI	S4C	rodent (phyllois?)	mandible	1	1				
	21	Ac100 153-III-H1	S5A	camelidae	distal radio	1	1				
	22	Ac100 276-III-H4	S5B	camelidae?	diaphysis?	1	1	not published			Yataco Capcha, 2011, 2020
23	Ac100 161-VIII-H4	S6	mylodontidae	rib	1	1		cut marks-defleshing	trampling		
i	24	Ac100 224-I-H7	S7A	mylodontidae (scelidotherium?)	vertebrae?	1	1	from activities in Area 2 or 3 where sloth and horse bones were associated with artefacts (killing and processing areas)	no human intervention	no human intervention	MacNeish, 1979; Yataco Capcha, 2011, 2020
	25	Ac100 259-II-4	S7B		rib	1	1	polished and cut-marked bone from activity Area 3			
	26	Ac100 347-VII	S7D*	indeterminate	1	1	from activities in Area 2 or 3 where sloth and horse bones were associated with artefacts (killing and processing areas)				
	27	Ac100 259-II-2	S7E	equidae	indeterminate	1	1				
il	28	Ac100 222-VI-6	S8A	indeterminate	indeterminate	1	1	not published	no human intervention + hearth stains	no human intervention + manganese	Yataco Capcha, 2011, 2020
	29	Ac100 222-VI-9	S8B			1	1				
	30	Ac100 269-III	S8C			3	1				
	31	Ac100 338-VII-2	S8D	equidae	indeterminate	9	1	associated with instruments			
	32	Ac100 340-VII-I	S8E	mylodontidae	phalange	1	1	associated with instruments from activity Area 2			
	33	Ac100 269-III-12	S8F	horse/camelidae	long bone	1	1				
34	Ac100 347-VIII	S8G	indeterminate	indeterminate	1	1	not published	Yataco Capcha, 2011, 2020			
j	35-39	Ac100 226-VIII-j	S9A	indeterminate	indeterminate	5	5	not published	5 fragments in a bag. no human intervention + hearth stains?	no human intervention + manganese	Yataco Capcha, 2011, 2020
k	40	Ac100 347-X-K	S9B	mylodontidae	mandible	2	1	not published	no human intervention + hearth stains	no human intervention + manganese	Yataco Capcha, 2011, 2020

* S7C Is not given in the table as it is a fragment of sediment **1** bones with probable human intervention (only in layer h)

Table 4. Summary of the main information of bones from layers h to k / *Résumé des principales informations des os des couches h à k.*

Results

Table 4 compares the different interpretations of the material from layers *h* to *k* resulting from the analyses performed by MacNeish, Yataco Capcha, and in this study. Layer *h* is the only one that presents bones showing human intervention. From the 17 specimens described that were exhumed from this layer, only eight, identified as bones of ungulates or indeterminate medium-size mammals, have possible traces of animal processing (figures 6-8). No megamammal bone presented anthropic marks (see Supplementary Information and table 4).

The main attributes of each bone are described below.

- #1. Ac100 204-5-15: This metapodium diaphysis (probably a Camelid or Cervid) presents two straight and parallel cut marks and borders with fresh fractures (figure 6A).
- #2. Ac100 276-VI-H7: This is an indeterminate mammal bone with fresh fractures and two sectors with probable cut marks (figure 6B).
- #4. Ac100 231-VII-H8: As with bone #2, this one also presents two sectors with probable cut marks and fresh fractures in all of the borders of the diaphysis (figure 7A).
- #5. Ac100 264-11-h: This is a probable polished point given its shape, the smoothed surface and the several sectors with thin, parallel marks (figure 7B).

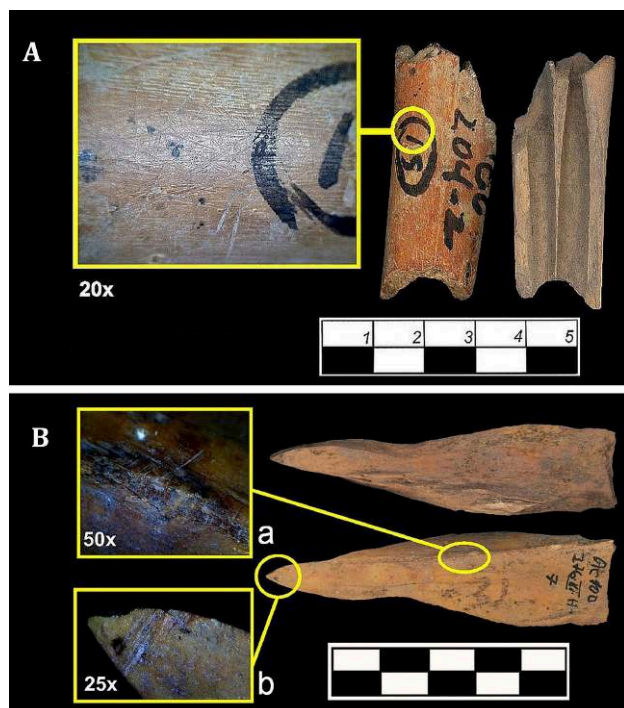


Figure 6. A: Ac100 204-5-15 diaphysis with cut marks and fresh fractures. B: Ac100 276-VI-H7 indeterminate bone with cut marks and fresh fractures / A : Ac100 204-5-15 diaphyse avec marques de coupe et fractures fraîches. B : Ac100 276-VI-H7 os indéterminé avec marques de coupe et fractures fraîches

- #7. Ac100 152-?-H3: This is a Camelid phalanx with longitudinal fresh fractures and probable parallel and short cut marks (figure 8A).
- #11. Ac100 153-2-H1: This indeterminate bone presents longitudinal and helicoidal fractures with a probable notch in the inner side (figure 8B).
- #14. Ac100 258-IV-H4: As seen for bone #5, this piece is a probable pointed bone. It has fresh and bevelled fractures with a triangular shape (figure 8C).
- #16. Ac100 346-III-1, S13E9: This is a Camelid diaphysis with longitudinal fresh fractures and a notch in the upper end (figure 8D).

The rest of the bones from *h* and from level *h1* to *k* do not present signs of any type of human intervention. The main surface modifications detected were manganese spots or staining and weathering and trampling marks. Bones #3 and #6 from level *h* have rodent gnawing (figure S1A-B). No carnivore intervention was identified.

Concerning the general state of preservation, there is a clear difference between the bone remains from *h-h1* and the rest of the layers. Those from *i* to *k* start to be

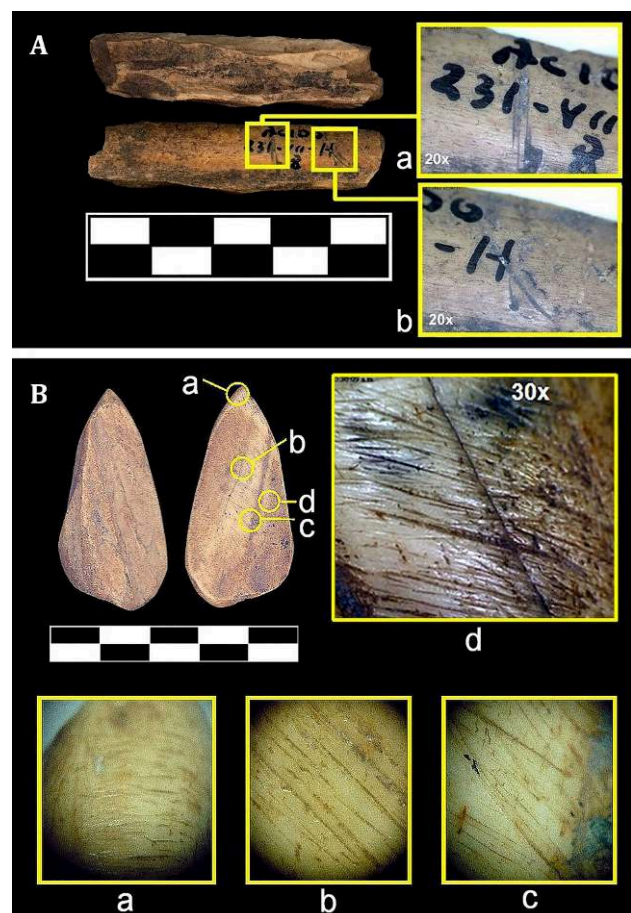
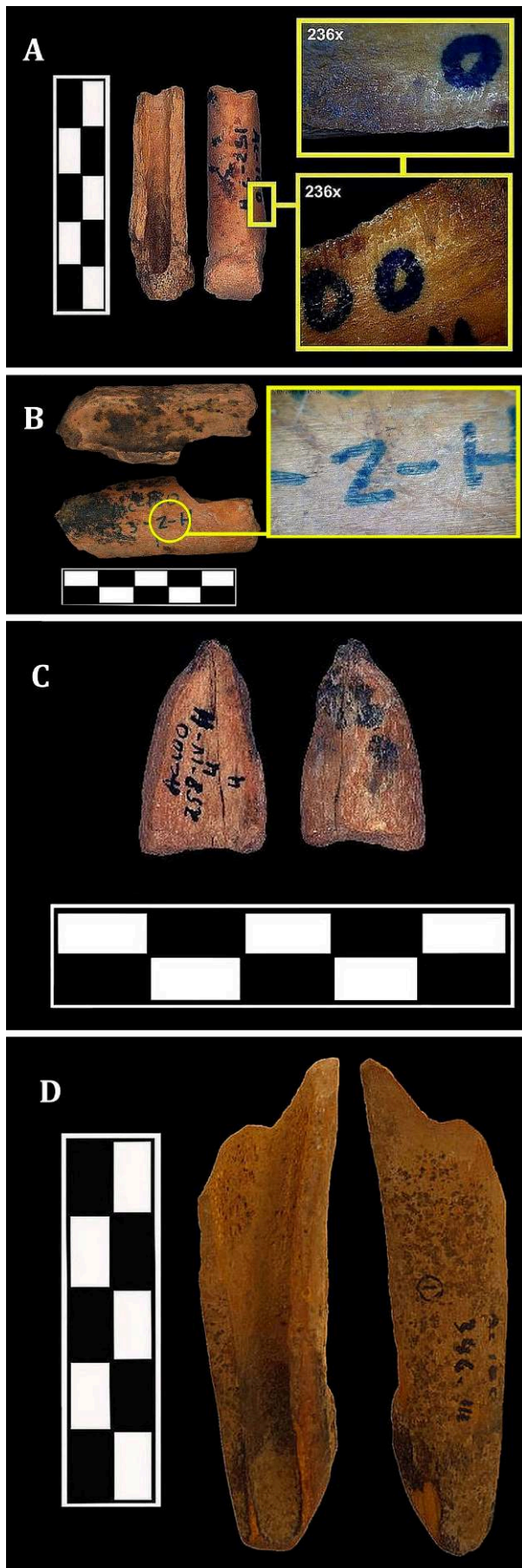


Figure 7. A: Ac100 231-VII-H8 indeterminate bone with cut marks and a fresh fracture. B: Ac100 264-11-h fossil bone point / A : Ac100 231-VII-H8 os indéterminé avec des marques de découpe et une fracture fraîche. B : Ac100 264-11-h pointe osseuse fossile



increasingly covered with hard sediment, and more manganese staining is observed. In some cases, there are small osseous pieces encrusted in compacted sediment, as in layer *i* (bone #27, figure S7E) or *j* (bones #35-39, figure S9A). Elsewhere, the bones are embedded in sediment, such as the material from *il* (bones #28, 30-34, figure S8A and figures S8C-G) and *k* (bone #40, figure S9B), although in a few cases, the cortical surface is exposed. They are generally covered with manganese, cracked or have surfaces that are not well preserved. In contrast, the specimens from *h* and *h1* (bones #1-23) are well preserved and most of the cortical surfaces are free of sediment.

Discussion

This study found that only two bones might be classified as tools, although MacNeish (e.g. MacNeish, 1979; MacNeish et al., 1980) interpreted some specimens from layer *h* as tools: “fossil bone point”, “deflesher”, and “antler punch”; additionally, one “humanly fractured bone” of a Camelid (table 4). In layers *h1* to *k*, no evidence of human manipulation has been found, except for bone #25 Ac100 259-II-4, on which MacNeish (1979:27) identified “polish” and “cut marks” in a Mylodontidae – probably *Scelidotherium* – rib (table 4). In the initial studies, the North American archaeologist presented these vestiges as belonging to “activity areas”, sometimes associated with “artefacts” or “tools”, especially those from *i* and *il* (MacNeish, 1979). In the review presented here, we focused mostly on the fresh longitudinal and helical fractures and cut marks as defined in table 3. Both features are generally used to define bones that were exploited and manipulated by humans, generally to extract the marrow (Lyman, 1994; Fernández-Jalvo and Andrews, 2016; Chichkoyan, 2019). Consequently, considering the taphonomic review presented in the previous section, we conclude that anthropic intervention is only present in the bone remains exhumed in stratum *h* (table 4). To discuss the different interpretations, we differentiate bones with anthropic and non-anthropic marks by their layers.

Layer h, anthropic: In the review presented here, we focused on the fresh longitudinal and helical fractures visible in these bone remains. Both features reveal that they resulted from human exploitation and manipulation to extract the marrow (Lyman, 1994; Fernández-Jalvo and Andrews, 2016; Chichkoyan, 2019).

Figure 8. A: Ac100 152-?-H3 camelid phalanx with a longitudinally fresh fracture. B: Ac100 153-2-H1 indeterminate bone with fresh fractures. C: Ac100 258-IV-H4 possible fossil pointed piece. D: Ac100 346-III-1, S13E9 diaphysis of a camelid with fresh fracture / A : Ac100 152-?-H3 phalange de camélidés avec une fracture fraîche longitudinale. B : Ac100 153-2-H1 os indéterminé avec des fractures fraîches. C : Ac100 258-IV-H4 possible pièce pointue fossile. D : Ac100 346-III-1, S13E9 diaphyse d'un camélidé avec fracture fraîche

Two specimens, #1-2, found in the UNMSM were classified by MacNeish as “cut split bone”, but not published. Furthermore, Yataco Capcha (2011) identified cut marks not previously recorded by MacNeish, which are also confirmed in the current revision. Specimen #1 (figure 6A) could have been broken for marrow extraction, while #2 (figure 6B) might have been intentionally fashioned by grinding, especially considering the marks over the pointed section of the bone (Buc and Loponte, 2007; Backwell and d’Errico, 2014; Nami, several pers. obs.). Nevertheless, a better review and the use of advanced technologies such as a Scanning Electron Microscope (SEM) would confirm this interpretation. The presence of cut marks as well as fresh fractures would at least indicate probable human manipulation.

Another unpublished specimen is #4, is labelled on the bag containing it as a “small animal polished bone” (figure 7A). Additionally, in his detailed revision, Yataco Capcha (2020) identified cut marks. This study agrees with this observation, but could not confirm polishing. The presence of longitudinal fractures would also indicate marrow extraction (Lyman, 1994; Fernández-Jalvo and Andrews, 2016; Chichkoyan, 2019).

Bone #5 (figure 7B) was published and interpreted as a “bone point” (MacNeish, 1979). As seen in table 4, and in agreement with the review undertaken by one of us (Yataco Capcha, 2020), the fashioned triangular shape and the ground and polished traces over the surface would confirm the original interpretation that it is a bone implement, but of unknown function.

Bone #7 (figure 8A) was originally presented as a fragmented phalange (MacNeish, 1979; MacNeish et al., 1980), a classification which has been further corroborated (Yataco Capcha, 2020). This author also observed possible cut marks on one of the borders that, in this review, cannot be confirmed at all. However, the fracture’s shape with a notch in the proximal end would support the initial determination, and as in other cases addressed in this re-examination, the fracture would indicate marrow extraction.

Found in the same bag as bone #4, #11 (figure 8B) was never published, but it was originally classified in its container as “polished bones of small animals”. On its surface, this specimen shows traces identified as cut marks (Yataco Capcha, 2020). However, their morphology indicates that they are the result of trampling (Lyman, 1994; Domínguez-Rodrigo et al., 2009). The original interpretation of polishing can be attributed to the effect that trampling marks can produce on bones, mainly when observed with magnification.

Like the osseous piece #5, and due to its triangular shape, #14 (figure 8C) was initially described as a “point” (MacNeish, 1979; MacNeish et al., 1980). It has also been suggested that it could indicate defleshing (Yataco Capcha, 2020). According to the observations made for this review, the freshly bevelled borders could also suggest that it is a pointed piece that, like piece #2, needs a more in-depth review and the use of advanced technologies such as SEM to examine its shaping and possible function.

Lastly, #16 is longitudinally fractured, and the notch seen in its upper end might indicate the place where the blow struck (figure 8D) (Chichkoyan, 2019). Consequently, this review identified four bones with cut marks and fresh fractures (#1-2, 4, 7), two with fresh fractures only (#11, 16), and two possible fossil implements (#5), one of which needs confirmation (#14). From the remains of these eight bones, three were previously published by MacNeish (two as “fossil points” and one as a “fragmented phalange”, #5, 7, 14), while five are recent finds (#1-2, 4, 11, 16). According to Yataco Capcha (2020), most of them show cut marks. Only the osseous pieces #5, 7 and 14 maintain MacNeish’s determination, which also done by Yataco Capcha (2020). The remaining published and unpublished pieces mostly coincide with the Yataco Capcha (2020) interpretations, but here we additionally highlight the fractures as a clear feature to identify human exploitation. This evidence was mostly recorded on bone remains of extant fauna, indicating exploitation of indeterminate animals and ungulates, mainly Artiodactyls, Cervidae and Camelidae. In most cases, we found evidence of meat or marrow exploitation. From the extinct species, none of the osseous pieces of Mylodontidae show traces of human manipulation, except for one Perisodactyl bone (#5), which, according to MacNeish et al. (1980), was shaped to make a “point”, or in our opinion, a pointed tool of undetermined function. It is worth mentioning that, as the material for its manufacture might have been collected from a palaeontological assemblage, an instrument made from a fossil bone does not guarantee that the animal was eaten. Therefore, it cannot be confirmed that extinct fauna represented an important food resource for the Pikimachay hunter-gatherers.

Layer h, non-anthropic: The other nine bone remains (#3, 6, 8-10, 12-13, 15, 17) do not show any evidence of human manipulation. From this sample, only two were previously described. Bone #8 was reported as a “sloth rib deflesher” (figure S2A), and #15 (figure S3C), a cast antler, was interpreted as a “punch” (MacNeish, 1979; MacNeish et al., 1980). Regarding the former, Yataco Capcha (2020) maintained the initial interpretations. However, the current observations on both specimens have recognised a spiral fracture along the contour of bone #8, giving it a triangular shape, but because more shaping signs that could identify it as a “deflesher” are lacking, there is no guarantee of intentional modification (Lyman, 1994; Fernández-Jalvo and Andrews, 2016). Specimen #15 is a cast, so that the lack of original features cannot confirm whether this piece was a tool. Concerning the rest of the unpublished bones (#3, 6-7) and those found labelled in the museums (#9-10, 12-13), the current analyses do not sustain their historical classifications or the interpretations of the second review.

Bone #3 (figure S1A) was described as a “charred” and “cut-marked” bone due to its black appearance (Yataco Capcha, 2011:270, figure 12). However, it is now known that this sort of stain could be due to chemical deposition of manganese on the surfaces, a relatively common occurrence

in archaeological and palaeontological bone remains, which is the most likely in this case (López-González et al., 2006; Marín Arroyo et al., 2008; Fernández-Jalvo and Andrews, 2016). Moreover, the cortical surface does not present cracking or flaking marks that might have been produced by fire and/or weathering (Hanson and Cain, 2007; Fernández-Jalvo and Andrews, 2016). Given that the traces observed are broad and flat-bottomed, they are probably the marks of gnawing by a rodent (Fernández-Jalvo and Andrews, 2016). This feature was also observed on bone #6 (figure S1B) and also interpreted as “cut marks” indicating defleshing (Yataco Capcha, 2011, 2020).

Specimens #9-10 (figure S2B; S2C), were historically classified as “cut split bone” and “polished bones of small animals”. Yataco Capcha (2020) suggested that cut marks were also present. However, the current taphonomic analyses reinterpreted these traces as a result of trampling.

Bones #12-13 (figure S3A, S3B) were also originally classified as “polished scratched slots” and, like #3, later reinterpreted as charred and cut-marked. In these cases, anthropic action could not be detected either. Although #12 may have a fresh fracture on one face, due to its type this cannot be ascribed to human action with certainty. Consequently, the hypothetical “cut marks” are therefore more likely to be related to the natural disposition of Mylodontidae bone tissue (Straehl et al., 2013). In bone #13, the previously identified “cut marks” might be due to trampling. We support this interpretation given the difference in colouration compared to the surrounding colour of the magnified area of the specimen. Bone #17 (figure S3D) was not previously published and the current observations cannot link its spiral fractures to human action with certainty, as this type of modification can also be ascribed to non-human factors (Lyman, 1994).

Layers h1 to k, non-anthropic: The bone remains from layers *h1* to *k* do not present any evidence of anthropic action or intentional exposure to fire. Six specimens from layer *h1* were described (figures S4-S6). Three of them (#18-20) were assumed to be associated with “activity areas” (MacNeish, 1979). However, further reviews such as those carried out by Yataco Capcha (2020) and for this paper did not find evidence of human manipulation. The initial interpretation (MacNeish, 1979) therefore cannot be sustained. Three further osseous pieces (#21-23) found in MAA-UNMSM had not been previously published. Bone #23 is a Mylodontidae rib that presented four areas with presumed cut marks (Yataco Capcha, 2020); however, in the light of the current examination and due to their location on the surface and random orientation, we now interpret these traces as trampling marks (Lyman, 1994; Domínguez-Rodrigo et al., 2009).

The sample from layer *i* (figure S7) was assumed to have come from areas where sloths and horses were slaughtered and processed (MacNeish, 1979). As the further observations offered by Yataco Capcha (2020) and this study failed to find evidence of any kind of human intervention, we conclude that this association was not intentional.

Consequently, no assessment of human exploitation can be made. In the case of the bone remains from *il* (figure S8), three (#31-33), were found in association with tools, according to MacNeish (1979). The other four (#28-30, 34) had never been published before. Despite the fact that the bones from this stratum are covered with sediments, some black spots were interpreted as “hearth stains” (Yataco Capcha, 2020). However, as stated before, these blackish dots mostly result from manganese action after the burial of osseous remains.

The five bones from layer *j* (figure S9A) were found by Yataco Capcha in RSPIA, and those from *k* (figure S9B) were identified as probable mandible fragments of Mylodontidae. In both cases, even though no evidence of human exploitation was found, manganese stains were also interpreted as hearth spots.

Finally, as seen above, Late Pleistocene fossils were exhumed in the Pikimachay cave as well as extant fauna bones in association with the stone artefacts. Our taphonomic observations indicate that several traces on bones from *h* were produced by human activity. This concurs with the lithic analysis that led us to conclude that they were made by foragers carrying raw materials for making tools into the cave (Yataco Capcha and Nami, 2022). More importantly, the two types of finds come from discrete sectors of the excavation (MacNeish, 1979, MacNeish et al., 1981:40-56; 1983:136-153, figures 5-3/12), which substantiates the human origin of several traces in the bone sample.

Considerations from the review of the Pikimachay Legacy Collection regarding the overall unresolved issue of megamammal extinction and the first human dispersal across South America

Different opinions have been expressed about the status of extinct fauna in the consumption patterns of the earliest inhabitants of this subcontinent, and particularly at Pikimachay (e.g. Lynch, 1974, 1983, 1990, 1992). As seen in the previous sections, various extinct fauna bones at Pikimachay come from strata *h-h1*, which contain human-made artefacts. However, the small sample analysed in this taphonomic study does not confirm their exploitation by humans.

In the Peruvian archaeological record, associations of extinct fauna with anthropic remains are extremely rare and raise many doubts (e.g. Rick, 1988; Lynch, 1990, 1992; Aldenderfer, 1999), in contrast to a significant number of fossil bones of extinct fauna in South America, on which various traces and fractures are evidence of anthropic modification (e.g. Chichkoyan et al., 2017; Chichkoyan, 2019; Politis et al., 2019; Carlini et al. 2022). In Peru, most lowland sites belonging to the Late Pleistocene and its transition with the Holocene show evidence of human exploitation of marine and other resources (Aldenderfer, 1999; De France et al., 2001; Dillehay, 2011; Dillehay et al., 2017; Sutter, 2021). As at Pikimachay in the highlands, the faunal assemblages found at Huarco cave (Cardich, 1973) included sloths and horses, as well as remains related to

extant deer and various camelids. This is also true for the lower levels of the Jaywamachay rock-shelter, where the bones of extinct horses, deer and possibly camelids have been recovered (MacNeish, 1971:43-44; MacNeish et al., 1981:65-71; Lynch, 1983:116; Yataco Capcha and Nami, 2016) in layers containing Fell points and well-made bone tools dated at ~9.9-10.3 uncalibrated kybp (Yataco Capcha and Nami, 2016).

In South America, the dated record of Late Pleistocene fossil bones suggests that, in certain regions, the extinction process occurred in two different phases separated by ~15/20 kyr. The first event happened at ~30.0 kybp, and the second at ~10.0 kybp (Lopes et al., 2020). In the latter, the radiocarbon ages indicate that several taxa were coeval with early human occupations (e.g. Núñez et al., 1994; Salemmé and Miotti, 2008; Villavicencio et al., 2016; Ubilla et al., 2016, 2018; Nami, 2019; Politis et al., 2019; Nami et al., 2020; among others). The same may be considered for the species reported in this paper, as several taxa found in the lower levels of this cave represent species that were affected by the worldwide mass extinction in the Late Pleistocene (Barnosky and Lindsey, 2010; Barnosky et al., 2004, 2011). As previously mentioned, the fallen roof blocks that sealed off the lower strata date from the Late Pleistocene/Early Holocene.

Pikimachay has also been much discussed for its chronology, which suggests that it is one of the earliest sites of human occupation in the New World. In the process of human dispersal across the globe, the Aspermericas were the last continents to be colonised (Meltzer, 2013). The palaeo-American population and its spread across the continent has always been a field of archaeological interest. However, for several reasons, it is one of the most controversial as regards the occurrence of events and the reliability of the evidence relating to a particular time in the process (Dillehay, 2009; Meltzer, 2013). Although caution is needed with certain approaches to the subject (Dillehay, 2019), various lines of scientific research have shown that the arrival of humans in the New World occurred during the Late Pleistocene, in a period that is still in debate (Dillehay, 2009; Meltzer 2009, 2013; Gruhn, 2020) but probably during several colonisation events (Goebel et al., 2008) and as a process driving the spread, occupation and growth of a population (Lanata et al., 2008; Waguespack, 2012). Despite this, it is notable that several probably reliable sites in North America are yielding records that predate Clovis points (Waters et al., 2011, 2018; Davis et al., 2019, among others). Uncalibrated radiocarbon dates reveal that Clovis technology spanned ~11.2-10.8 kybp (Waters and Stafford, 2007), although Prasciunas and Surovell (2015) propose a wider chronology. Until recently, it was thought that the Clovis point was the oldest example of bifacial technology in North America, although recent finds of earlier bifacial tools at different sites bring this into doubt (e.g. Waters et al., 2011, 2018; Halligan et al., 2016). Nevertheless, the Clovis point

is still considered to be the oldest example of fluted point technology in the New World. In South America, various sites predate, by a few millennia, the use of “fishtail” or Fell points, a widespread socio-cultural phenomenon that occurred during the last millennium of the Pleistocene (Dillehay, 2009, 2011; Capriles et al. 2016; Dillehay et al., 2019; 2021; Nami, 2021). An overlap with the last centuries of Clovis technology, coeval with Folsom and other palaeo-American manifestations, is possible (Frison and Stanford, 1982; Bonnichsen et al., 1987; Kuntz et al., 2003; Erlandson, 2013; Erlandson and Braje, 2007, 2015; among many others); generally, radiocarbon assays suggest that Fell points were used within a time frame spanning ~11.0-10.0 kybp (Núñez et al., 1994; Nami, 2007, 2017, 2019, 2021; Jackson et al., 2007; Maggard and Dillehay, 2011; Maggard, 2015; Waters et al., 2015; Nami and Stanford, 2016; Yataco Capcha and Nami, 2016). In this regard, and considering that new research based on updated methods and approaches is necessary, Taima-Taima in Venezuela has yielded distinctive El Jobo armature tips associated with fossil bones, with dates between ~13.0 and 14.2 kybp (Bryan et al., 1978; Ochsenius and Gruhn, 1979, Carlini et al. 2022), also observed in other sites in this Caribbean country (Jaimes, 1999, 2003). A growing number of finds in recent decades suggests that foragers lived at a similar time in the Central and Southern Andes (Lavallée, 1995; Dillehay, 2014; Rademaker et al., 2014; Jodry and Santoro, 2017; Carlini et al., 2022). In northern Peru, excavations at Huaca Prieta have revealed a simple stone technology and other remains manipulated by humans, with radiocarbon dates ranging from ~12.4 to 13.0 kybp (Dillehay et al., 2012a, 2012b, 2017:table 1). Jobo-like points and one armature tip with a contracting stem have been found in South Central Chile at the Monte Verde locality. Most radiocarbon assays for these show a range of ~12.0-13.2 kybp, but some dates are as early as ~19.0 kybp (Dillehay et al., 2017:table 1, 2019). The nearby Monte Verde, Pilauco and Los Notros sites have yielded a similar simple, trimmed and expedient technology (Pino and Astorga, 2020), with a chronology ranging from ~13.5 to 14.6 kybp (Navarro-Harris et al., 2019, 2020). In the Argentinian Pampas, Arroyo Seco 2 provided a record dated between ~11.2 and 12.2 kybp (Politis et al., 2016). Several authors (e.g. Gruhn, 2020) have considered that these sites provide useful material for discussions on the earliest arrival of humans in South America (*cf.* Dillehay et al., 2021; Politis and Prates, 2021). Therefore, based on our review of the lithic materials and bone remains from the Late Pleistocene levels in the Pikimachay cave, we can assume that the newly compiled information from this study indeed justifies the hypothesis that the bones and lithic materials from layer *h* were produced during the Late Pleistocene between the rockfalls that occurred at ~9.0/10.0 and ~14.1 kybp, the latter being the radiocarbon date considered for this layer, given also that the stone artefacts from *h1* have a similar morphology and age.

Conclusions

To summarise, our taphonomic analysis of a sample of bones from the Late Pleistocene levels of Pikimachay Cave suggests that eight specimens from layer *h* show signs of modification by humans. These are the result of cutting and bone breakage for different purposes, but mainly for marrow extraction. Furthermore, two fragments were identified as probable well-fashioned pieces, probably tools. The anthropic bone modifications agree with the presence in *h* of lithic remains that were undoubtedly flaked by humans, but also in *h/l* possibly belonging to the Late Pleistocene at $\sim \geq 9.0/10.0-14.0/14.7$ kybp. Similarly to the results obtained from the re-examination of the stone vestiges (Yataco Capcha and Nami, 2022), the bone remains from layers *i* to *k* do not show any signs of anthropic action.

Therefore, if the reported chronology and its associations with the anthropic remains are true, the Pikimachay cave might still be relevant to an assessment of the complex and nagging issue of human colonisation of the Americas (Waguespack, 2012; Gruhn, 2020; Dillehay et al., 2021). This is the reason why Pikimachay cave could still be a site that may have witnessed the presence of hunter-gatherer groups who were living in the Andean Cordillera at the time of the colonisation process of western South America (Dillehay et al., 2017). More research is essential to further the debate about the true role of Pikimachay Cave in the initial peopling of the Southern Andes.

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Supplementary information

The supplementary information is available in .docx from the BMSAP website (<https://journals.openedition.org/bmsap/12069?file=1>).

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