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RESEARCH ARTICLE

Tolas, fish traps and radiocarbon dating: The spatial characterization of the Manteño site of Ligüiqui in Ecuador and its contextualization within the chronological framework of other pre-Hispanic cultures

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Abstract
Ecuador is a key area in South America when it comes to understanding the economic, social and archaeological aspects of pre-Hispanic cultures in the northwestern region of the Andes. Among the most complex societies to have inhabited this territory is the so-called Manteño culture (AD ~800–1530), which spanned across most of Ecuador's central Pacific coast. Ongoing research at the site of Ligüiqui (Manta, Manabí) has enabled us to obtain a more complete overview of the chronological sequence of the Manteño period as well as contributing further data on the advanced stage of social development reached during the period; characterized by the hierarchical arrangement of sites, the use of extensive settlement models, and semi-circular stone fish traps (*corrales*). In order to understand the role played by this coastal site in the complex Manteño culture, a detailed radiocarbon study was performed in the sequence of the Ligüiqui site. In addition, using a detailed review of available Manteño settlement radiocarbon data (13 sites and 64 dates), we established a chronostratigraphic framework for the culture. Our data indicate that Ligüiqui probably acted as a supply centre for marine-origin products from the twelfth century onwards with activity peaking during the Late Manteño period. A multisite comparison using Bayesian modeling indicates an early onset of the Manteño culture in Ligüiqui around AD 700, and a general demise in most of the sites AD ~1500 or slightly before. This culture finally collapsed before AD ~1600 during the early Spanish colonial period. Only one site, La Libertad, shows potential evidence of having remained a Manteño settlement after that date.

1. Introduction

Pioneering studies on early coastal civilizations in Ecuador were conducted in the 1950s by Ecuadorian archaeologist Estrada (1916–1961) and North American anthropologists Meggers (1921–2012) and Evans (1920–1981). They were some of the first to integrate radiocarbon dating in Latin American countries—the Valdivia period 4400–1450 BC (Estrada et al. 1962) and the Chorrera period 1300–300 BC (Evans and Meggers 1957)—in order to unveil the archaeological characteristics of pre-Hispanic settlements. Using the chronological estimates proposed by Meggers and Evans (1965), Estrada focused his research on the stratigraphic description of various archaeological assemblages located along the central and southern coast of Ecuador. In 1956, he published *Valdivia, un sitio Arqueológico Formativo en la Provincia del Guayas, Ecuador* (Valdivia, an Archaeological Site from the Formative Period in the

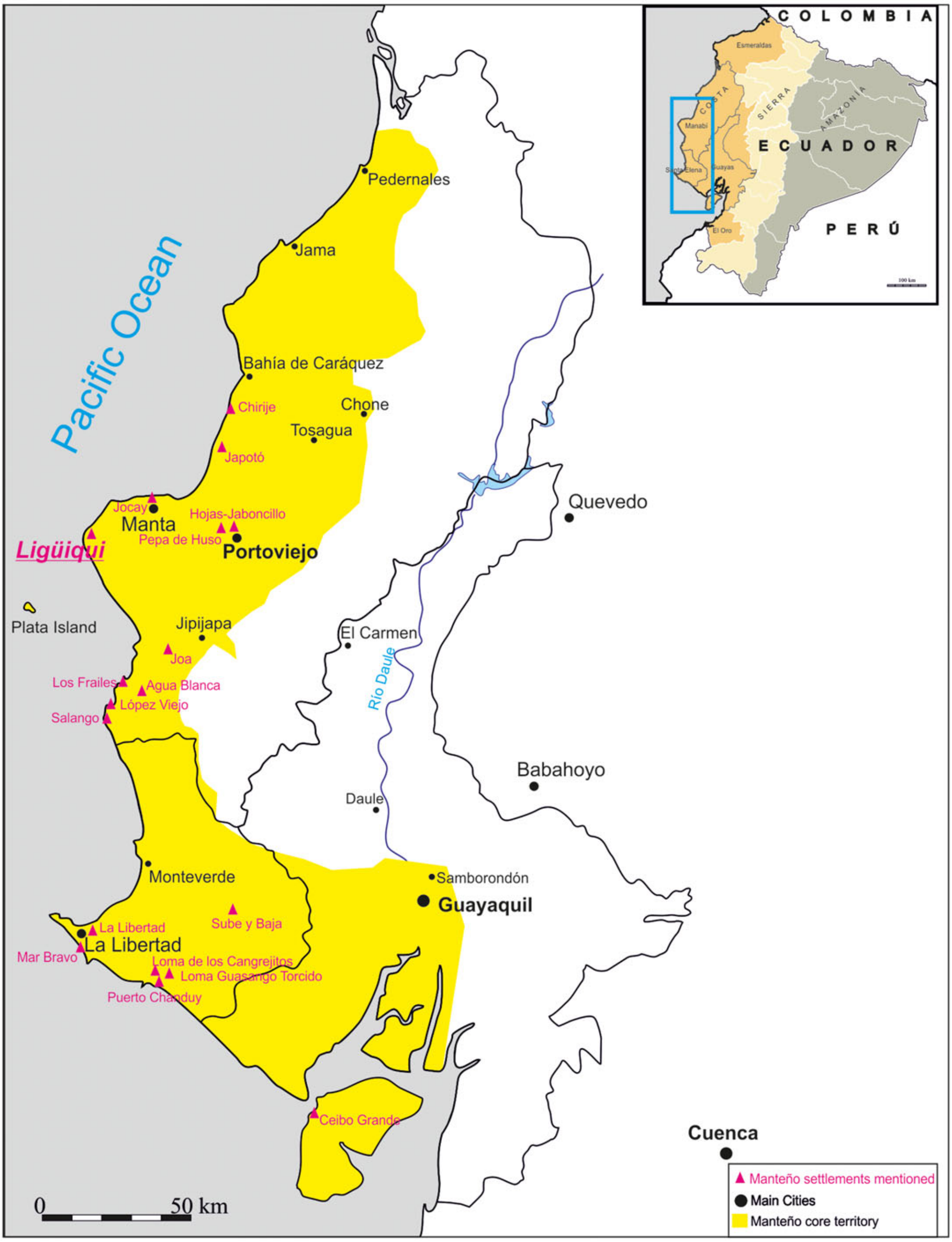

Figure 1. *The geographical scope of the Manteño settlements described in this paper.*

Province of Guayas, Ecuador) (Estrada 1956). In this brief report, he confirmed that Valdivia was one of the oldest sites to have produced pottery in northwest South America through the analysis of ^{14}C samples (Delgado-Espinoza 2018). Throughout his career, Estrada performed more than 1400 archaeological surveys (Estrada 1957a, b, 1962) the majority of which were based in the provinces of Manabí, Guayas and Santa Elena (Figure 1B). However, his work did not only analyze early periods and

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cultures, he also conducted a chronological analysis that extended the culture's timeline to the period immediately before the arrival of Europeans.

One of the most geographically widespread civilizations was the so-called "Manteño" culture. Remains of the civilization can be observed especially in the centre-south of the province of Manabí (Figure 1). Based on his own and previous studies (Jijón 1951), Estrada proposed a preliminary chronology for the Manteño period from AD 600 to AD 1530. Following his research, further studies have unveiled long-term Manteño occupancy throughout the central coast of Ecuador and highlighted a fundamental distinction between three possible ethnic groups: the Southern Manteños—also referred to as the Huancavilca—the Northern Manteños and the pre-Hispanic inhabitants of Puna Island and the Gulf of Guayaquil. Archaeological research has continued to embrace this ethnic differentiation which has been primarily distinguished by the construction techniques and burial patterns of each group (Lunniss 2020).

In the 1970s, research performed in the Manabí province was newly published due to significant advances in Ecuadorian archaeology and funding for new research projects that involved cooperation with international researchers. What is, undoubtedly, most remarkable about this period of research is the launch/initiation of archaeological excavations in the southern area of the province of Manabí, whose foremost objective was to delimit the spatial extent of the Çalangome chiefdom (*Señorío de Çalangome*), the first Manteño territory to have been described in Spanish colonial sources (AD 1526) (Bravo-Guerreira 1985; Szászdi 1978). Over the course of the following two decades, several archaeological surveys that covered the Buenavista and Ayampe valleys were conducted (Damp 1984; Graber 2020), in addition to other excavations spanning across the sites of Salango, Agua Blanca (McEwan 2003), Los Frailes (Mester 1990) and López Viejo (Currie 1995) (Figure 1). Archaeological fieldwork from the 1980s and the 1990s came to some interesting conclusions about the Manteño culture as well as opening up relevant avenues of research. First, the central role that chiefdoms may have played in the Manteño political system, which has remained to this day a major topic of debate in Ecuadorian archaeology. Second, the possibility of chiefdoms evolving into diverse state forms throughout the Ecuadorian Integration Period (AD 400–1532) (Masucci 2008), especially between AD 900–1100. Nevertheless, the increase in social complexity and the construction of *tolas* (residential and/or ceremonial buildings on raised earth platforms or mounds) appears to be a heterogeneous process that started around 400 BC, for example in the Esmeraldas territory, where the Tolita culture was first identified (400 BC to AD 500) but may have originated earlier in another area (e.g., the Guangala period 500 BC to AD 550 in the provinces of Manabí and Santa Elena).

Coastal resources, in particular the trade of Spondylus shells, seems to have played a crucial role in the transformation of Manteño coastal communities into chiefdoms arranged into a de facto state system (Marcos 1986, 2005). One of the Manteño sites with a particular connection to coastal activities is Ligüiqui. The presence of vast, complex fish traps, arranged into a system of platforms known as *corrales* make this a singular site in Latin-American Pacific archaeology. These *corrales* extended along the coastline over an area of 4.5 km as interconnected, semi-circular constructions built using basalt rocks (Figures 2 and 3). Some of the fish traps were located as much as 100 meters out to sea. Taking into consideration this distance from the coast, we can infer that fishing may have been carried out from rafts, using nets or harpoons. However, the relationship between this fishing area and the Ligüiqui site is still under study.

Although significant progress has been made in recent years towards a more complete picture of radiocarbon chronologies in large parts of the Andes; e.g., recent publications by Manon et al. (2023) regarding the period before 2000 BC, and Pagán-Jiménez et al. (2021), there are no similar comprehensive studies for the coastal region of Ecuador except for a few occasional contributions that study the era prior to the Integration Period (i.e., before AD ~500) (Tabarev et al. 2016). Therefore, we selected the Ligüiqui coastal site to improve our knowledge of the temporal and spatial heterogeneity of the pre-Hispanic Manteño culture and the role that coastal resources might have played in its socioeconomic framework. By using extensive radiocarbon dating and reviewing archaeological data, we aim to add new temporal indicators to the proposed chronological Manteño sequences. Dates and

Figure 2. *Areas of archaeological research at the Ligüiqui site.*

Figure 3. *Ligüiqui. Fishing structures.*

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results obtained at Ligüiqui have been compared with reviewed radiocarbon dates from other Manteño sites. In the comparative analysis of ^{14}C dates, we have reflected on certain social changes that we believe to have taken place over time in the Manteño culture. As a result, this study aims to assess and revise previous chronologies attributed to the Manteño period of coastal Ecuador, given that most were primarily based on radiocarbon analyses of charcoal remains, which, potentially, could be older (inbuilt age) than the context where the fire events actually occurred (Gavin 2001).

1.1. Previous and ongoing research at the Ligüiqui site

In 2012, locals attested to the existence of valuable archaeological finds at Cape San Lorenzo and the small fishing area of Santa Marianita. Owing to this, Ecuador's National Cultural Heritage Institute (INPC) funded a series of archaeological surveys that covered both sites. Headed by archaeologist Ortiz-Aguilú, the research focused on the small village of Ligüiqui situated 20 km southwest of the city of Manta (Figure 1).

The initial size of the archaeological area at Ligüiqui was estimated to be 2 km^2. Moreover, the age of the settlement was dated somewhere between the Middle Formative Period (2800–1600 BC) and the early years of the Late Formative Period (1600–500 BC) (Ortiz-Aguilú 2012b, 8). The chronology of the site might even have extended to the Late Manteño period, presumably to the fourteenth and the fifteenth century AD, or even to the earliest colonial occupation period (Ortiz-Aguilú 2012b, 8). It was revealed that more than ten *tolas* from the site contained a wide range of sculptural and ceramic materials. Following these finds, in a paper published in 2019, Ortiz-Aguilú and his team discussed the characterization of Ligüiqui and several of the fish traps found at the site that might have been intrinsically related to the settlement as an immediate productive space. Research focused on the central space of Las Chácaras area and the maritime zone of Punta Cangrejo, where a charcoal sample provided a ^{14}C age of 1390 ± 70 BP or AD 641–766 (1σ), thus corroborating the existence of an early Manteño period (Favier-Dubois et al. 2019).

Although written sources dating to the colonial era have proven rather imprecise, the most plausible hypothesis is that Ligüiqui was originally known as Levique, which appears in the document *Descripción anónima de Guayaquil de 1605* (Anonymous Description of Guayaquil from AD 1605) where it is described as a Manteño settlement (Ponce Leyva 1994). According to this source, the chronological sequence of Ligüiqui would have extended to the seventeenth century when it was populated by only thirty-five inhabitants and on the verge of disappearing.

Archaeological surveys and excavations conducted since 2018 by the Alcala University´s team and INPC (Ecuador) have documented and confirmed that remains of constructions in Ligüiqui had been built on mounds from 20 to 60 meters above the level of the Pacific Ocean (Olmo-Enciso and Castro-Priego 2019). A recent reconnaissance shows the site to extend parallel to the coast over an area of 1500 hectares surrounded by tropical dry forests. Within this spatial analysis, the territory studied was ascertained to have been arranged in various settlements that were separated by ravines through which seasonal streams have continued to flow to the present day. Similar to other Manteño sites discovered in the Manabí province, for instance Cerro de Hojas-Jaboncillo (Marcos et al. 2012), Ligüiqui was plateau-structured, with settlements founded on uplands delimited by their own slopes.

As previously mentioned, one of the elements that makes the Ligüiqui site unique are the *corrales*, the complex, semi-circular fish traps built using basalt rocks (Figures 2 and 3), which have a maximum diameter of 141 meters. Although the tide covers the traps during the day, numerous interconnected structures have been observed that extend farther out to sea, manifesting a particularly complex system with various extraction levels that is still used to this day. Therefore, fishing, primarily for small species, together with shellfish harvesting seems to have been the dominant activity in the direct surroundings of the shoreline.

Since 2018, archaeologists have mainly focused their efforts on three areas of the site. First, a series of excavations were conducted in the areas of Las Chácaras and Los Charcos (Figure 2). Second, intensive field surveys were performed along the coastline stretching from Ligüiqui to Santa Marianita. A 3D survey of the traps in Punta Cangrejo and Santa Marianita, conducted in 2018, produced a preliminary evaluation of the materials used in their construction and the different fishing strategies employed (Figure 3). Third, non-intrusive magnetometer surveys were used to assess the northern area of the site (Figure 2). All three endeavours gave rise to a proposal of the first stratigraphic sequence for the Ligüiqui site, which provides evidence not only of a period of Manteño occupation, but also to earlier settlement periods.

3. Methodology

In this study of Ligüiqui, in addition to a radiocarbon sample analyzed in 2016 (Favier-Dubois et al. 2019), a further twenty-one unpublished dates are included (Appendix 1). However, only five, including the one taken from Favier-Dubois et al. (2019), correspond to charcoal/charred remains. The samples belong to the same stratigraphic context, Las Chácaras, but were obtained from three different sections. Almost all the samples were recovered in Chácara I-Sector 1 using open area excavation (Barker 1993; Harris 1979), while some came from existing trenches and ditches at the site (Chácara I-Sector 2 and Lower Chácara) (Figures 4, 5, 6, 7, 8). The latter were analyzed after re-excavation and profiling. Chácara I-Sector 2 is stratigraphically located below Chácara I-Sector 1 and Lower Chácara, which are thought to belong to the Manteño culture (Lunnis 2020).

The potential datable material found in the archaeological outcrops was scarce and we selected the most suitable remains (fish bones, shells, charcoal and organic terrestrial sediment) from well-preserved and consistent archaeological levels. A few samples did not fully meet the criteria for the study objectives but were the best materials available to date the site. The organic sediments came from various archaeological layers at ~80 m asl with no marine contribution. Shells were identified (Appendix 1a) while deposit-feeding gastropods were avoided. Charcoal dating is usually challenging given the potential inbuilt age of old wood, especially from long-living tree species, and the possible differences between the ^{14}C derived age of charcoal and the time-since-fire. Although these issues are usually associated with wildfires (Gavin 2001) and the charcoal remains from the studied site probably come from sub-desert bush and scrubs associated with hearths and earthworks, we cannot completely discard the potential effect of inbuilt age as no anthracological analyses were performed. Consequently, due to the potential uncertainties of the dated material, we followed a general outlier model for most of the samples and used a standard charcoal outlier analysis for the charcoal samples (Bronk Ramsey 2009b) (see section 3.2).

Furthermore, a radiocarbon date compilation based on previous studies and unpublished results from the main Manteño sites surrounding Ligüiqui on the Ecuadorian coast was also performed (Appendix 2). We did not include Cerro de Hojas in the selection because the body of published dating is still small and inconclusive. We selected radiocarbon dates from stratigraphic contexts and clearly identified elements (mainly charcoal, human bone collagen and marine shells) belonging to the Manteño culture according to different archaeological studies on the coastal areas of Manabi and Guayas (e.g., Carter 2008 and Touchard-Houlbert 2009, 2010). The use of human bones for radiocarbon dating is sometimes challenging, given that the results could also be affected by diet (i.e., variable terrestrial or marine contributions). We only selected one human bone sample from the literature on Loma Guasango owing to the fact that no other chronological data were available at the site. In summary, sixty-four radiocarbon dates were compilated from the Manteño sites surrounding Ligüiqui and sixty came from charcoal/charred remains.

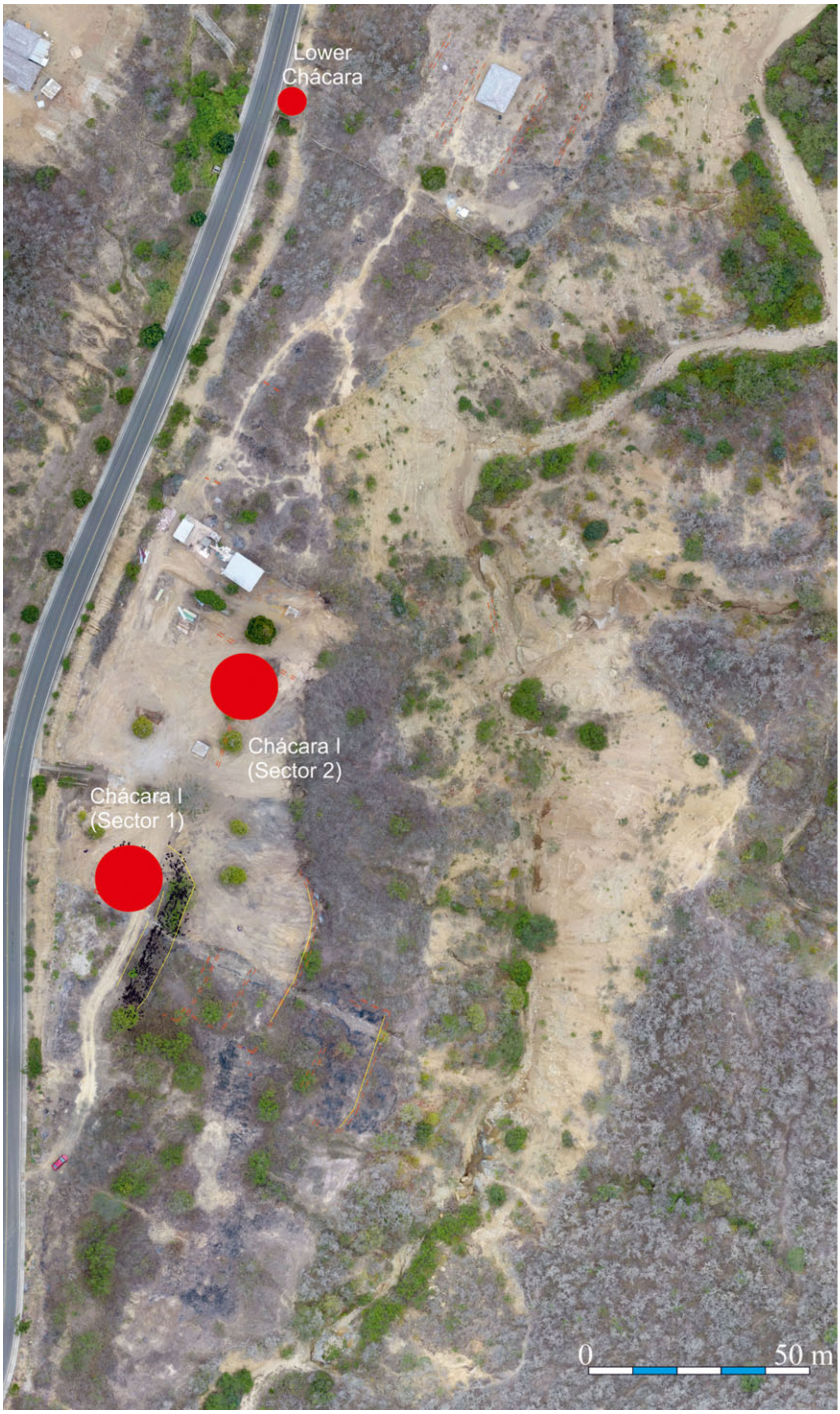

Figure 4. *Location of the studied Ligüiqui sections: Chácara I (Sector 1 and 2) and Lower Chácara.*

3.1. Sample treatments

The different types of samples were processed following specific in-house protocols at BETA laboratories.

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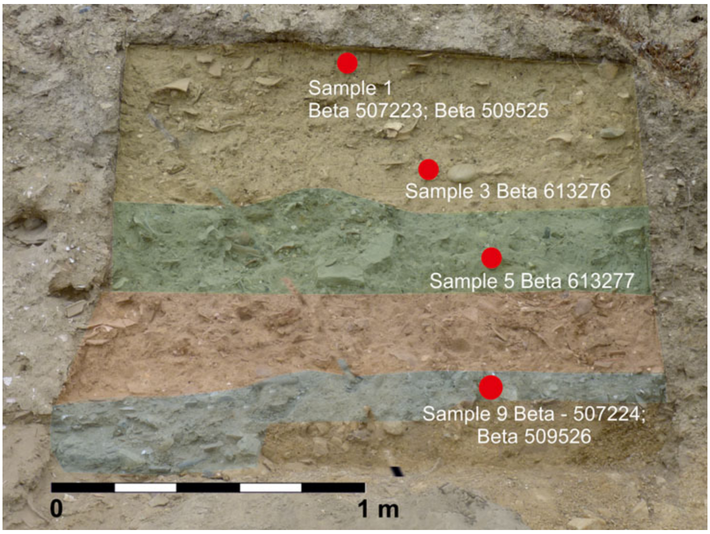

Figure 5. *Location of the radiocarbon samples collected in Lower Chácara.*

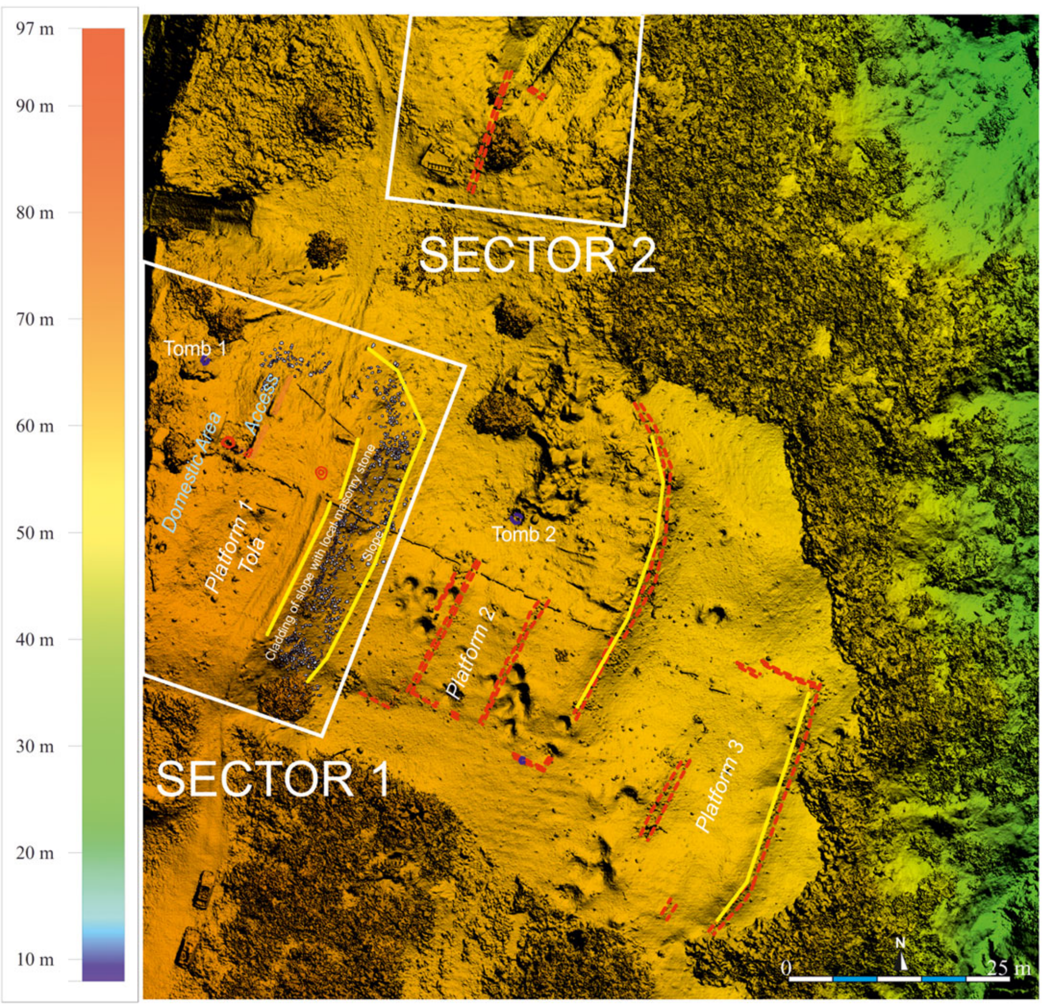

Figure 6. *Chácara I, Sector 1 and 2. Digital Terrain Model. The main tola and other main structures have been indicated.*

Figure 7. *Chácara I, Sector 1 area. (A) General picture of the area. (B) Location of the radiocarbon samples collected in the tola.*

- Charcoal samples. After a visual inspection to determine size and suitability for dating, charcoal samples were reduced to ~1–2 mm particles by dissecting and crushing and then saturated in deionized water at 70°C. Subsequently, they were reacted with repeated soakings in 0.1 N HCl for 1–2 hours to eliminate any potential carbonate remains. After rinsing to neutral pH in deionized water, a solution of 1–2% alkali was applied (50/50 wt.% NaOH) at 70°C for 2–4 hours. The latter process was repeated until no colour change in the supernatant was observed. Afterwards, samples

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Figure 8. *Location of the radiocarbon samples collected in Chácara I-Sector 2.*

were again rinsed to neutral pH with deionized water, and a final acid wash (0.5–1.0 N HCL) was applied at 70°C for one hour to ensure the alkali was neutralized. Lastly, samples were again rinsed to a neutral pH with deionized water and dried at 100°C or desiccated for 12–24 hours depending on their size and conservation. Prior to analysis, samples were microscopically examined for cleanliness and uniformity. Roots and organic debris were physically eliminated when observed.

- Organic sediment samples (bulk organic sediment). After a visual inspection to determine the size, homogeneity, debris, inclusions, clasts, grain size, organic constituents and potential contaminants, sediment samples were dispersed in deionized water, homogenized through stirring and sonication, and then sieved to <180 μm to remove macrofossils, roots, and other debris. Subsequently, samples were acid washed with 1.25 N HCl at 90°C for a minimum of 1.5 hours. Once the carbonate was removed (if needed, this step was repeated to ensure the complete removal of any carbonate), serial de-ionized water rinses at 70°C were applied until reaching neutral pH. The remaining samples were dried at 100°C for 12–24 hours, then HCl was applied to a representative sub-sample under a microscope to validate the absence of carbonates. Lastly, a microscopic examination was performed to assess the organic sediment characteristics and to determine the appropriate size for sub-sample and AMS dating.
- Shell samples. Depending on size, conservation, and other characteristics, shells were physically abraded to remove the outermost layer where possible. Additionally, an acid etch was applied to remove as much of the shells' outer surfaces as possible (typically 10–30% by weight or more, sample dependent), to ensure that the shells were clean and free of any adhering, infilling, mineral or other extraneous matter. Subsequently, the shells were rinsed with deionized H_2O to neutral pH and dried in an oven. Lastly, shell surfaces were visually inspected to identify any obvious signs of remaining contamination or alteration. If present, those areas were removed or excluded from the sample.
- Bone collagen samples. Bone collagen was extracted following a BETA laboratory in-house modified Longin (1971) method. Although the concentrations of chemicals, duration and number of extractions varied depending on initial sample size, level of conservation and burial conditions (if known), the general process consisted of an initial physical bone cleaning stage where the bone was washed and cleaned as needed with a wire brush or abraded with a Dremel electric tool to remove any surface contamination. Subsequently, the mineral fraction was dissolved with 0.2 N HCl at ~21°C for 12–24 hours and the bone surface, which might contain deeply imbedded dirt or rootlet materials, was scraped to remove the outermost layers (size permitting). This material was generally discarded (provided there was sufficient remaining bone for dating—note this is why the % collagen yield cannot be calculated). Over the course of several days, collagen was periodically scraped away as the surface mineral fraction dissolved. Afterwards, the extracted collagen was rinsed to neutral pH with deionized H_2O and a solution of 1–2% alkali (50/50 wt./wt. % NaOH) was carefully applied and reapplied under observation at room temperature until the solution became clear, which indicates effective removal of secondary organics such as humic acids. Lastly, after rinsing to neutral pH with deionized H_2O, a final acid wash was applied to remove any adsorbed CO_2 and the extracted collagen was again rinsed to neutral pH with deionized H_2O. The purified gelatinous collagen was then dissected, microscopically examined for

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cleanliness and uniformity, and dried by vacuum desiccation prior to combustion. The $\delta^{13}C$, $\delta^{15}N$, %C and %N composition was analyzed in a collagen aliquot by Isotope Ratio Mass Spectrometry coupled with an Elementar Analyser. The values obtained (Appendix 1b) fall within expected ranges of well-preserved collagen (DeNiro 1985, Van Klinken 1999).

3.2. Radiocarbon sample calibration and Bayesian modeling

Radiocarbon dating from the sequence studied in Ligüiqui (Appendix 1), along with the dating obtained from a thorough literature review of other Manteño sites on the Ecuadorian coast (Appendix 2: 64 dates) were calibrated using the latest radiocarbon calibration curves and OxCal software (Bronk Ramsey 2009a): 1) SHCal20 calibration curve (Hogg et al. 2020) for terrestrial samples (organic sediment, charred material/charcoal and terrestrial bones) and 2) Marine20 radiocarbon curve (Heaton et al. 2020) for marine samples (shells and fish bones). Although the local ΔR was applied to the marine samples, this potentially adds a level of chronological uncertainty given that the estimate is not accurate in equatorial areas and might have changed over time. This local ΔR was calculated using the nine closest available ΔR data to the study area, which gave a $\Delta R = 11 \pm 55$ years (http://calib.org/marine/). A close ΔR sample obtained from a deposit-feeding gastropod was discarded ($\Delta R = -369 \pm 37$ years; http://calib.org/marine/). Furthermore, the time boundaries for the Manteño periods in Ligüiqui and other Manteño sites were modeled following a Bayesian approach using OxCal software (Bronk Ramsey 2009a) when two or more dates were available for the periods (Appendices 1 and 2). Appendices 1 and 2 show the 1σ–2σ probability ranges and median for the calibrated and modeled ages and boundaries. However, for the sake of simplicity, the 1σ probability range was used to narrow the calibrated and modeled ages of individual samples. This provides a representative picture of the dispersion of calibrated and modeled ages and relatively high probability. In the case of the modeled boundaries for the different phases and sequences, median values were used in the main text to constrain and summarize the events.

A general outlier model (Outlier_Model (“General”, T(5),U(0,4),“t”; Bronk Ramsey 2009b) was used for all the samples due to the potential uncertainties of the different dating material, except for charcoal/charred remains. A prior = 0.05 was applied to each sample. In the case of charcoal remains, we used a standard charcoal outlier model (Outlier_Model (“Charcoal”,Exp (1,−10,0),U(0,3),“t”; Bronk Ramsey 2009b) with prior = 1 for each sample. Agreement indices were not provided as they are not reliable in simulations that use general and charcoal outlier models. The charcoal outlier model generates calibrations that centre almost symmetrically around the target date, even in the absence of any short-lived material (Dee and Bronk Ramsey 2014). The precision of the charcoal outlier model increases when short-lived material is included, even if it is less than 10% of the samples, according to the examples provided by Bronk Ramsey (2009). In the case of Ligüiqui, although there are no “true” short-lived materials, there is a mixture of sample sources, charcoal, organic matter, marine shells and fish collagen, that reduces the impact of charcoal dating.

The sequence model for Ligüiqui was designed taking into account the archaeological stratigraphy of the site. A two-stage sequential structure was adopted due to the potential temporal gap between the oldest (Chácara I-Sector 2) and the youngest Manteño sections (Lower Chácara and Chácara I-Sector 1). The three radiocarbon dates in Chácara I-Sector 2 were taken in stratigraphic order (Figure 8) and modeled as a sequence. The potential Manteño phase consists of a coeval sequence (Lower Chácara, where six radiocarbon samples were recovered in stratigraphic order from a vertical profile) and phase (Chácara I-Sector 1, where thirteen radiocarbon samples were recovered in a horizontal open area excavation) (Figures 5 and 7). The sequences and phases were considered uniform, with default OxCal settings. In the case of Lower Chácara, one phase was established for Beta-507224 and Beta-509526 (sample 9) and another for Beta-507223 and Beta-509525 (sample 1) given that the samples from each phase are of a different nature (different source/material) yet were recovered at the same level (Figure 5).

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Two temporal constrains were used in the model. 1) *Terminus post quem* (TPQ) for Beta-507224 and Beta-509526 (sample 9) samples, which belong to the lowest archaeological level in Lower Chácara. Below this level, sandy sediments, probably belonging to the geological basement, show through. The ceramic remains obtained from the geological basement do not exhibit proper "Manteño" features, but they do share common features with the Manteño, Guangala and Bahia phases. Nevertheless, the overlying levels, where samples 5, 3 and 1 were recovered, yielded proper Manteño remains of "stone-burnished" potteries. Future field campaigns are needed to determine the level of sample 9 in order to discard or accept its Manteño origin. Until such time, we consider that the level corresponds to an earlier or transitional period before the "proper Manteño" phase registered in the overlying levels. Therefore, sample 9 is considered as TPQ in the Lower Chácara sequence. 2) *Terminus ante quem* (TAQ) is considered for sample Beta-613356. This sample in section Chácara I-Sector 1 was obtained in a spoliation trench that was dug in an attempt to open a Manteño grave with a markedly negative interfacies. Thus, the sample is probably related to a subsequent phase of spoliation in the area and, therefore, is considered as TAQ in the model.

The boundaries in the Ligüiqui sequence were established using the default OxCal parameters. Although it is assumed that the Manteño period ended around AD 1530–1535, with European presence on the Ecuadorian coast (Lunnis 2020), we preferred not to include this boundary as a prior in the model to evaluate the results obtained. To summarise the probability distribution of the chronological data of the Manteño period in Ligüiqui, a Kernel Density Estimation was calculated using a KDE model function with the default settings in OxCal (Bronk Ramsey 2017). The code can be found in Appendix 3.

The estimations for the Manteño period for the other Manteño sites cited in the literature were modeled as uniform phases given that the data provided from the archaeological context for most of the sites did not allow us to reconstruct their Manteño stratigraphy. Default OxCal parameters were used to constrain the boundaries for the Manteño phases for the sites when two or more dates were available. The results and the code for the models are available in Appendices 2 and 4, respectively. The large number of radiocarbon analyses of charcoal remains and the absence of evident priors prevented us from obtaining accurate boundaries for the Manteño phase in each site. Therefore, we used a composite Bayesian chronological model for the boundaries that included the radiocarbon data from the complied Manteño sites on the Ecuadorian coast (64 radiocarbon samples) and Ligüiqui results (19 radiocarbon samples), along with a composite KDE using a KDE model function to synthesise all the chronological data on Manteño culture. The code for the model is available in Appendix 5.

4. Results

During the 2018 campaign, a first approach to Ligüiqui focused on the area of Lower Chácara, where a stratigraphy formed by four large horizontal deposits was observed. Abundant remains of ceramic material and ichthyofauna were registered in all four deposits. Lastly, a set of six radiocarbon samples corresponding to four contexts were taken (Appendix 1a and Figures 5 and 9). Sample 1a Beta 507223 and 1b Beta 509525 yielded radiocarbon measurements of 860 ± 30 BP (AD 1188–1270, modeled age AD 1354–1506; 1σ;) and 630 ± 30 BP (AD 1322–1402, modeled age AD 1341–1462; 1σ) (Appendix 1a). Charcoal remains from Sample 3 (Beta 613276; Figure 5) and Sample 5 (Beta 613277) provided an age of 560 ± 30 BP (AD 1405–1434, modeled age AD 1329-1436; 1σ) and 660 ± 30 BP (AD 1315-1395, modeled age AD 1306-1399; 1σ), respectively. The ages of the organic sediment and charred material from samples 9a and 9b (Beta 507224 and Beta 509526; Figure 5), which could belong to a transitional archaeological level between the Manteño and earlier cultures in the area, were 1760 ± 30 BP (AD 253–366; 1σ) and 800 ± 30 BP (AD 1229–1283; 1σ), respectively (Figure 9). According to these dates, sample 9a could belong to the early stage of the Regional Development Period (AD 50–950) (Damp 2014), whereas sample 9b suggests that the materials might belong to the Late Manteño period (Appendix 1a). This mixture of dates in the same level could also point to its transitional nature.

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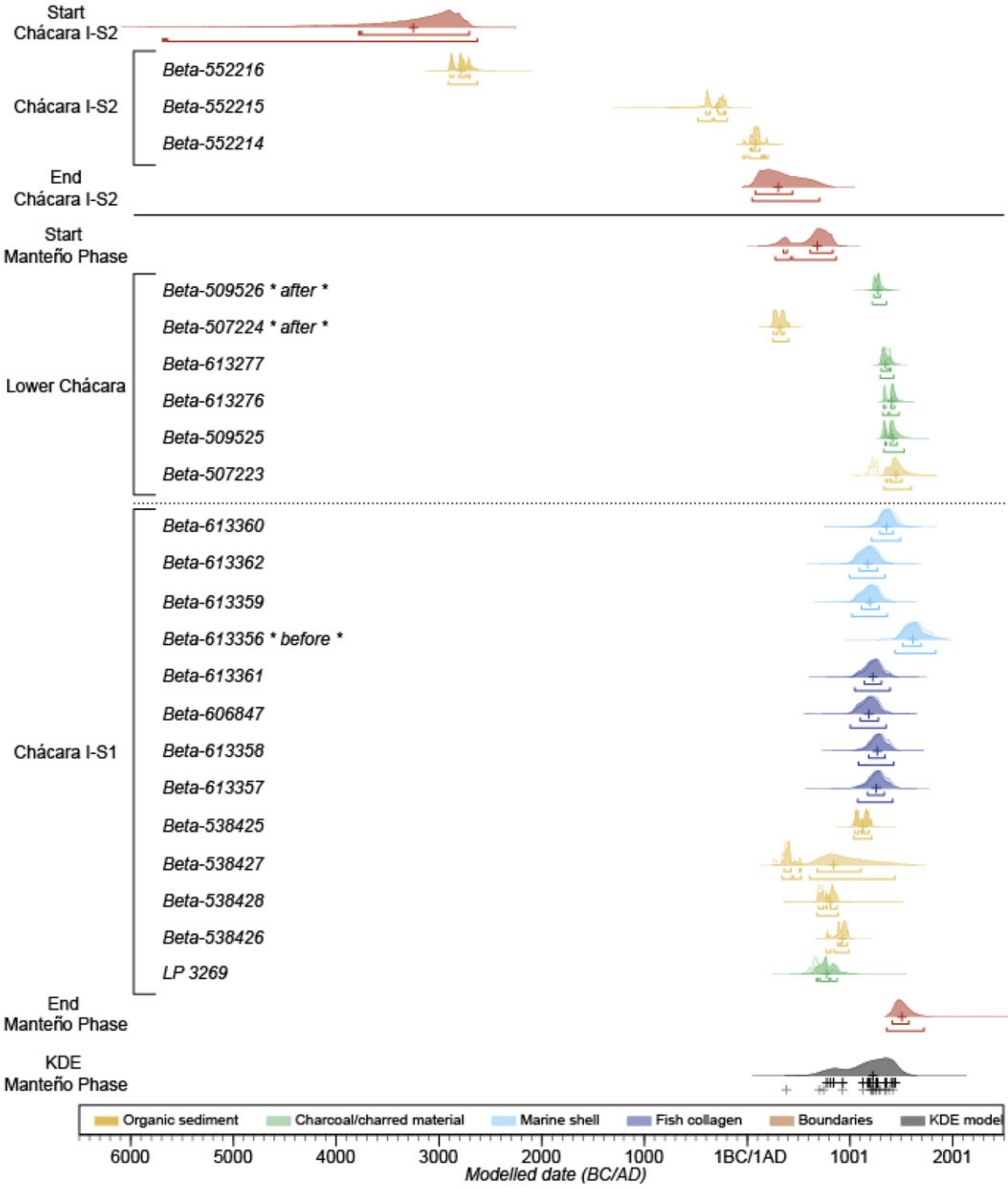

Figure 9. *Radiocarbon chronology from the studied archaeological sections in Ligüiqui (see Appendix 1a). The age probability of the unmodelled (light shade) and the Bayesian-modelled probability distribution (dark shade), the 1σ - 2σ standard deviations and the median values of the radiocarbon samples for Chácara I-Sector 2 (three samples), Lower Chácara (six samples) and Chácara I-Sector 1 (thirteen samples) are represented. The Bayesian-modelled boundaries between Chácara I-Sector 2 and the Manteño phase (Lower Chácara and Chácara I-Sector 1) along with a summary of the probability distribution of the chronological data for the Manteño period in Ligüiqui, calculated using a Kernel Density Estimation – KDE model function – are also shown. The KDE model also exhibits the unmodelled distribution (light shade +) and the modelled distribution (dark shade +) for the radiocarbon samples. OxCal software (Bronk Ramsey 2009a) was used for the Bayesian modelling (see results in Appendix 1a and the code used in Appendix 3) and the graphical output was edited and formatted in Adobe Illustrator.*

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However, future fieldworks are needed to analyze the level in order to obtain a correct interpretation. Despite the controversial dates, the data obtained from Lower Chácara provided the first chronology for this particular area based on four radiocarbon samples. This set of samples, which consist of organic sediment, charcoal and charred remains, was ascribed a date between AD 1306 and AD 1508 1σ, which verified the absence of discontinuities in the archaeological section of the area. This also suggests that the surveyed area might belong to the Late Manteño period (twelfth–fifteenth centuries AD).

During the 2019 campaign, data were obtained in the areas known as Chácara I-Sector 1 and Chácara I-Sector 2 (Figures 4, 6, 7 and 8), where the most outstanding feature is the existence of at least three large *tolas* with immediate built spaces reaching 2500 hectares. The excavation work focused on the *tola* located furthest to the south, measuring 51 by 25 meters (Chácara I-Sector 1). This large construction has a rectangular floorplan and is four meters high (Figures 3 and 4). It is built on an embanked platform covered with clay and large masonry blocks. According to the radiocarbon analysis of the sediments in the area, this building complex has been assigned a date ranging from the twelfth to the fourteenth century based on the modeled age (Beta 613361, 1320 ± 30 BP or AD 1165–1328 modeled age AD 1142–1308; 1σ) (Appendix 1a). Given that the abovementioned structure was built on a mound, excavation work confirmed that the last structure had been built over other structures. In the upper area of the main *tola* we were able to identify openings to looters' pits for looting burials, a practice that has been taking place for at least the last three hundred years. The entrance to the north sector of the *tola* is accessed through a ramp to the top of a clay platform delimited by rough stones. This type of entrance was commonplace during the Late Manteño period in other sites such as Cerro de Hojas and Jocay, primarily from the eleventh to the fifteenth century (Lunniss 2020; Touchard-Houlbert 2009). Excavations also revealed a north–south oriented adobe wall that probably served as the façade for the east side of the building. Inside, a stone structure, intersected by a rammed-earth wall in parallel to the façade, separates a domestic space that appears to have been a cooking area. This "kitchen" contained a high percentage of mollusc and ichthyofauna remains (samples Beta 613358 and 606847) that provided an age of 1270/1360 ± 30 BP (AD 1131–1385, modeled age AD 1101–1343; 1σ) (Appendix 1a).

The modeled boundaries for the Manteño period in Ligüiqui, obtained from the Bayesian model integrating Lower Chácara and Chácara I-Sector 1 range from AD 680 to AD 1505 (median values for the boundaries).

In the 2019 field season, documentation work was also extended to Chácara I-Sector 2, located 50 meters to the north of the first sector (Figures 4 and 8), and stratigraphically below Lower Chácara and Chácara I-Sector 1. To contextualise the site chronologically, a recently deep cut profile that had partially damaged some of the terraces was examined and various overlying occupation levels were observed, each delimited by two east-west oriented walls. The integrated Bayesian model for the radiocarbon samples (organic sediments) embedded in the horizontal soil deposits suggests that the boundaries for this section could range from 3252 BC to AD 300 (median values for the boundaries; Appendix 1a and Figure 9). Masonry structures were found above the most recent layers, which provides evidence that terracing was the preferred way of arranging the space from at least the second century AD. However, we are cautious about potential interpretations and discussions regarding the period given the significant chronological uncertainties regarding Chácara I-Sector 2 due to insufficient radiocarbon dates.

5. Discussion

The characterization of Manteño culture has been approached in various ways over the last two decades (Marcos 2005). Not only has the material framework been reviewed, but also the elements that make it possible to defend a predominantly evolutionary interpretation of Manteño culture. So far, the research has had two principal aims. First, to interpret the evolution of the occupation patterns and their possible

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relationship to the formation of a state. Second, to achieve a clearer vision of Manteño culture (Marcos 2005) based on its material elements, but also on its cosmology and understanding of the environment (Lunniss 2020).

However, the research still has important gaps in its periodization and its geographical framework given that most of the dates obtained so far come from a narrow coastal strip. To determine whether the periods of social change identified with Ligüiqui could be integrated into the same evolutionary chronological framework as other Manteño sites, the radiocarbon dating obtained from Ligüiqui was compared to those assigned to other sites considered to be Manteño in the provinces of Manabí, Santa Elena and Guayas (Figure 1).

The compendium of ^{14}C measurements presented by archaeologists Ziólowski et al. (1994) has been a source of reference. This database accommodates radiocarbon dates for different sites located in central coastal Ecuador, including Agua Blanca, Salango, Chirije (Manabí), La Libertad, Sube y Baja, Puerto Chanduy and Loma Guasango Torcido (Santa Elena), among others. Shortly after the publication of Ziólowski's research, Marcos and Bogomil (Marcos 1998; Marcos and Bogomil 1998) subjected the dates previously assigned to the Formative Period (4000–200 BC) of coastal Ecuador to a thorough revision. Given the chronological framework constructed by both researchers predated the Manteño occupation period, it has not been incorporated to this study. However, the outcomes of their research, together with their description of the cultural periods prior to the Manteño period have provided a solid theoretical foundation for this study.

The unpublished doctoral thesis of French archaeologist Touchard-Houlbert (2009) was also contemplated in the framework of this study. Touchard-Houlbert's research is based on the comparative analysis of fifteen archaeological sites, from which 59 radiocarbon samples were obtained that were dated from the period AD 600–1700 (Touchard-Houlbert 2009). Moreover, her work used the results from the Manabí Central Research Project, which was conducted between 2004 and 2008 and focused on the areas of Chirije and Japotó (Guinea and Bouchard 2010). To establish a comparable framework for discussion, this study revised and calibrated dates previously assigned to various Manteño sites located in Manabí using the most recent radiocarbon curve (see Section 3 for the applied methodology, Appendix 2; Figure 10). However, this previous chronological framework was not sufficiently robust given that most of the radiocarbon dates came from charred/charcoal material.

In order to enrich the results provided, our study has updated the available database with a significant number of dates obtained from three of the excavated areas at Salango (especially the OMJLP-140 area [Carter 2008, 575; Touchard-Houlbert 2009, 35-AII; Touchard-Houlbert 2010, 555]). In addition, the heterogeneous finds published since the 1990s made in the Los Frailes, López Viejo, Mar Bravo, Loma de los Cangrejitos, Puerto Chanduy and Pepa de Huso archaeological sites have also been considered in this study (Figure 2). Owing to the fact that most of the previous Manteño chronologies were obtained from charcoal remains, the new radiocarbon dataset provided in this study from both charcoal (4 samples) and non-charcoal (15 samples) samples reinforce the area's Manteño chronology. Using the results of the Bayesian analysis, we made the following inferences: i) the first phases of Manteño culture in most of the sites in the study start around AD 850 (Figure 10), preceded by early Manteño evidence in Ligüiqui AD ~700, Japotó AD ~830 and La Libertad AD ~840, and ii) based on the available data, Manteño culture suffered an early demise at AD ~ 1500 and almost completely disappeared before AD 1600, except for the La Libertad site (Figure 10; Appendix 2). Only the radiocarbon chronologies from two of the three sites, Ligüiqui and La Libertad, were also obtained from other types of samples as well as charcoal, which minimizes the effect of the potential inbuilt age of charcoal-based chronologies. Other two sites, Salango (Lunniss 2001 and 2020) and Ligüiqui, show discontinuous but long-term occupation in their chronology, from the Valdivia period (4000–1450 BC, in the studied area) to the Spanish colonization period (AD 1530). Permanent occupation of certain spaces has been attributed to rituality, which might have been inherently linked to the nucleation process undergone by settlements, together with their possible arrangement into a new social hierarchy (Lunniss 2019). However, light has yet to be shed on the exact date as to when sites such as Cerro de Hojas and Agua Blanca emerged, which may have been major centres of Manteño power from at least the late eleventh or early twelfth

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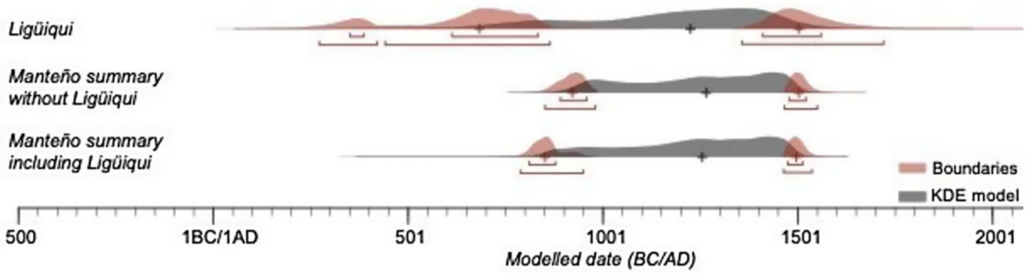

Figure 10. *Summary of the Bayesian-modelled boundaries (1σ - 2σ standard deviations and median) and of the probability distribution using a Kernel Density Estimation (KDE model function) for the Manteño period in Ligüiqui (19 radiocarbon dates) and the reviewed literature sites (64 radiocarbon dates) by means of OxCal software (Bronk Ramsey 2009a) (see the code used in Appendices 3 and 5). The boundaries and KDE models were inserted and formatted in Adobe Illustrator.*

century AD (McEwan 2004). Similarly, further data on the sites located in the interior of the provinces of Manabí, Guayas and Santa Elena must be obtained to complete the partial picture that mid-range geographical studies have thus far provided of Manteño occupation models.

Radiocarbon dating confirmed the coetaneous temporal trajectory of the Manteño period for the Ligüiqui, Japotó, Salango and Agua Blanca sites (Figure 10). However, only the radiocarbon chronology for Ligüiqui was based on non-charcoal and charcoal remains, which minimizes the effect of the potential inbuilt age of charcoal dating. Although new models of social organization arose between AD 600–900, it was not until AD 1050–1220 that small-scale Manteño settlements became more complex and were probably arranged into a hierarchy (Touchard-Houlbert 2010). These changes involved further transformation in the inner spatial organization of sites—for instance, burial sites were placed at specific locations, buildings were clustered around a central area and so forth. Furthermore, numerous monuments were built to serve a ritual function (Lunniss 2020), a coeval phenomenon that can be observed along the central coastal and southern areas of the Manabí province, including the sites of Agua Blanca, Ligüiqui, Japotó and Cerro de Hojas (Figure 10). In fact, the most relevant radiocarbon samples obtained, used in the comparative analysis presented above, date this period. It might have been during this period, from AD 1100 onwards, that the settlements studied began to be visually intercommunicated, which might also respond to a possible settlement hierarchy (Castro-Priego et al. 2021; McEwan and Delgado-Espinoza 2008). In short, the emergence of the Manteño urban model can be directly associated with the monumental phase of construction undergone at these sites, which also involved the practice of rituals in which water and solar cycles played a transcendental role (Lunniss 2020).

In some cases, research has clarified dominant productive activity that took place in particular sites in the early Manteño period. For example, Mester (1990) underlined the importance of shell workcraft in Los Frailes. In turn, McEwan (2003) and Lunniss (2020) shed light on the important role that rituality played in the layout of Late Manteño settlements. In this regard, McEwan (2003) highlighted the presence of chieftain chairs at the Agua Blanca site that were endowed with an outstanding sense of power. Oriented towards the rising sun and the solstices, buildings seem to have an important symbolic and ritual significance (Castro-Priego et al. 2021; McEwan and Delgado-Espinoza 2008). As in other ancient Andean cultures, the development of the Manteño urban model seems to have been related to rituals wherein water and solar cycles played a major role. However, the functionality of other settlements is unknown. Perhaps they all had the same symbolic-political components, albeit on a different geographical scale. Similarly, the Manteño ceramic materials (ceremonial and cooking potteries) that were studied from Ligüiqui share considerable similarities with other sites, such as Japotó (Stothert 2007) within a radius of almost 200 kilometers. However, due to the limited studies on ceramics (Estrada et al. 1962; Paulsen 1970; Stothert 2007 and 2010), currently pottery cannot used as a

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chronological marker and its production area is also unknown. In other words, whether most of the pottery was worked in one settlement from where it was delivered to others or whether the ceramic series were produced at different sites is unknown. In this regard, a shared material culture could imply a commercial, political and religious coherence between the different Manteño settlements. Within the relevance of this social analysis, the presence of extensive fisheries close to Ligüiqui suggests that it might have been a centre of distribution and supply of marine-origin products.

Most of the dates proposed for the Manteño period in Ligüiqui are based on a significant amount of ichthyofauna remains found in the area, which could be a link between the settlement and the fish traps or *corrales*. However, in order to fully interpret the site, two fundamental questions remain. First, the probability that the fish traps survived during the Spanish colonial period. And second, the exact dates of when the fish traps were built needs to be determined to confirm that they belong to the Manteño period. There are numerous parallels of these structures throughout the world. In the case of Latin America, the Chiloé complex on the present-day Chilean coast is a prime example and its pre-Hispanic origin has been confirmed (Álvarez et al. 2008). The Ligüiqui structures present some particularities with respect to those previously mentioned, such as their geographical extension and their location in a Pacific area where the swell is intense. However, if these structures existed at the end of the Manteño period, why are they not mentioned in colonial sources? We believe that a first answer lies in the fact that the Spanish already knew about such structures, which were also numerous in the southwest of the Iberian Peninsula. It should be noted that the term used to name the traps is similar in both Ecuador and Spain, *corral* or *corral de pesquería*. In the case of Spain, their existence is well documented in written sources from the fourteenth century, and they were still in use at the beginning of the nineteenth century (Florido del Corral 2011). Another complex question relates to the conservation and maintenance of this type of structure, which are quite labour intensive. Albeit, in the case of Ligüiqui, only two main platforms from structures have been preserved, although there is evidence of a much more extensive system that has been dismantled. In any event, the fishing activities that are currently employed have little to do with those employed in pre-Hispanic times; a situation similar to that of the Spanish *corrales*, which systematically suffer from the lifting of stones to catch octopodes and small fish.

The dates obtained present some uncertainties about the Late Manteño period. Based on the Bayesian approach performed, several Manteño settlements might have been uninhabited, or occupation might have fluctuated around AD 1500 or slightly before (Figure 10). These variations could be linked to internal Manteño populational dynamics and/or to the influence of the Inca expansion in the region. Tupac Inca Yupanqui and Huayna Capac ruled the Inca Empire from AD 1471 to 1527 and led extensive military conquests and crushed rebellions in nearby locations. Archaeological evidence of the Inca influence in the study region is limited. Except for specific places such as Plata Island where excavation work uncovered an assortment of Inca tombs, there is still little knowledge on how the Inca state may have affected goods production and commercial routes in the Manteño territory along coastal Ecuador (Marcos and Norton 1981, 1984; McEwan and Silva 1989). According to Carter (2011), there may have been a decrease in the number of goods produced using Spondylus shells as a raw material in the present-day territory of Peru between AD 1470 and 1532, which would correlate with the early demise of the Manteño culture (Figure 10). In the event that certain Manteño communities had specialized in certain goods production and long-distance trade, the disappearance or limitation of raw materials would have influenced their organization.

The final demise of the Manteño culture seems to have occurred during the colonial period. However, archaeological documents have not recorded the presence of any colonial ceramic materials at the sites of Ligüiqui, Japotó, Agua Blanca or Loma de los Cangrejitos. In the case of Ligüiqui, colonial occupation must have been minimal, where it occurred at all, according to both the excavation results and the various colonial documentation sources studied that date to the seventeenth century. Therefore, based on the results of the Bayesian analysis and the archaeological results, the disappearance of most of the coastal Manteño settlements might have occurred before AD 1600, except for the La Libertad site. Within this chronological and spatial analysis, the policy of "reductions" implemented by the Spanish viceroy Francisco de Toledo in the Manteño territory in 1569 (Jurado 2004) may have played a determining role in the reorganization of settlements. This European occupation model called "system of reductions" consisted of forcibly relocating Andean populations into new villages to impose Christianity or integrate them into the Viceroyalty of Peru economic system. The resulting occupation model may have interrupted or accelerated ongoing changes in the already-existing Manteño sites.

6. Conclusions

This paper provides a chronological framework of occupation at the Ligüiqui site as a novel contribution to the characterization of the Manteño settlements in the central sector of the Ecuadorian coast, an area in which, to date, there is limited evidence of the Manteño culture. Despite the heterogeneity of the radiocarbon samples from the different Manteño sites studied, we developed an initial integrated chronological approach to constrain the time boundaries for the Manteño period in Ecuador.

Bayesian modeling of radiocarbon data provided a robust chronology for the Manteño period in the area. The beginning of the Manteño culture is well established at around AD 850, although earlier evidence has been registered in Ligüiqui (AD ~700), Japotó (AD ~830) and La Libertad (AD ~840). The dates obtained indicate that the sites at Ligüiqui, Agua Blanca and Japotó were coetaneous during the Manteño period. Future research should focus on investigating a possible political, commercial and religious connection between the surveyed Manteño sites, in addition to corroborating the existence of a potential settlement hierarchy structure. Manteño culture sites appear to decline around AD 1500, or just before, possibly linked to internal Manteño population dynamics and/or the Inca expansion. The final demise of the Manteño culture seems to have occurred during the early Spanish colonial period between AD 1530 and 1600 despite the fact that there are no archaeological records of any colonial ceramic material found at the Ligüiqui, Japotó, Agua Blanca or Loma de los Cangrejitos sites. Nevertheless, the weakest point of this first attempt to integrate Manteño chronologies is the large amount of radiocarbon samples obtained from charcoal that can be affected by inbuilt age. Future samplings should focus on short-lived material to constrain this framework.

Excavations conducted in the area of Las Chácaras enabled us to identify a large building complex (*tolas*) whose construction may have spanned from the twelfth to the fourteenth century AD. Based on the study of Manteño hill settlements, the Ligüiqui site presented a complex internal arrangement, with its layout bearing similarities to other sites that date to the Integration Period, for example Cerro de Hojas-Jaboncillo (Marcos et al. 2012). In connection with this, remote sensing-work detected various functional spaces in Cerro de Hojas-Jaboncillo (Castro-Priego et al. 2021), such as workshops, water storage structures, agricultural terraces, dwellings and ritual complexes, structures that might exist but have yet to be identified in Ligüiqui.

This study confirmed that the pre-Hispanic Ligüiqui site belongs to the group of coastal sites that exhibit undeniable signs of anthropogenic activities over long periods of time. However, despite the abundant assortment of fauna remains discovered during the archaeological excavations, with fish and mollusc species representing 93% of the total amount of the recovered archaeofauna, the relationship between the fishing area and the Ligüiqui site is still under study.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/RDC.2024.111

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APPENDIX 1Appendix 1a

Radiocarbon samples analyzed throughout the Ligüiqui sequence along with their calibrated and Bayesian-modeled ages (OxCal: Bronk Ramsey 2009a). A general outlier model and a standard charcoal outlier analysis (Bronk Ramsey 2009b) were applied. The boundaries for the two main phases were also modeled using the default settings. Terrestrial samples (organic sediments and charred material) were calibrated using the SHCal20 radiocarbon curve (Hogg et al. 2020). Marine samples (shells and fish bones) were calibrated using the Marine20 radiocarbon curve (Heaton et al. 2020) with $\Delta R = 11 \pm 55$ years (http://calib.org/marine/). Agreement indices were not provided as they are not reliable in simulations that use general and charcoal outlier models. To summarise the probability distribution of the chronological data for the Manteño period in Ligüiqui, a Kernel Density Estimation was calculated using a KDE_Model function and the default settings in OxCal (Bronk Ramsey 2017). "AD" (Anno Domini) positive values from year 0 onwards; "BC" (Before Christ) negative values from year 0 backwards. "CI" indicates confidence interval. Codes for the models are included in Appendix 3 in the Supplementary Materials.

Sample	Material	$\delta^{13}C$ ‰	^{14}C age BP	Error ±	Calibrated unmodeled ages (BC/AD) 1 σ (CI) from	to	2 σ (CI) from	to	median	Calibrated modeled ages (BC/AD) 1 σ from	to	2 σ from	to	median
Start Chácara I-S2										−3769	−2707	−5740	−2629	−3252
Beta-552216	Organic sediment	−22.7‰	4250	30	−2894	−2703	−2906	−2640	−2789	−2893	−2700	−2909	−2629	−2781
Beta-552215	Organic sediment	−18.7‰	2350	30	−404	−210	−455	−199	−292	−404	−210	−480	−196	−296
Beta-552214	Organic sediment	−19.2‰	1960	30	31	123	−40	203	87	31	121	−42	201	83
End Chácara I-S2										84	445	49	704	300
Start Manteño Phase										352	834	273	865	680
KDE Manteño period														1215
				Lower Chácara										
Beta-509526 *After*	Charred material	−24.6‰	800	30	1229	1283	1220	1292	1256	1235	1294	1220	1356	1274
Beta-507224 *After*	Organic sediment	−20.8‰	1760	30	253	366	247	410	317	253	367	247	410	317
Beta-613277	Charred material	−23.5‰	660	30	1315	1395	1297	1401	1345	1306	1399	1296	1428	1347
Beta-613276	Charred material	−25.1‰	560	30	1405	1434	1393	1449	1419	1329	1436	1322	1479	1409
Beta-509525	Charred material	−26.0‰	630	30	1322	1402	1304	1416	1347	1341	1462	1330	1536	1421
Beta-507223	Organic sediment	−20.9‰	860	30	1188	1270	1163	1276	1228	1354	1506	1332	1596	1447
Chácara I-S1														
Beta-613360	Marine shell	+2.4‰	1160	30	1312	1446	1239	1524	1382	1294	1422	1211	1491	1355
Beta-613362	Marine shell	+1.0‰	1370	30	1120	1290	1030	1360	1202	1090	1265	998	1339	1175
Beta-613359	Marine shell	+2.1‰	1350	30	1141	1306	1049	1381	1220	1111	1284	1021	1367	1194
Beta-613356 *Before*	Marine shell	+2.5‰	850	30	1531	1727	1473	1841	1647	1516	1691	1446	1821	1613
Beta-613361	Bone collagen: fish	−12.5‰	1320	30	1165	1328	1070	1405	1248	1142	1308	1047	1391	1222

(*Continued*)

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					Calibrated unmodeled ages (BC/AD)					Calibrated modeled ages (BC/AD)				
					1 σ (CI)		2 σ (CI)			1 σ		2 σ		
Sample	Material	$\delta^{13}C$ ‰	^{14}C age BP	Error ±	from	to	from	to	median	from	to	from	to	median
Beta-606847	Bone collagen: fish	−12.3‰	1360	30	1131	1298	1040	1371	1211	1101	1275	1006	1353	1185
Beta-613358	Bone collagen: fish	−12.0‰	1270	30	1225	1385	1131	1447	1295	1182	1343	1091	1426	1267
Beta-613357	Bone collagen: fish	−12.1‰	1280	30	1215	1375	1119	1440	1286	1175	1335	1075	1415	1258
Beta-538425	Organic sediment	−22.5‰	950	30	1047	1185	1043	1212	1128	1047	1185	1038	1213	1129
Beta-538427	Organic sediment	−20.1‰	1710	30	344	417	252	466	382	360	1106	338	1442	840
Beta-538428	Organic sediment	−19.5‰	1300	30	685	843	680	876	745	691	872	680	884	808
Beta-538426	Organic sediment	−21.9‰	1190	30	882	972	772	990	928	881	974	773	991	929
* LP 3269	Charcoal	–	1390	70	640	772	583	873	702	675	875	602	975	773
End Manteño Phase										1415	1573	1359	1721	1505

Appendix 1b

Values of $\delta^{13}C$, $\delta^{15}N$, %C, %N and C/N atomic ratios of the extracted collagen from fish bones in five radiocarbon samples. The C/N atomic ratios agree with the range of well-preserved collagen (2.9–3.6) and (3.1–3.5), according to DeNiro (1985) and Van Klinken (1999), respectively.

Sample	$\delta^{13}C$ ‰	$\delta^{15}N$ ‰	%C	%N	C/N
Beta-613357	−12.1‰	+11.0‰	39.27	13.96	3.3
Beta-613358	−12.0‰	+12.7‰	36.66	12.80	3.3
Beta-606847	−12.3‰	+11.6‰	40.54	14.78	3.2
Betal-613361	−12.5‰	+13.6‰	34.88	12.25	3.3

Appendix 2

Compilation of radiocarbon dates from different archaeological sites surrounding Ligüiqui. These dates were calibrated and modeled following a Bayesian approach using OxCal software (Bronk Ramsey 2009a), as well as a general outlier model and a standard charcoal outlier analysis (Bronk Ramsey 2009b). The boundaries for the different phases in each site were also modeled with the default settings when two dates from the phase were available. Terrestrial samples (charcoal, bone collagen-human, and wood mangrove roots) were calibrated using the SHCal20 radiocarbon curve (Hogg et al. 2020). Marine samples (shells) were calibrated using the Marine20 radiocarbon curve (Heaton et al. 2020) with $\Delta R = 11 \pm 55$ years (http://calib.org/marine/). Agreement indices were not provided as they are not reliable in simulations that use general and charcoal outlier models. "AD" (Anno Domini) positive values from year 0 onwards; "BC" (Before Christ) negative values from year 0 backwards. "CI" indicates confidence interval. Codes for the models are included in Appendix 4 in the Supplementary Materials.

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Site	Sample	Material	^{14}C age BP	Error ±	Calibrated unmodeled ages (BC/AD) 1 σ (CI) from	to	2 σ (CI) from	to	median	Calibrated modeled ages (BC/AD) 1 σ (CI) from	to	2 σ (CI) from	to	median
Agua Blanca	Start Phase									1188	1363	1038	1464	1261
Agua Blanca	Gd-4662	Charcoal	780	80	1394	1486	1315	1625	1438	1267	1402	1209	1488	1337
Agua Blanca	GD-6351	Charcoal	650	70	1300	1404	1280	1437	1351	1311	1415	1280	1490	1368
Agua Blanca	BM-2539	Charcoal	650	50	1309	1401	1290	1416	1349	1316	1410	1289	1478	1367
Agua Blanca	Gd-4665	Charcoal	520	70	1220	1382	1153	1401	1274	1324	1464	1300	1520	1415
Agua Blanca	BM-2538	Charcoal	820	50	1220	1281	1158	1379	1246	1230	1390	1196	1474	1298
Agua Blanca	End Phase									1357	1516	1313	1685	1454
Japotó	Start Phase									588	1424	158	. . .	829
Japotó	Gif-12221	Charcoal	490	35	1424	1460	1410	1610	1446	1428	1507	1410	1641	1471
Japotó	Gif-12220	Charcoal	770	45	1229	1379	1220	1386	1282	1234	1416	1219	1574	1343
Japotó	Gif-12103	Charcoal	900	45	1074	1262	1046	1275	1187	1072	1445	1050	1533	1244
Japotó	Gif-12102	Charcoal	900	45	1074	1262	1046	1275	1187	1072	1442	1049	1540	1245
Japotó	Gif-12222	Charcoal	1280	45	690	877	677	892	803	696	1478	688	1520	929
Japotó	End Phase									1448	1694	1421	2189	1594
La Libertad	Start Phase									550	1443	91	. . .	839
La Libertad	L-1232X	Charcoal	550	100	1312	1487	1284	1627	1421	1326	1505	1286	1663	1438
La Libertad	L-1232Z	Charcoal	600	100	1303	1445	1228	1620	1384	1320	1466	1240	1642	1412
La Libertad	L-1232W	Marine shell	950	80	1457	1660	1358	1803	1564	1419	1607	1325	1720	1515
La Libertad	L-1042H	Marine shell	1200	100	1243	1456	1087	1571	1348	1278	1473	1124	1575	1371
La Libertad	L-1232T	Marine shell	1750	100	685	945	561	1085	819	724	1465	644	1525	968
La Libertad	End Phase									1435	1801	1339	2362	1663
Loma Cangrejitos	Start Phase									876	986	793	1090	932
Loma Cangrejitos	Beta-124410	Charcoal	1190	70	775	990	689	1022	895	925	1031	868	1148	984
Loma Cangrejitos	AA-31707	Charcoal	1130	45	896	1018	773	1030	957	921	1036	894	1131	995
Loma Cangrejitos	Beta-124409	Charcoal	1130	50	895	1019	772	1035	955	925	1038	893	1137	997
Loma Cangrejitos	AA-31706	Charcoal	1165	45	893	987	773	1020	931	927	1024	885	1130	982
Loma Cangrejitos	Beta-124408	Charcoal	1020	50	1021	1150	991	1182	1087	1025	1130	992	1193	1082
Loma Cangrejitos	AA-39566	Charcoal	1094	42	903	1027	892	1135	997	968	1062	904	1147	1016
Loma Cangrejitos	Beta-141684	Charcoal	890	60	1073	1270	1045	1280	1190	1045	1196	1030	1237	1104
Loma Cangrejitos	Beta-141683	Charcoal	1140	60	892	1017	772	1044	943	927	1039	890	1149	995

Loma Cangrejitos	AA-39564	Charcoal	934	41	1050	1215	1036	1222	1154	1046	1183	1033	1218	1098
Loma Cangrejitos	Beta-141686	Charcoal	960	60	1045	1182	995	1225	1118	1034	1139	1019	1221	1093
Loma Cangrejitos	AA-39565	Charcoal	915	41	1054	1222	1045	1267	1174	1048	1200	1036	1228	1104
Loma Cangrejitos	Beta-141685	Charcoal	1020	50	1021	1150	991	1182	1087	1025	1130	992	1193	1081
Loma Cangrejitos	End Phase									1081	1238	1060	1303	1178
Lopez Viejo	Start Phase									1209	1272	1102	1304	1234
Lopez Viejo	UB-4321	Charcoal	806	32	1228	1280	1216	1292	1253	1237	1281	1220	1313	1261
Lopez Viejo	UB-4322	Charcoal	816	31	1227	1277	1215	1288	1250	1236	1280	1219	1311	1260
Lopez Viejo	Beta-124719	Charcoal	820	100	1156	1381	1040	1393	1236	1231	1286	1183	1338	1260
Lopez Viejo	UB-4320	Charcoal	834	51	1212	1280	1153	1376	1239	1235	1280	1198	1318	1259
Lopez Viejo	End Phase									1246	1311	1229	1413	1286
Los Frailes	Start Phase									709	1094	330	1427	899
Los Frailes	ISGS-1449	Charcoal	660	70	1298	1400	1275	1436	1349	1295	1408	1227	1530	1356
Los Frailes	ISGS-1450	Charcoal	920	140	1029	1270	889	1392	1143	1049	1307	907	1475	1197
Los Frailes	ISGS-1483	Charcoal	1150	100	774	1025	685	1151	927	893	1167	775	1438	1033
Los Frailes	ISGS-1479	Charcoal	1120	100	775	1135	689	1180	960	909	1180	779	1428	1059
Los Frailes	ISGS-1446	Charcoal	1000	70	1024	1155	906	1224	1095	1031	1216	976	1451	1141
Los Frailes	End Phase									1312	1570	1238	2011	1457
Mar bravo	Start Phase									1159	1475	1108	1490	1363
Mar bravo	AA-68846	Charcoal	493	38	1450	1612	1435	1625	1489	1452	1499	1434	1543	1477
Mar bravo	Beta-194789	Charcoal	510	60	1401	1482	1321	1623	1442	1429	1490	1340	1546	1460
Mar bravo	/a	Charcoal	530	60	1397	1458	1318	1617	1430	1422	1489	1329	1539	1456
Mar bravo	Beta-194788	Charcoal	720	50	1283	1386	1233	1398	1323	1360	1490	1279	1519	1423
Mar bravo	Beta-194788b	Charcoal	980	50	1041	1154	1021	1213	1104	1175	1503	1141	1521	1411
Mar bravo	/b	Charcoal	530	60	1397	1458	1318	1617	1430	1422	1489	1329	1539	1456
Mar bravo	Beta-194787	Charcoal	520	60	1398	1461	1318	1621	1435	1425	1490	1332	1543	1458
Mar bravo	Beta-194790	Charcoal	590	60	1323	1436	1298	1453	1396	1401	1491	1319	1523	1443
Mar bravo	AA68845	Charcoal	583	36	1394	1432	1321	1445	1407	1406	1481	1326	1528	1445
Mar bravo	AA68843	Charcoal	609	45	1322	1419	1300	1440	1385	1394	1490	1320	1518	1438
Mar bravo	Beta-194791	Charcoal	580	50	1327	1439	1312	1454	1405	1406	1486	1325	1522	1445
Mar bravo	/c	Charcoal	650	50	1309	1401	1290	1416	1349	1346	1488	1301	1515	1429
Mar bravo	/d	Charcoal	800	40	1226	1285	1188	1380	1257	1234	1495	1225	1512	1413
Mar bravo	/e	Charcoal	850	50	1188	1275	1054	1292	1229	1221	1498	1192	1516	1412
Mar bravo	End Phase									1461	1529	1445	1599	1501
Puerto Chanduy	Start Phase									932	1286	625	1447	1088

(*Continued*)

(*Continued*)

Site	Sample	Material	^{14}C age BP	Error ±	Calibrated unmodeled ages (BC/AD)					Calibrated modeled ages (BC/AD)				
					1 σ (CI)		2 σ (CI)			1 σ (CI)		2 σ (CI)		
					from	to	from	to	median	from	to	from	to	median
Puerto Chanduy	AA-31704	Charcoal	657	43	1309	1398	1291	1408	1347	1305	1400	1283	1519	1358
Puerto Chanduy	Beta-124405	Charcoal	790	80	1214	1382	1054	1399	1265	1221	1389	1071	1536	1296
Puerto Chanduy	Beta-124406	Charcoal	870	50	1181	1270	1049	1286	1213	1165	1305	1055	1481	1253
Puerto Chanduy	AA-31705	Charcoal	1035	65	993	1150	897	1210	1070	1024	1262	978	1484	1162
Puerto Chanduy	W-835	Charcoal	760	500	772	1665	257	. . .	1195	1139	1431	909	1665	1293
Puerto Chanduy	End Phase									1322	1530	1290	1915	1445
Salango	Start Phase									1277	1471	1064	1588	1368
Salango	Beta-194793a	Charcoal	630	60	1311	1415	1291	1436	1356	1335	1466	1302	1585	1420
Salango	Beta-194792	Charcoal	570	60	1327	1446	1297	1460	1408	1393	1494	1321	1594	1439
Salango	AA-68847	Charcoal	468	32	1436	1485	1424	1615	1458	1441	1506	1426	1622	1478
Salango	AA-68844	Charcoal	374	24	1498	1627	1464	1632	1560	1465	1566	1459	1647	1528
Salango	End Phase									1480	1650	1462	1905	1586
Pepa de Huso	SI-42	Charcoal	1100	105	885	1146	692	1212	984	883	1192	688	1560	1038
Loma Guasango	IVIC-883	Bone collagen: human	1180	70	775	992	689	1025	906	775	992	689	1026	906
Sube y Baja	IVIC-855	Charcoal	950	70	1045	1210	995	1268	1128	1044	1239	993	1583	1174
Joa	GrN-8639	Charcoal	625	50	1318	1413	1296	1432	1355	1318	1446	1289	1718	1401
Chirije	ZXX-1305	Charcoal?	850	105	1050	1296	1023	1391	1210	1050	1296	1022	1392	1209

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