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Peru archaeological radiocarbon database, 13,000–7000 ^{14}C B.P.

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ABSTRACT

We synthesize the available radiocarbon data from Peruvian archaeological sites for the Terminal Pleistocene through Middle Holocene. Compilation and calibration of this dataset provide a new opportunity to examine trends in archaeological site distributions and occupation intensity. We compare the spatial and temporal patterning of radiocarbon dated archaeological sites with paleoenvironmental information to discuss possible human–environment dynamics and to identify major taphonomic biases affecting the existing dataset. Further, we evaluate the history of radiocarbon dating of Terminal Pleistocene to Mid-Holocene archaeological sites in both coastal and highland settings to identify research biases affecting the record and suggest ways in which future research may address these deficiencies.

1. Introduction

Calibration and analysis of radiocarbon and geospatial data can provide archaeologists with a means to examine the geographic and chronological patterning of archaeological sites and estimate the directionality and timing of colonization (Hamilton and Buchanan, 2007; Faught, 2008; Steele, 2010) and prehistoric demographic change (Rick, 1987; Kuzmin and Keates, 2005; Buchanan et al., 2008; Peros et al., 2010; Steele, 2010) in large landscapes. A necessary first step for such analyses is the synthesis of the primary radiocarbon and geospatial data, summary of the major geographic and chronological trends in the dataset, and identification of taphonomic and sampling biases affecting the record.

We created a digital database of all archaeological radiocarbon data for Peru for the period 13,000 to 7000 ^{14}C B.P. using primary literature, published review papers (Ravines, 1982; Rick, 1987; Chauchat, 1988; Lynch, 1990; deFrance et al., 2009), and a previous radiocarbon database (Ziolkowski et al., 1994). Our new database does not include radiocarbon dates produced from earth science investigations, such as lake and wetland sediment coring projects.

2. Methods

All data were entered in an Excel spreadsheet following protocols designed by the editors and database organizers. Our priority was to obtain the most complete record of radiocarbon dates, including site names and locations, references, lab numbers and dating method, radiocarbon means and standard errors, and information about the archaeological contexts sampled and materials dated. Due to the large number of radiocarbon dates for Peru for the period of interest, we were not able to provide comprehensive summaries of associated technologies or detailed information on paleoenvironment and paleoeconomy of the sites, but we invite other researchers to contribute information and further develop this collaborative database. Many radiocarbon dates were published in obscure literature, so in addition to primary publications we accessed lab reports in the journal *Radiocarbon* where numerous labs reported date information up to the early 1980s, and we relied heavily upon the Ziolkowski et al. (1994) radiocarbon database for dates obtained prior to the mid-1990s.

There is a wide range in quality and availability of published site-location data. Where possible, we gathered site coordinates published in the primary literature, but we did not verify the accuracy of these coordinate data. For cases in which horizontal coordinates were available and elevations were not, we used the Google Earth program to estimate the site elevation, rounded to the nearest 5 m. To facilitate use of site coordinate data in geographic information systems (GIS), geographic coordinates in degrees, minutes, and seconds were converted to decimal degrees using the Federal Communications Commission online converter (2011). For cases in which coordinate data were provided in the Universal Transverse Mercator (UTM) projection, we used an online converter to yield decimal degree coordinates (Ewert Technologies, 2011). We were able to provide *X*, *Y*, and *Z* coordinates for nearly all sites in the database.

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In addition to the standard fields, we included four additional fields in our database, which are used in our analysis of the database in the following sections. To examine trends in the history of archaeological radiocarbon dating research, we listed the year the sample was dated. In some cases the year of the sample dating was unavailable, so for these cases we listed the year the date was first published. While this inconsistency will tend to shift some radiocarbon dating work forward in time, the effect should not result in great inaccuracy, as we are examining the data on a decadal scale.

The other three additional fields include the maximum, minimum, and median values of the 1-sigma calibrated age range, using the Calib 6.0.1 program to calibrate all ages (Bronk Ramsey, 2009). We used the IntCal09 and Marine09 calibrations (Reimer et al., 2009) where appropriate, with no added delta-R correction for dates on marine materials since the data are widely distributed geographically throughout Peru and chronologically through the 13,000–7000 ^{14}C age range. The Marine09 calibration assumes a constant 405 ^{14}C-y offset, which is an oversimplification because of the large variability of marine reservoir corrections in some oceanic regions, particularly in strong upwelling regions (Reimer et al., 2009). The Pacific Coast of Peru is an area of strong but variable upwelling, with potentially large fluctuations in the marine reservoir effect over seasonal to millennial scales, and the reservoir effect may be expressed differently in different species (Kennett et al., 2002; Owen, 2002; Jones et al., 2007, 2010; deFrance et al., 2009). As this variability is currently poorly constrained both geographically and temporally, there is no alternative at this time but to use Marine09 and to acknowledge that radiocarbon dates on marine materials may be inaccurate (Reimer et al., 2009). All reported calibrated ranges and maximum, minimum, and median values are 1-sigma cal B.P. The southern hemisphere calibration curve SHCal04 (McCormac et al., 2004) does not yet include the entire 13,000–7000 ^{14}C B.P. span, so no southern hemisphere offset was applied to any of the dates.

For our analysis of the radiocarbon data we evaluated all dates using accepted criteria for dating past activity at an archaeological site location, which require undeniable human artifacts or skeletons in undisturbed geological contexts and indisputably associated with the dated material, which must be appropriate for the dating technique applied (Haynes, 1969; Dincauze, 1984). A further criterion developed for evaluating Terminal Pleistocene-age sites, but one which we consider valid for sites of all time periods, is precise (1-sigma standard errors $\leq$300 ^{14}C y) radiometric dates based on cultural carbon found in primary stratigraphic association with artifacts (Roosevelt et al., 2002; Steele and Politis, 2009). We eliminated from our analysis all dates that did not meet the above criteria. We did not discard singular dates that meet all of these criteria, as eliminating sites with single ages would significantly decrease the number of dates and sites in our analysis. We also did not discard dates obtained on aggregate organic samples unless these samples failed to meet the other criteria. Although we do not consider the discarded dates in our discussion, all radiocarbon dates are retained within the database so that other investigators may choose whether or not to include these dates in their analyses.

3. Results

3.1. Summary

The new Peru archaeological 13,000–7000 ^{14}C B.P. radiocarbon database contains 308 radiocarbon dates from 109 archaeological sites and 43 distinct projects of investigation. There are 220 dates from 92 coastal sites and 88 dates from 17 highland sites (Appendices A and B).

For our analysis of the radiocarbon database, we flagged and removed 37 dates from 20 archaeological sites (Appendix B). Twelve of these are accepted dates for non-cultural contexts at three sites. These dates were discarded because we wished to examine trends in the absolute number of cultural dates through time and space. Following well-established criteria for evaluating the validity of radiocarbon data (Haynes, 1969; Dincauze, 1984; Roosevelt et al., 2002; Steele and Politis, 2009), discussed above in Section 2, we discarded 25 radiocarbon dates from cultural contexts at a total of 17 archaeological sites. These dates are problematic due to 1-sigma standard errors >300 ^{14}C y, dating of inappropriate material (*e.g.*, bone apatite fraction, animal feces), substantial disagreement with other, more precise ages from the same stratigraphic context and/or site, contamination issues indicated by the dating laboratory, and poor or no association with dated material and cultural materials.

Fifteen of 25 (60%) problematic dates have 1-sigma errors exceeding 300 ^{14}C y, and many of these dates were obtained on basal organic material. Of these, 11 dates had one or more additional problems other than the large sigma, for example, stratigraphic inconsistency, inconsistency with other, more precise dates from the same context, dating of inappropriate material, or dating of aggregate organic samples. While it is tempting to accept anomalously early and imprecise basal ages as accurately dating an initial human occupation event, their large analytical uncertainties may result from insufficient organic material to yield reliable ages.

The problem of imprecision of earliest ages is exacerbated by the frequent presence of non-cultural organic material at the base of cultural sequences in Peru and the possible incorporation of this material in samples used for obtaining basal human occupation ages. This particular issue is common in Central Andean rockshelters, which act as natural sediment traps and which frequently have been used as dens by rodents, birds, and mammalian predators. Acceptable basal ages must come from levels containing cultural material, not from animal feces (Ravines 1967a, 1967b, 1972) or organics from sediment containing no associated artifacts or unequivocal cultural materials (*e.g.*, Jaywamachay, MacNeish et al., 1981).

Moreover, imprecise, singular basal ages that are chronologically and stratigraphically inconsistent, such as the single 12,000+ ^{14}C ages from Guitarrero Cave (Lynch, 1980), Telarmachay (Lavallée et al., 1982, 1985, 1995), and Pachamachay (Rick, 1980), must be rejected unless supported by additional age determinations. Where more precise dates have been obtained from the same occupation level, such as at Guitarrero Cave (Jolie et al., 2011), the totality of the evidence illustrates the statistical variation inherent in attempting to date an initial occupation event; viewed in this context, the singular anomalous age can easily be detected and discarded.

The problem of imprecise, singular basal ages is also common to coastal sites that contain shallow, compressed, or deflated occupation sequences, which often lack sufficient organic material for dating. In some cases, dates have been obtained on aggregate charcoal samples or organic material in subsoil, resulting in large 1-sigma errors. The absence of sufficient datable organic material at some sites led to attempts to date bone apatite, which is not a reliable material for radiocarbon dating (Tite, 1972).

Despite the obvious problems with imprecise dates, which in most cases the original investigators have pointed out, models of human settlement and chronology of specific technologies in Peru have frequently been hinged upon these questionable data. The tendency to accept these ages is understandable, given the general dearth of radiocarbon data on the initial settlement phases. However, imprecise radiocarbon dates are problematic for constructing accurate and precise chronologies of occupation events, regardless of the time period being investigated.

Problematic radiocarbon dates were discarded for the following analyses of Terminal Pleistocene to Mid-Holocene archaeological settlement patterns in Peru. We discuss coastal and highland settlement dynamics chronologically for each ^{14}C millennium, providing maximum and minimum 1-sigma calibrated age ranges. No archaeological sites have been dated from 13,000 to 7000 ^{14}C B.P. in the lowlands east of the Peruvian Andes. Consequently, coastal and low-elevation sites are defined as all sites <1200 m elevation on the western side of the Andes Mountains, and highland sites include all sites ≥1200 m elevation.

3.2. Terminal Pleistocene, 11,100–10,000 ^{14}C B.P. (~13,000–11,500 cal B.P.)

No accepted radiocarbon dates from coastal or highland Peruvian archaeological sites pre-date 13,000 ^{14}C (Rick, 1987). Initial human settlement of the coast of Peru in the Terminal Pleistocene is indicated by 33 radiocarbon dates ≥10,000 ^{14}C B.P. from 13 archaeological sites (Fig. 1) and 10 projects of investigation. Terminal Pleistocene sites include maritime-focused occupations at Quebrada Jaguay (Engel, 1981; Sandweiss et al., 1998), the Ring Site (Sandweiss et al., 1989), and Quebrada Tacahuay (Keefer et al., 1998; deFrance et al., 2001, 2009; deFrance and Umire Álvarez, 2004) on the south coast, interior Fishtail and Paiján sites in the Chicama-Jequetepeque area on the north-central coast (Chauchat, 1988; Dillehay et al., 1989, 2003, 2007; Stackelbeck, 2008; Maggard, 2010; Dillehay, 2011) and on the central coast near Lima (Patterson, 1966; Chauchat, 1988), and possibly an Amotape site on the far north coast (Richardson, 1978).

The oldest coastal Terminal Pleistocene radiocarbon dates are 11,650 ± 180 ^{14}C B.P. (~13,700–13,340 cal B.P.) obtained on charcoal at El Palto CA-9-89 on the north-central coast (Dillehay, 2011) and 11,200 ± 115 ^{14}C B.P. (~12,800–12,580 cal B.P.) obtained on shell at the Amotape PV-8-29 site on the far north coast (Richardson, 1978). The earliest El Palto date is followed by 11 additional Terminal Pleistocene ages spanning ~13,050–11,400 cal B.P. from eight sites in the same region (Dillehay et al., 2003, 2007; Stackelbeck, 2008; Maggard, 2010). The early Amotape date is a singular Terminal

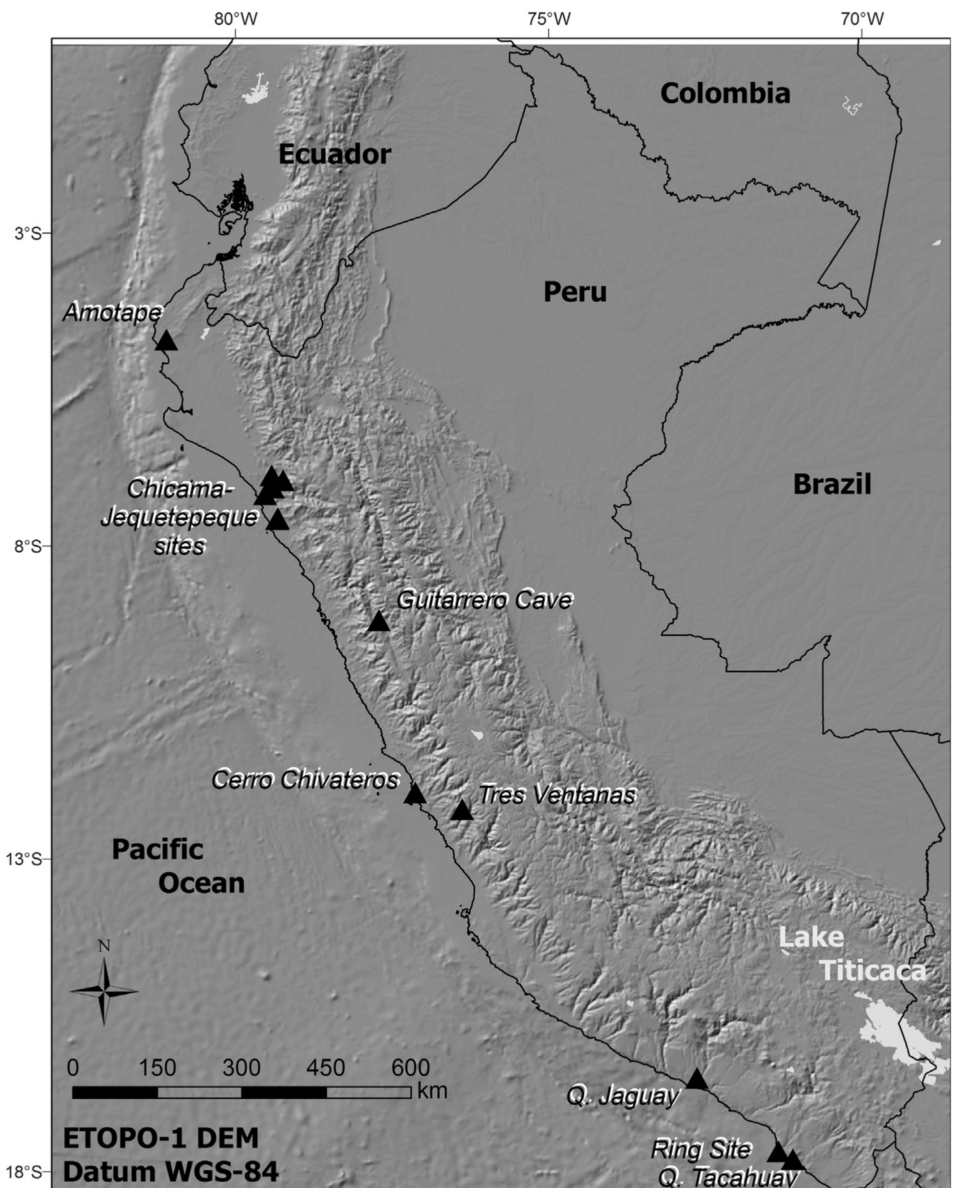

Fig. 1. ETOPO-1 digital elevation model with Terminal Pleistocene (11,100–10,000 ^{14}C B.P.) archaeological sites contributing radiocarbon dates to the Peru database.

Pleistocene age obtained for this site and is ~1700 ^{14}C y older than the next oldest date obtained at any of the five sites in this area. Further, the early age for Amotape was determined on an *Anadara tuberculosa* mangrove mollusk shell with an unknown reservoir. We decided to retain this date in the database, but we caution that this single early age is equivocal.

The earliest thoroughly dated Terminal Pleistocene coastal sites are Quebrada Jaguay and Quebrada Tacahuay, maritime-focused sites located on Peru's southern coast. Twelve published conventional dates from Quebrada Jaguay span ~13,200–11,400 cal B.P. Quebrada Tacahuay has four conventional and six accelerator mass spectrometry (AMS) ages spanning ~12,850 to 11,350 cal B.P. The Ring Site, a large shell midden on the south coast, yielded a single Terminal Pleistocene basal date of 10,575 ± 105 ^{14}C B.P. (~12,040–11,430 cal B.P.) obtained on marine shell. This early date is nearly 2000 ^{14}C y older than five other dates obtained for overlying levels, and like the date from the Amotape site on the far north coast, incorporates an unknown reservoir effect.

Although singular Terminal Pleistocene dates have come from several Andean cave sites, PAn-12-58 (Lynch, 1971), Pachamachay (Rick, 1980), Telarmachay (Lavallée et al., 1982, 1995), and Jaywamachay (MacNeish et al., 1981), all of these early dates are problematic. The only acceptable pre-Holocene dates for settlement of the Peruvian Andes are from two cave sites, Guitarrero Cave at 2580 m elevation in the Callejón de Huáylas (Lynch and Kennedy, 1970; Lynch, 1971, 1980; Lynch et al., 1985) and Tres Ventanas at 3810 m elevation in the Upper Chilca canyon (Engel, 1969, 1970). A single radiocarbon date on charcoal from Tres Ventanas indicates an initial occupation at ~11,940–11,260 cal B.P.

Guitarrero Cave is the most thoroughly dated site in the Peruvian Andes, with an initial occupation as early as ~12,700–11,850 cal B.P., indicated by conventional radiocarbon ages on probable aggregate charcoal samples (Lynch, 1971, 1980; Lynch et al., 1985). Recent, precise AMS dating of textile and cordage fragments from the same contexts dated previously suggests an initial occupation of Guitarrero Cave at ~12,100 cal B.P., with the bulk of the site sequence dating between ~11,300 and 10,300 cal B.P. (Jolie et al., 2011).

3.3. Early Holocene, 10,000–9000 ^{14}C B.P. (~11,500–10,200 cal B.P.)

Data on the Early Holocene is provided by 46 radiocarbon dates from 27 coastal sites and 27 dates from eight highland sites (Fig. 2). There were eight coastal and seven highland projects that contributed dates in this time range. In the Early Holocene, areas on the Pacific Coast initially colonized during the Terminal Pleistocene continued to be occupied. Two replicate dates on a single sample from Siches PV-7-19 span ~11,070 to 10,300 cal B.P. (Piperno, 2011), suggesting either continuity with the Terminal Pleistocene age at Amotape or an initial Early Holocene occupation of the far north coast.

On the south coast at Quebrada Jaguay and Pampa Colorada (Ravines, 1966; Engel, 1970; Sandweiss et al., 1998; McInnis, 2006) and at the Chicama-Jequetepeque area on the north-central coast (Chauchat, 1988; Dillehay et al., 1989, 2005; Piperno and Dillehay, 2008; Stackelbeck, 2008; Maggard, 2010), multiple new sites were created in the vicinity of earlier occupied Terminal Pleistocene sites, reflecting a pattern of localization. Investigators working in these areas suggest that springs in *lomas* and thorn forest-covered hills were more active than today and were foci for hunter–gatherer settlement. Continued occupation is evident at Quebrada Tacahuay (Keefer et al., 1998; deFrance et al., 2001, 2009; deFrance and Umire Álvarez, 2004), and numerous new sites were created along that section of the Pacific Coast (Engel, 1970, 1981, 1987, 1991; Keefer et al., 2003), as in the Quebrada Jaguay/Pampa Colorada and Chicama-Jequetepeque regions.

In the Early Holocene occupation continued at Guitarrero Cave (although not at Tres Ventanas) and widespread settlement began in the western Peruvian Andes, including the high-altitude *puna* ecozone (Fig. 2). Sites include caves and rockshelters, including Lauricocha (3930 m) (Cardich, 1964), Pachamachay (4300 m) (Rick, 1980), Panalauca (4030 m) (Rick and Moore, 1999), Telarmachay (4200 m) (Lavallée et al., 1982, 1995), Quiqche (3900 m) (Engel, 1970), Puente (2580 m) and Jaywamachay (3400 m) (MacNeish et al., 1981), Toquepala (2800 m) (Ravines, 1966, 1967a, 1972), and the open-air site Asana (3450 m) (Aldenderfer, 1998).

The predominance of occupation of caves and rockshelters over open-air locales probably reflects the higher preservation potential and greater visibility of these protected settings compared to open-air sites subject to burial and erosion, rather than forager settlement preference. The increase in the number of settlements in the Early Holocene may indicate biogeographic and demographic expansion into highland valleys and the puna from lower-elevation source areas (Aldenderfer, 2006), although the relative lack of earlier Terminal Pleistocene settlement data from the Peruvian Andes may result from inadequate sampling rather than the absence of people.

3.4. Early to Mid-Holocene, 9000–8000 ^{14}C B.P. (~10,200–8800 cal B.P.)

For the Early to Mid-Holocene, there are 53 radiocarbon dates from 38 coastal sites and 25 dates from nine highland sites (Fig. 3). Eleven coastal projects and seven highland projects contributed dates. The general geographic pattern appears to be one of continuity. Previous sites on the coast and in the highlands continued to be occupied, and new sites were created in their vicinity. The overall geographic clustering of sites in the Early to Mid-Holocene likely results from the spatial limits of individual survey projects. However, the absolute increase in coastal sites and dates from previous periods may track a steady demographic expansion. New coastal sites contributing dates for this period include Kilometer 4 (deFrance et al., 2009) and Quebrada de los Burros (Fontugne et al., 1999; Lavallée et al., 1999a, 1999b) on the far south coast and numerous sites discovered by Engel (1966, 1969, 1970, 1980, 1981, 1984, 1991) on the central-south coast.

3.5. Mid-Holocene, 8000–7000 ^{14}C B.P. (~8800–8000 cal B.P.)

Settlement shifts at the coast are apparent for the 8000–7000 ^{14}C B.P. period, indicated by 52 radiocarbon dates from 34 coastal sites. By contrast, 20 dates from 10 highland sites suggest considerable consistency with the previous period (Fig. 4). What does the geographic change at the coast represent? Two areas densely settled in the previous period, the Chicama-Jequetepeque area of the north-central coast, and the Quebrada Jaguay-Pampa Colorada area of the south coast, both had a substantial decline in the number of settlements during this period. The Chicama-Jequetepeque area settlements decreased from 13 to six sites, while the Quebrada Jaguay-Pampa Colorada area settlements decreased from 13 to five sites. Meanwhile, the number of sites at the mouths of perennial river valleys along the central-south coast increased substantially, from five to 12 settlements. The geographic change in coastal settlements therefore was not unidirectional but varied between regions, suggesting that these settlement trends cannot be artifacts of the difference in number of calibrated years (1400 vs. 800) between periods. deFrance et al. (2009) have suggested that regional settlement shifts along the south coast resulted

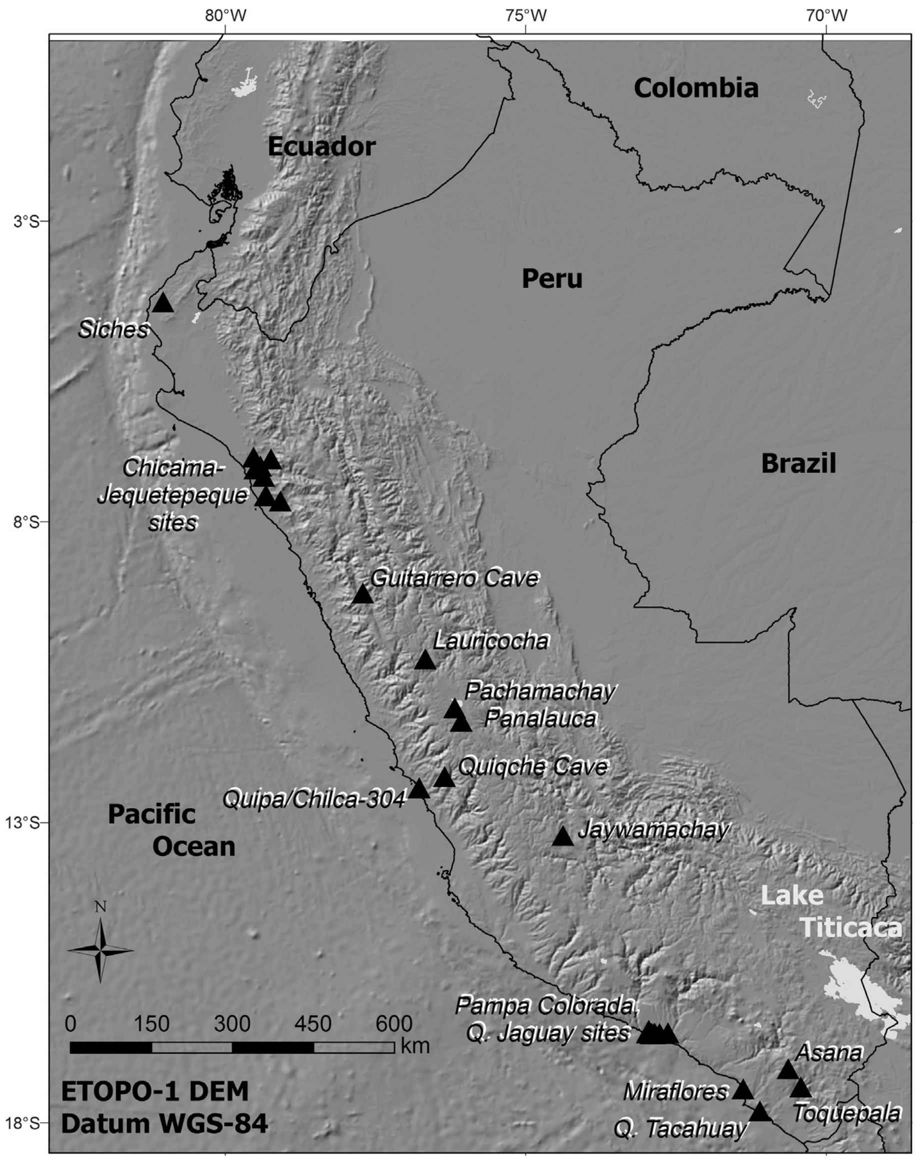

Fig. 2. ETOPO-1 digital elevation model with Early Holocene (10,000–9000 ^{14}C B.P.) archaeological sites contributing radiocarbon dates to the Peru database.

from drier conditions, making some locales unfavorable for continued settlement.

4. Discussion

4.1. Human–environment dynamics

The most significant feature of Terminal Pleistocene climate was the brief return to stadial conditions during the late-glacial period. Although the occurrence of this cold reversal has now been firmly established by paleoecological and glacier records (*e.g.*, Rodbell et al., 2009 and references therein), there remains considerable uncertainty as to the timing of this event. In Peru, where the cold reversal commonly has been correlated with the Younger Dryas (YD) event from ~12,900 to 11,600 cal B.P. (Alley et al., 1993; Clapperton et al., 1997; Mahaney et al., 2007), there is growing glacial geologic evidence suggesting that the late-glacial re-advance predated the YD interval (Mercer and Palacios, 1977; Rodbell and Seltzer, 2000; Goodman et al., 2001; Bromley et al., 2011a).

Despite the chronological uncertainty, the broad distribution of existing geologic evidence suggests that the potentially abrupt late-glacial cold anomaly occurred throughout the Peruvian Andes, with significant implications for both highland and lowland environments. These effects include expansion of permafrost and snow cover at high altitudes (>4000 m), in addition to enhanced glacial input to local drainage basins. At lower elevation and along the Pacific Coast, increased glaciation 'upstream' likely resulted in generally elevated levels of river discharge, particularly during the winter highland dry season.

On the basis of glacial-geomorphic reconstructions made throughout the Peruvian Andes, it is clear that nowhere did the late-glacial advance present a significant physical barrier to human migration. Glaciers along the length of the Andes were confined to cirques and high alpine valleys (Rodbell and Seltzer, 2000; Smith et al., 2005; Hall et al., 2009). In the western cordillera of southern Peru, for example, the ice margin did not descend below ~4700 m on Nevado Coropuna (Bromley et al., 2009, 2011a, 2011b). Moreover, if late-glacial cooling did indeed pre-date the YD interval, the high-elevation Peruvian Andes were

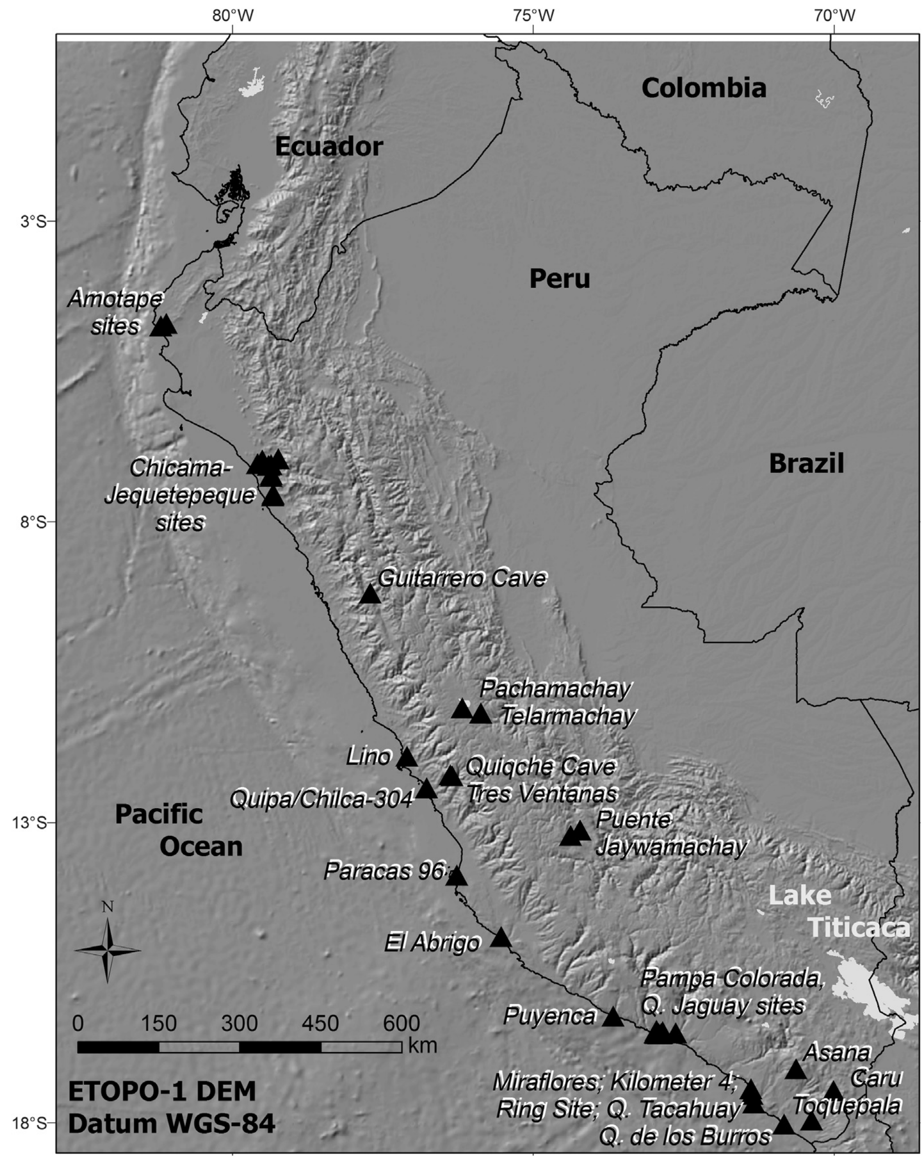

Fig. 3. ETOPO-1 digital elevation model with Early to Mid-Holocene (9000–8000 ^{14}C B.P.) archaeological sites contributing radiocarbon dates to the Peru database.

already warming before the first people were settling both coastal and highland Peru.

The glacial events described here largely represent temperature fluctuations. However, there is abundant evidence from Peru, and tropical South America in general, indicating that the late-glacial climate also experienced high-magnitude and potentially abrupt changes in precipitation. Starting ~12,700 cal B.P., YD cooling in mid- and high-northern latitudes was accompanied by a pronounced southward shift of the inter-tropical convergence zone (ITCZ). This phenomenon has been reproduced by modelling studies (*e.g.*, Vellinga and Wood, 2002; Chiang and Bitz, 2005) and confirmed by an array of observational data from both the northern and southern hemispheres (Schulz et al., 1998; Haug et al., 2001; Wang et al., 2001, 2004). Although primarily an oceanic effect (Chiang and Bitz, 2005), displacement of the ITCZ also would have affected rainfall patterns over land, likely resulting in an increase in moisture availability and precipitation during the austral wet season, accompanied by decreased rainfall in the northern tropics (Haug et al., 2001). The YD in Peru, therefore, probably was manifested as an overall increase in available precipitation, a scenario that is consistent with lake-level reconstructions from Lake Titicaca (Baker et al., 2001), faunal evidence from the Peruvian coast (Mächtle et al., 2010), and an ice-core oxygen-isotope record from Nevado Coropuna (Buffen, 2008).

Following the end of the Younger Dryas interval, the ITCZ shifted north in response to both the end of stadial conditions in the northern hemisphere and increasing northern insolation. This effect is illustrated best by the sedimentary record from Cariaco Basin, which shows increasing rainfall in the northern tropics until ~9000 cal B.P. (Haug et al., 2001). On a first-order scale, the northward migration of the ITCZ at that time likely would have reduced available precipitation in the southern tropics, including Peru, though this pattern may have been variable.

It is possible that the apparent fluorescence of Early Holocene sites and subsequent Mid-Holocene decrease in the number of sites in the Chicama-Jequetepeque and Quebrada Jaguay-Pampa Colorada areas stemmed from common causes; in any case, at least in the latter region, this trend toward abandonment continued for several millennia through the Mid-Holocene (Sandweiss et al., 1998; Sandweiss, 2003). Terminal Pleistocene–Early Holocene

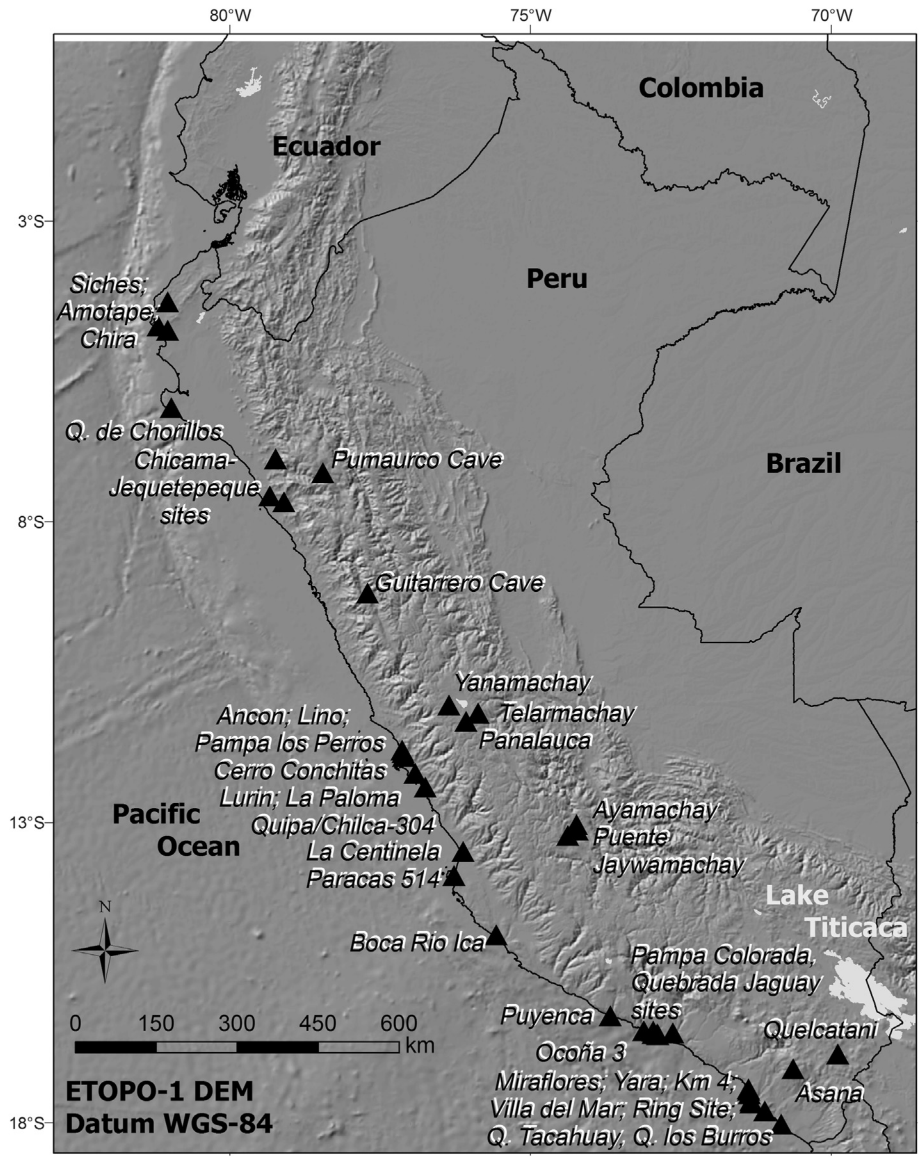

Fig. 4. ETOPO-1 digital elevation model with Mid-Holocene (8000–7000 ^{14}C B.P.) archaeological sites contributing radiocarbon dates to the Peru database.

sites in both of these areas were located near spring locations, and these springs may have been more active prior to the Mid-Holocene. Coastal aquifers are recharged by coastal rains associated with a breakdown in the thermal inversion under El Niño-Southern Oscillation (ENSO) conditions. Is there evidence for a reduction in ENSO conditions between ~8800 and 8000 cal B.P.? Various lines of evidence suggest this is so (Rollins et al., 1986; Sandweiss et al., 1996, 2001, 2007).

Sedimentologic evidence indicates enhanced ENSO activity for Peru's south coast in the Terminal Pleistocene and Early Holocene (Fontugne et al., 1999; Keefer et al., 2003; Carré et al., 2005), with a decrease in ENSO activity beginning ~8400 cal B.P. and lasting until ~5300 cal B.P. (Keefer et al., 2003 and references therein). While the effect of severe ENSO rainfall events on particular sites has been linked with site abandonment (Fontugne et al., 1999; Keefer et al., 2003), generally enhanced ENSO conditions and associated greater coastal precipitation would have recharged coastal aquifers on the south coast until the cessation of ENSO activity ~8400 cal B.P. Sites located at ephemeral springs and quebradas may have been abandoned after the onset of more arid conditions (Sandweiss et al., 1998), while settlements in better-watered locales, *e.g.*, Quebrada los Burros (Fontugne et al., 1999), Ring Site, Kilometer 4, and Yara (deFrance et al., 2009), persisted.

Greater coastal humidity has also been documented for the Terminal Pleistocene and Early Holocene on the desert coast at 14.5° S latitude (Mächtle et al., 2010) and in a marine sediment core at 12° S latitude (Rein et al., 2005). Tropical marine taxa in coastal archaeological faunal assemblages indicate that warmer sea surface temperatures persisted north of 10° S latitude from ~9000 to 5800 cal B.P. (Sandweiss et al., 1996; Sandweiss, 2003). Although southward depression of tropical water masses may have increased coastal humidity, it is unknown whether there was a dramatic change in coastal precipitation in northern Peru.

4.2. Taphonomic biases

Several investigators previously have pointed out the apparent cultural diversity suggested by site assemblages below 1200 m elevation (Ossa, 1973; Richardson, 1981; Dillehay et al., 2003; Sandweiss, 2003). Early maritime-focused sites have been discovered on the far north and far south coast, areas where the continental shelf is steep and where lateral sea-level transgression following the last glacial termination was minimal. Early Paiján sites are located 15 km or more from the modern shoreline, and they would have been 20–100 km inland when first occupied (Richardson, 1981; Chauchat et al., 1992). Not surprisingly, faunal remains at Paiján sites indicate a subsistence strategy focused primarily on terrestrial resources. However, these sites also contain small quantities of marine fish bone, indicating contact with the shore. Given the distance, either the Paiján people spent time on the coast, or they were in contact with shoreline settlements, yet, no Terminal Pleistocene shoreline sites have been found in this area (Sandweiss, 2003). Because the continental shelf is wide and shallow in central and north-central Peru, early coastal archaeological sites in this area were probably submerged with post-glacial sea-level transgression (Richardson, 1981); the few known Terminal Pleistocene to Mid-Holocene sites on the Peruvian coast occur in areas of relatively narrow, steep shelf, as Richardson predicted.

Regional patterning of different economic orientations among Peruvian Terminal Pleistocene sites below 1200 m elevation is at least in part due to the differential preservation of maritime-oriented sites along the coast. The sample of early sites includes different portions of settlement systems preserved in different areas, but we currently lack a complete set of coastal and interior sites from a single area. This gap in our knowledge prevents us from determining the nature of inter-zonal connections and addressing the links between sites with different resource orientations at this time.

We discussed the radiocarbon data from the coast and the highlands as separate entities, without reference to possible geographic continuity between coastal and highland archaeological settlements. The reason for this is apparent in Fig. 5, which plots calibrated 1-sigma median ages of all coastal and highland dates in the radiocarbon database against elevation. At 4480 m elevation, Yanamachay is the highest dated site in the database. Only one site, Ascope-5, has been dated above 600 m and below 2580 m elevation for the first five millennia of Peruvian prehistory. What is the reason for the absence of dated sites in this elevation range?

Lynch (1967) pointed out the conspicuous absence of pre-4000 year old archaeological sites at intermediate elevations and in valley bottoms in Peru, suggesting that intensive irrigation agriculture and dense settlement of the valley bottoms with the last few thousand years obscured or destroyed earlier occupation evidence. This situation applies to nearly all of the perennial river valleys descending from the Andes to the Pacific Coast, and very few, if any, survey projects targeting Terminal Pleistocene to Mid-Holocene archaeological sites have been conducted in drier inter-valley areas. Outside of the river valleys and approximately at the ~1000 m elevation limit of seasonal fog (*garua*), the landscape is extraordinarily arid even by the standards of the Peruvian coastal desert. Vegetation of any kind is lacking, and it is hard to imagine any occupation that is not transient and ephemeral.

Geomorphic investigations in the Majes and Moquegua River Valleys of southern Peru indicate profound landscape alteration since the Terminal Pleistocene. In the Majes River there are no intact fluvial terraces below the Capiza River confluence at ~950 m elevation (Steffen et al., 2009). Geomorphic study and radiocarbon dating of fluvial landforms of the Moquegua River, ~200 km southeast of the Majes River, revealed that ~80 percent of the Moquegua River floodplain is younger than 550 ^{14}C B.P., a result of periodic ENSO floods (Manners et al., 2007). Burial and erosion, along with intensive agricultural activities, have likely obscured or destroyed many early sites in river valleys between 600 and 2500 m elevation.

Relative to intermediate elevations within corridor drainages, lower-elevation zones including coastal desert and lomas and thorn forest-covered hills, and higher-elevation zones, including the upper reaches of inter-Andean valleys and the puna, are conducive to preservation and visibility of archaeological sites. Low sedimentation rates and limited fluvial erosion have preserved early sites in areas without major population centers and intensive irrigation agriculture. Rockshelters at high elevations are particularly conspicuous on the landscape and exhibit great potential for preservation of datable organic remains (Goldberg and Macphail, 2006).

Although looting of Late Holocene archaeological sites, particularly of prehistoric cemeteries and sites with art and monumental architecture, is a serious problem on the coast of Peru, looting generally does not plague early sites at the coast or in the highlands. Unlike the situation in North America, early projectile point styles

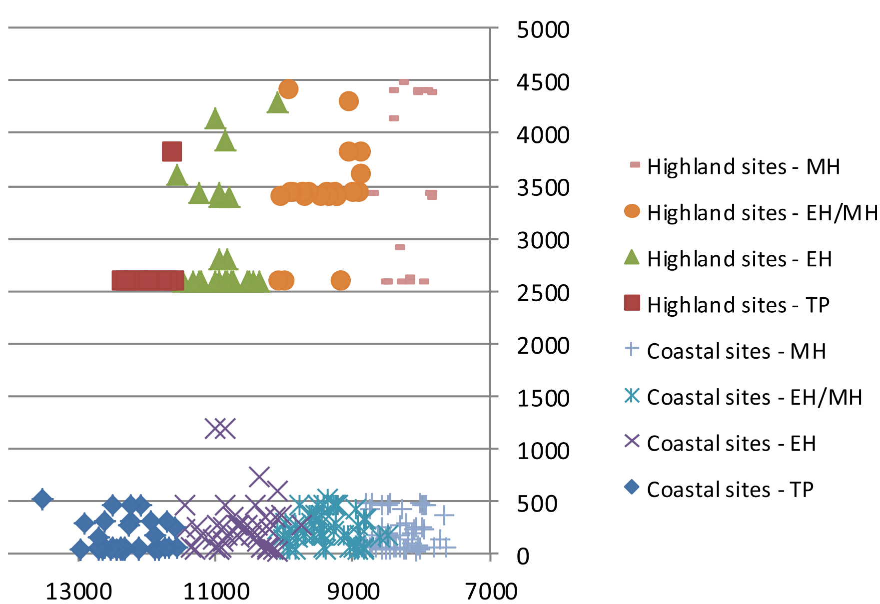

Fig. 5. One-sigma cal B.P. median values on *X*-axis plotted against elevation (in m) on *Y*-axis for all radiocarbon dates, arranged by time period for coastal and highland archaeological sites. Time periods include: TP – Terminal Pleistocene, EH – Early Holocene, EH/MH – Early to Mid-Holocene, MH – Mid-Holocene.

Table 1
Peru radiocarbon data 13,000–7000 ^{14}C B.P. by decade. Decades producing virtually no highland radiocarbon dated-sites are highlighted.

Decade	#Dates	#Sites	#Projects	#Coastal sites	#Highland sites	#Coastal dates	#Highland dates
1950–1959	1	1	1	0	1	0	1
1960–1969	44	21	12	13	8	16	27
1970–1979	32	22	6	21	1	31	1
1980–1989	80	19	9	11	8	26	54
1990–1999	59	23	6	23	0	59	0
2000–2009	60	27	7	27	0	60	0
2010–2011	20	8	2	7	1	16	5
Total	**296**		**43**			**208**	**88**
% Total	**100.0**		**100.0**			**69.7**	**30.3**

are not the focus of hobby collection by non-archaeologists, and monumental sites containing ceramics, textiles, metals, and other grave goods sought by collectors are ubiquitous on the landscape and more obvious targets for looters.

4.3. Dating issues

Aldenderfer (2006) has suggested that high elevations in the Peruvian Andes were colonized from low-elevation source areas, with higher-elevation settings colonized progressively later as technological and physiological adaptations were acquired. No archaeological research targeting early sites has been conducted in the lowlands east of the Peruvian Andes, but we can compare the earliest-dated archaeological sites in the highlands with those on the Pacific Coast. The distribution of calibrated 1-sigma median ages vs. elevation plotted in Fig. 5 appears to confirm Aldenderfer's hypothesis, with the earliest coastal dates from Quebrada Jaguay and Quebrada Tacahuay pre-dating the earliest highland dates at Guitarrero Cave by up to 630 years and progressively later initial occupation of higher altitudes.

However, the earliest coastal dates may be inaccurate for constraining the age of initial coastal occupation if those dates were obtained on marine shells incorporating a substantial reservoir or on old wood that was scavenged long after the date of death (Kennett et al., 2002; Jones, 2008; deFrance et al., 2009; Jones et al., 2010). One way to resolve this issue would be to date archaeological bone from coastal sites where old wood and old water are potential problems for accurate dating of initial human presence.

4.4. Sampling biases

An examination of the number of archaeological radiocarbon dates, sites, and projects in coastal and highland settings by decade illustrates strong research biases affecting the existing database. Table 1 includes all radiocarbon dates – accepted and rejected – from cultural contexts in all archaeological sites (accepted non-cultural dates are still omitted). The most prominent trend is the much larger sample of sites and dates obtained at the coast vs. the highlands. Coastal research has contributed 84.4% ($n = 92$) of all sites ($n = 109$) and 70.3% ($n = 208$) of all dates ($n = 296$) documented for the 13,000–7000 ^{14}C B.P. period. One potential reason for the greater number of sites and dates at the coast relative to the highlands is the much easier access of coastal areas via more developed transportation infrastructure and more numerous and dense modern population centers. Moreover, archaeological research programs focusing on early periods have a longer and more continuous history at the coast than in the highlands due to many factors, including the impact of the Shining Path insurgency on highland research from 1980 to the early 1990s (see below). More recent investigations have been conducted in proximity to areas previously under study.

Including problematic dates, highland sites tend to be better dated than coastal sites, with averages of 5.12 dates per site for the highlands and 2.26 dates per site for the coast. Over half (55.7%, $n = 49$) of all highland dates ($n = 88$) come from only two sites, Guitarrero Cave (37.5% of all highland dates, $n = 33$) and Asana (18.2% of all highland dates, $n = 16$). By contrast, the three best-dated coastal sites, Quebrada Jaguay-280 ($n = 21$), Quebrada Tacahuay ($n = 18$), and Quebrada de los Burros ($n = 12$) together contribute 24.5% ($n = 51$) of all coastal dates ($n = 208$) since the sample of coastal sites is greater. What this point illustrates is not that the two best-dated highland sites are over-dated – in fact, extensive dating of any site is good scientific procedure. Rather, the sample of dated highland sites is so small that the two best-dated highland sites dominate the record.

An examination of coastal and highland dates obtained since 1960 shows that of the last five decades of archaeological research, three decades (the 1970s, 1990s, and 2000s) have had virtually no dated highland sites contributed to the record. The absence of investigations in the 1990s is understandable, given the hazards posed by the Shining Path and associated unrest in the Peruvian highlands; however, the continued absence of data from 2000 to 2009 is more difficult to explain and may reflect lasting effects from the interruption of research programs focused on the Peruvian Andes.

The result of this disparity between coastal and highland research is that we lack adequate site and chronological information from elevations >1200 in Peru. The two well-dated sites of Guitarrero Cave and Asana do not provide adequate spatial coverage to understand long-term Andean cultural patterns, and dating from most other highland sites is generally inadequate to provide chronologically constrained long-term records of human activities. Considering the total absence of archaeological data in this time period from the eastern Andean slope and Amazon Basin, only the Pacific coastal zone has received adequate attention – and there, the record is systematically biased by post-glacial sea-level rise. Understanding the directionality of human settlement, demographic patterns, and human–environment dynamics from the Terminal Pleistocene to Mid-Holocene will not be realized until investigation and absolute chronology building of the interior zones of Peru are given higher priority.

5. Conclusions

Both the Pacific Coast and Andes of Peru were settled approximately 13,000 years ago in the Terminal Pleistocene, with initial settlement of the coast possibly occurring ~600 years earlier than the highlands and progressively later initial settlement of higher elevations in the Peruvian Andes in the Early Holocene. However, understanding the chronology of initial coastal settlement, as well as the directionality of initial settlement of the coast and the highlands, is limited by considerable imprecision and uncertainty in early coastal dates obtained on marine shell and charcoal from possible old wood.

The geographic distribution of coastal sites through the Early Holocene suggests patterns of localization and demographic expansion, beginning in initially settled areas and possibly encouraged by generally wetter conditions than those that prevail today. Coastal populations in Peru grew through time, indicated by more numerous settlements and more radiocarbon dates from the Early to Mid-Holocene. Highland data indicate stable numbers of sites and dates from the Early to Mid-Holocene. Settlement shifts in the Mid-Holocene along the Peruvian Coast and near-abandonment of some areas previously occupied were regionally variable, possibly reflecting variations in water availability along the coastal plain and hills.

The existing Terminal Pleistocene to Mid-Holocene archaeological radiocarbon data for Peru point mainly to large gaps still existing in the archaeological record as a result of severe taphonomic and research biases. Some of the site preservation problems, such as the lack of shoreline sites in areas of shallow, broad continental shelf and the likely destruction of landforms and sites in intermediate elevations in Andean corridor drainages, are largely beyond remedy. Although evidence from some early sites is suggestive of inter-zonal connections, understanding the nature of such connections is limited by a lack of a complete set of linked sites situated in various resource zones. Research biases over the past 50 years, including a total lack of highland research over three decades, have resulted in a large disparity between coastal and interior datasets, limiting the understanding of basic patterns of settlement, population, and technology in the highlands, as well as the nature of inter-zonal connections.

Synthesis and analysis of archaeological radiocarbon and geospatial data from Peru from 13,000 to 7000 ^{14}C B.P. should facilitate additional large-scale analyses, and we hope that some of the biases currently plaguing the record may be addressed by future field and laboratory research. Some recommendations for future work include:

1) More archaeological survey and excavation work in interior zones above 1200 m elevation is needed to construct basic chronological sequences.
2) As Terminal Pleistocene to Mid-Holocene archaeological data from intermediate elevations ~600–2500 m is almost completely missing, landforms with the potential of preserving sites of Terminal Pleistocene to Mid-Holocene age in corridor drainages should be located and investigated. Additional survey work in intermediate elevations in inter-valley areas would also help address current deficiencies.
3) The accuracy of coastal radiocarbon data needs to be improved to address the old wood and old water problem for Terminal Pleistocene sites and sites dated solely with marine shells. Development of pretreatment protocols and the success of high-precision AMS dating of archaeological bone collagen (Steele and Politis, 2009) suggest that dates obtained on bone collagen could resolve many of the ambiguities surrounding early coastal dates.

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Appendices A and B. Supplementary material

Supplementary data related to this article can be found online at http://dx.doi.org/10.1016/j.quaint.2012.08.2052.

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