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# The Influence of El Niño on Settlement Patterns in Lomas de Lachay, Central Coast, Peru

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*ABSTRACT*

The Lomas de Lachay region is located about 100 kilometres north of Lima, between Río Chancay and Río Huaura valleys. It is situated approximately 10 km from the coastline, where advection fogs meet the first ridges of the Andes allowing for the development of a peculiar ecosystem of fog oases known as *lomas*. Three distinct geosystems have been distinguished there: coastal desert, lomas and mountain desert.

While during El Niño with episodes of ENSO the mountain desert and valleys of perennial rivers are devastated by catastrophic floods caused by torrential rains, in lomas El Niño less abundant precipitation comes about which permits the development of vegetation and also the presence of active springs during the dry season.

Due to the increased availability of water in periods of frequent El Niño episodes human groups in the past were able to establish permanent settlements in the Lomas de Lachay area. When El Niño events became rare, however, only seasonal exploitation of lomas were possible. Changes in settlement patterns in the research area were therefore strongly influenced by the frequency and magnitude of El Niño events. Moreover, due to the El Niño benevolent impact, only a lomas geosystem is convenient for human activity on a larger scale, thus the majority of the archaeological sites are located within the limits of fog oases.

## 1. Introduction: methodology and theory

Interdisciplinary geoarcheological investigations were undertaken in Lomas de Lachay region (Central Andes, Peru). The aim of the research is the reconstruction of relations between Pre-Colombian human activity and the natural environment, particularly human adaptation strategies to the marginal ecosystem of the lomas. Archaeological survey and geomorphologic mapping with sediment sampling of the Lomas de Lachay area were conducted during the fieldwork and covered about 80 km$^2$.

Despite the fact that archaeologists have been working in Lomas de Lachay since the beginning of the 20$^{th}$ century (Villar 1935; Tello 1943; 1957; Strong and Willey 1943; Kroeber 1944) the region still remains poorly understood. Our team conducted geoarcheological research for the first time in Lomas de Lachay which can be used to verify previous results and propose new interpretations.

During the fieldwork, deposits were sampled in 25 outcrops. The structural properties of the accompanying sedimentary series were recorded from the walls of the pit. 27 sediment samples for sedimentological (mainly textural) analysis and 11 for geochronological (thermoluminescence) analysis were collected. One profile will be presented below in detail.

Archaeological investigations only provided the preliminary results, which should be verified by future research. Potential archaeological sites, localized on satellite images, were verified during the fieldwork and new sites were also discovered. Relics of architecture and profiles of trenches and pits left by *huaqueros* (grave robbers)

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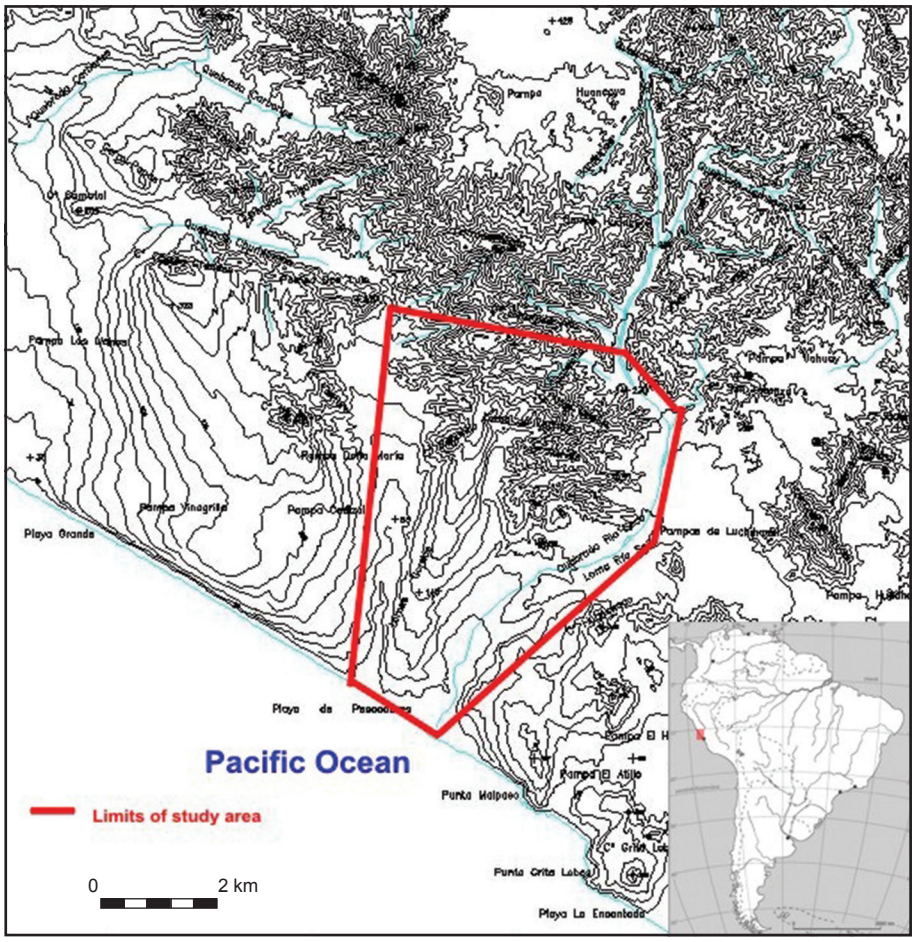


**Figure 1.** Location of Lomas de Lachay.

were documented. Diagnostic pottery sherds and other artefacts were documented. It should be emphasized that archaeological fieldwork was only a survey and therefore the presented results have a preliminary character and need to be confirmed by future research.

## 2. Environment

Lomas de Lachay (11°21′30″S; 77°22′10″W; 150–600 m a.s.l.) is situated on the western slopes of the Andes, on the first low ridge from the coast of the Pacific Ocean (400–1.500 m a.s.l.). The research area is located on the western coast of South America, approximately 100 km north of Lima (Figure 1).

The western slopes of the Central Andes are characterized by large relief dynamics resulting from the intense tectonic uplift of the Andes (Sébrier *et al.* 1988). At a distance of about 100 km from the Pacific Ocean, the main ridge of the Western Cordillera above 5.000 m a. s. l. The relief of the western slopes of the Western Cordillera developed in an extremely active tectonic regime connected with the subduction zone, with climatic changes due to the Cenozoic uplift of the Andes and sea level changes associated with the Quaternary glacial-interglacial cyclicity. The main valleys of the rivers flowing down from the mountains are separated by relatively low ridges (400–1.500 m a.s.l.), which descend directly to the Pacific Ocean. Fluvial erosion has created a dynamic landscape with deep gorges and narrow ravines.

The study area is situated within two ecological zones: the extremely dry, hot coastal desert *chala* (0–500 m a.s.l.) and the warm and dry *yunga* (500–2.300 m a.s.l.) (Pulgar Vidal 1987). The Lomas de Lachay area is characterized by an arid climate due to the influences of the cold Humboldt Current, the orographic barrier of the Andes and the location in a low latitude zone. Dense fog from the ocean (*garúa*) is periodically deposited on the westernmost slopes of the Andean barrier during the austral winter. The first mountain ridge acts as an orographic barrier causing condensation of the fog during the austral winter and thus allowing for the development of various ecosystems. It results in overgrowing in the area with fog-alimented seasonal oases (lomas). Two distinct seasons are particularly characteristic: 1) the humid season (from June to November) with a precipitation peak from the end of July to mid-September) and 2) the dry season (from December to May). During the humid season the relative humidity reaches 100% and average temperatures are less than 15 °C. In the summer (the dry season) the relative humidity is about 82% and average temperatures 20°C (Shoobridge 2003). Occasionally, heavy rains associated with El Niño episodes occur in the summer and allow for the development of relatively abundant vegetation during

**Figure 2.** Shrubby lomas on the western slopes of Lomas de Lachay.

the dry season. During the years with El Niño episodes, the mean precipitation reaches more than 300 mm per year and is 2–3 times higher than the average (Saito Diaz 1972, Ordóñez and Faustino 1983, Pinché 1994). According to the meteorological data from Lomas de Lachay, the annual sum of precipitation in a normal year is 163 mm, while during an El Niño year it reaches 322 mm[1].

The seasonally humid ecosystem of the Lomas de Lachay is an oasis in the coastal desert with refuge for a rich number of flora and fauna species. During the winter season, the lomas ecosystem allows many animals to feed, rest, and reproduce in the area. Four kinds of lomas communities are present in the Lomas de Lachay: "lomas de herbáceas" (with only herbaceous plants at ca. 150–300 m a.s.l.), "lomas arbustivas" (park-like lomas ca 300–600 m) (Figure 2), "lomas de bromeliáceas" (on rocky cliffs), "lomas de cactáceas" (with cactus on the areas not alimented by fogs).

[1]We would like to thank Head and the personnel of Reserva Nacional de Lachay for providing us with data on precipitation in Lomas de Lachay.

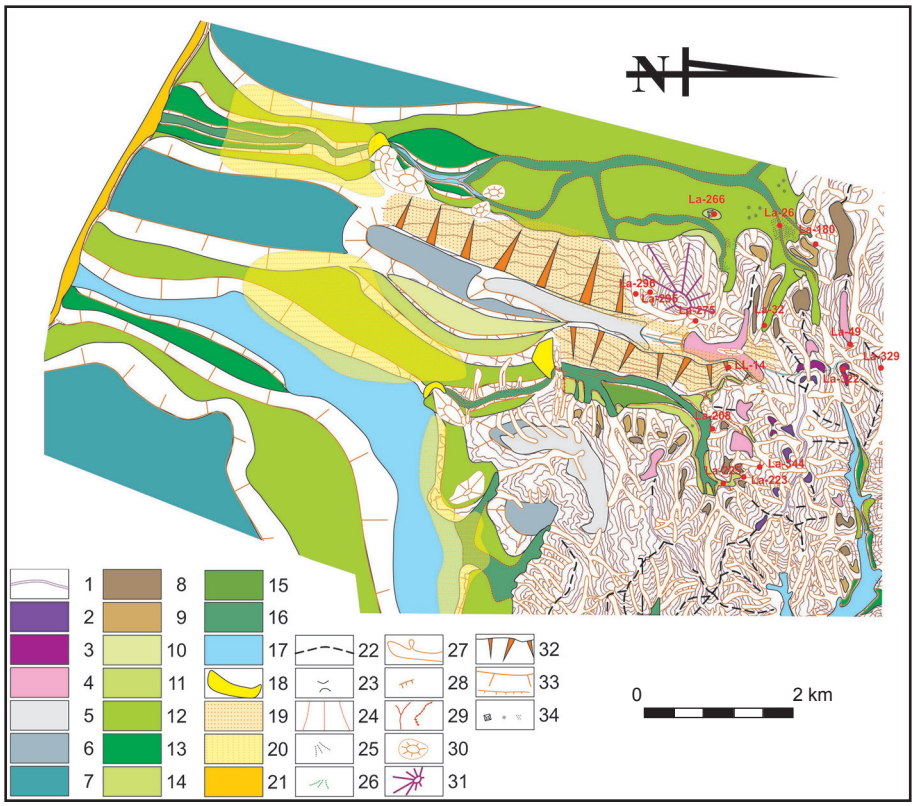


**Figure 3.** Geomorphological map of Lomas de Lachay with the archaeological sites and profiles discussed in the text. 1 – hilltop planation surface; 2 – planation surface 550 m a.s.l.; 3 – planation surface 500 m a.s.l.; 4 – planation surface 430 m a.s.l.; 5 – marine terrace 350–250 m a.s.l.; 6 – marine terrace 250–150 m a.s.l.; 7 – marine terrace 150–50 m a.s.l.; 8 – planation surface 350–250 m a.s.l.; 9 – planation surface 300–200 m a.s.l.; 10 – terrace IV 250–150 m a.s.l.; 11 – terrace III 200–140 m a.s.l.; 12 – terrace II; 13 – terrace I; 14 – terrace III in Q. Hato Viejo; 15 – terrace II in Q. Hato Viejo; 16 – valley floor; 17 – valley floor of episodic braided river; 18 – barkhan; 19 – older aeolian cover; 20 – present-day aeolian cover; 21 – beach; 22 – watershed; 23 – pass; 24 – ravine; 25 – talus; 26 – alluvial fan; 27 – small erosional valley; 28 – scarp in the valley floor; 29 – young erosional gorge; 30 – hummock; 31 – volcanic form; 32 – slope; 33 – edge; 34 – anthropogenic form (pyramid, mounds, looted graves).

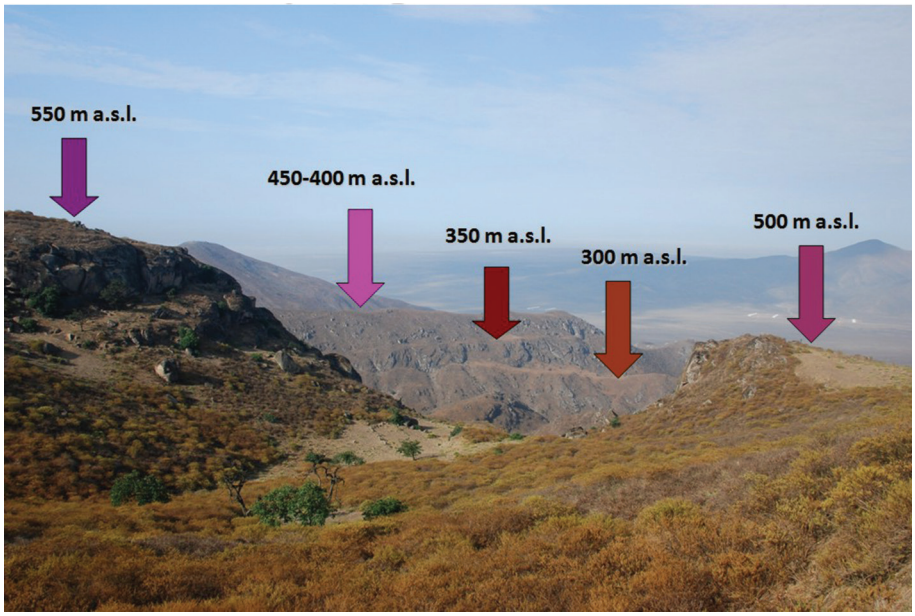


**Figure 4.** Tertiary planation surfaces in Lomas de Lachay.

Above lomas communities, deserts occur (Ferreyra 1953; Rundel *et al.* 1991).

The present-day relief of the Lomas de Lachay area is composed of a sequence of both old planation surfaces and uplifted marine terraces, deeply cut by valleys with perennial and episodic streams. High relief diversity was triggered by endogenic (uplifting, faulting, volcanism) and exogenous processes (marine, mass movements, fluvial, aeolian) during the Cenozoic (Kalicki *et al.* 2013b) (Figure 3).

The main erosion and accumulation forms on the western slopes of the Lomas de Lachay probably developed during the Neogene and Pleistocene and are relatively stable at present. The oldest relief development stages are connected with tectonic movements and reflected in the planation surfaces (terrestrial peneplanes). Six main planation surfaces have been recognized: 600 m, 550 m, 500 m, 430 m, 350 m, 250 m and 300–200 m a. s. l (Figure 4). Uplifted marine terraces occur at elevations: 350–250, 250–150 and 150–50 m a.s.l. Relatively high denivelation of one marine terrace (surface of the bench) may be related to the uplift during the formation of the abrasion platform or later neotectonic movements (comp. *e.g.* Macharé, Ortlieb 1992; Marquardt *et al.* 2004).

Four types of river valleys in two groups were discovered in the study area: A) an allochtonous group with large drainage basins and B) an autogenous (local) group with small drainage basins. In the first group there are: 1) valleys of permanent rivers, while the second one has 2) valleys of ephemeral rivers; 3) short dry valleys of tributaries in the lomas area and 4) short dry valleys in the mountain desert area. A permanent river is represented by Río Seco which developed a wide valley with four terraces (Figure 5) during


**Figure 5.** Pleistocene terrace and Holocene alluvial plain with braided alluvium of Rio Seco.

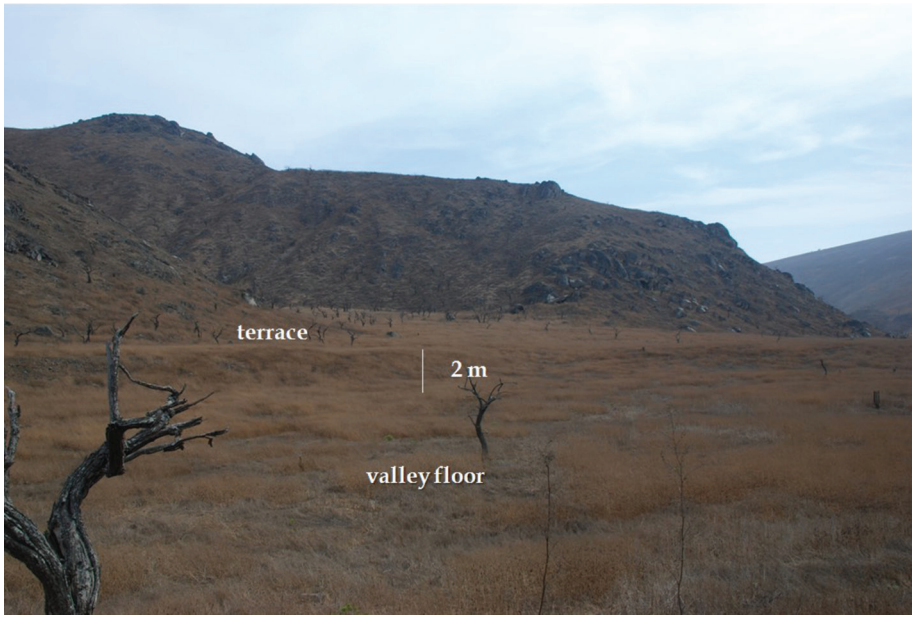


**Figure 6.** Dry valley of Quebrada Hato Viejo (Rio Seco drainage basin).

the Neogene and the Pleistocene. The stages of terrace formation were connected with tectonic uplift and relative sea level changes. Due to intensive irrigation in the upper reaches, Río Seco has changed from a perennial to a periodic river. Its valley floor is not covered, however, by aeolian sands. The braided system is well developed and the present-day overbank deposits occur in the valley floor due to the blocking of the valley by the Pan American Highway.

Ephemeral rivers (Quebrada Doña Maria), flowing only during El Niño episodes, have created large valleys in the Neogene and the Pleistocene. Two terraces formed by braided alluvia have been recognized in the Doña Maria valley of the study area. Very few traces of current fluvial activity with the additional meandering pattern (*e.g.* a thin cover of overbank deposits, a short reach with a meandering channel with a point bar) have been recorded in the valley and it is closed by barchan dune in the area of the narrowing of the valley by erosional hummocks (erosional remnants). Dry valleys of secondary streams in the Lomas de Lachay (*i.e.* Quebrada Hato Viejo; Quebrada Teatino I; Quebrada Teatino II) have one or two terraces formed by colluvial-alluvial deposits and valley floors with partly preserved dry channels (Figure 6). Traces of fluvial activity in those valleys and V-shaped valleys of their tributaries are extremely uncommon – above all: slack water deposits in gapes (*e.g.* Quebrada Herbabuena) or debris flows "huaico/huayco" (*e.g.* Quebrada Cactus) (Figure 7). These features are results of flash floods during the El Niño episodes. In the dry valleys of the secondary rivers situated in the mountain desert areas (Quebrada Guayabito), the relief dynamics are extremely high having been formed by catastrophic processes associated with El Niño episodes (flash floods, debris flows, etc.). A braided alluvial plain and certain terraces have been found there (Figure 8). The dynamics and efficiency of the processes are so high due to the extremely sparse vegetation caused by the lack of seasonal fogs.

In the study area, climate drying has resulted in the deposition of aeolian covers on planation surfaces and marine terraces up to 430 m a.s.l. with the exception of the

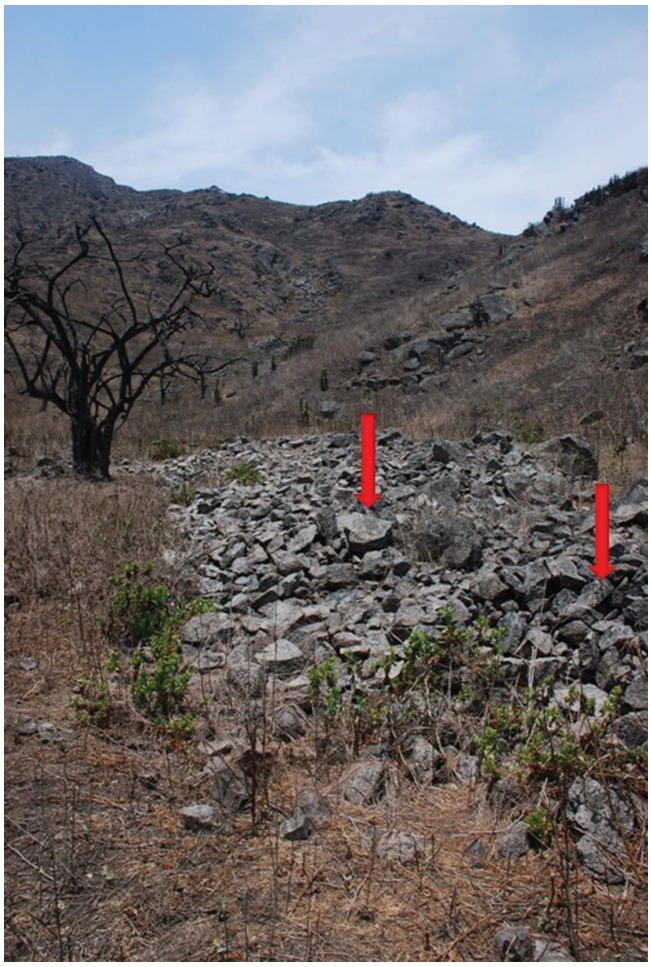

**Figure 7.** Debris flow (*huaico*) accumulation (marked with red arrows) in the valley floor of Quebrada Cactus.


**Figure 8.** Mountain desert geosystem (Quebrada Guayabito). Notice terrace and active braided river alluvial plain.

Quaternary river terraces. According to our TL dating: 21.2±3,2 ka BP (KIE-790) and 18,6±2,8 ka BP (KIE-792), aeolian sedimentation began in the LGM and has continued up until the present. Moreover, differences in the spatial distribution of the weathering types of granite have been observed: chemical with tafoni within lomas and physical with scree (regoliths) in the coastal desert and mountain desert.

The aeolian activity is remodeling coastal desert plains. The western slopes and western parts of the valleys overgrown by herbaceous lomas and shrubby lomas are characterized by intense chemical weathering and extremely uncommon traces of fluvial or slope processes. Traces of catastrophic events (*i.e.* flash floods, debris flows, episodic river erosion, road cuttings) are connected with the El Niño episodes. Rainfalls during El Niño episodes provided water for springs and autogenous river discharge even in dry valleys. In the cactus lomas of the eastern slopes, torrential rains during El Niño triggered catastrophic events such as debris flows and flash floods, which led to the strong Holocene alluviation of the older relief. Intense fluvial activity and slope processes are transforming the eastern valleys and slopes of Lomas de Lachay during El Niño episodes. The influence of ENSO events is radically different in lomas and desert geosystems. It changes water circulation allowing the formation of perennial springs and rivers in the lomas, while initiating the clustering of catastrophic events in mountain deserts. As a consequence of this climatic factor, there is high ecological diversity within a small area: the stable geosystems of lomas on the western slopes contrast with the extremely dynamic mountain desert (with "lomas de cactáceas") geosystems on the eastern slopes (Kalicki *et al.* 2013b).

Due to the microclimatic conditions, plant cover and geomorphologic processes, three separate geosystems can be distinguished in the studied Lomas de Lachay areas: 1) coastal desert, 2) herbaceous and shrubby lomas on the western slopes and 3) cacti lomas and mountain deserts on the eastern slopes (Ferreyra 1953; Rundel *et al.* 1991).

## 3. Archaeological survey

Within the limits of coastal desert, several concentrations of shells of marine molluscs and land snails, usually mixed with pottery fragments were found. These sites manifest themselves in the landscape as light yellow, cream or white spots on the darker surface of the desert. The marine shell fragments were too large and well preserved to be carried by wind or animals, so they were probably brought there by humans. In a number of cases we also found the well preserved shells of the small land snails which inhabit lomas. The pottery fragments were of a different age, even within a few metres in distance. We found pottery with characteristic Formative coma rim, pottery with red angoba from the Early Intermediate Period, Teatino fragments with incised motives, typical Black-on-White Chancay ware and even some black, reductive fragments (possibly Chimú Inka).

Such a variety of styles from different periods and cultures suggests that these sites are archaeological palimpsests, which were formed as a result of centuries of human activity. It is suggested by the presence of more than 20 separate concentrations of potsherds and fragments of shells of marine molluscs. The human impact was presumably not intensive, since the shell and pottery fragments only create a discontinuous and extremely thin (a few centimetres thick), superficial layer overlying aeolian sands without any artefacts. Moreover, since fragments from earlier periods have not been removed by erosion or buried by sediments, we suggest that at least since the Early Horizon (800–500 BC) there were no significant changes in the sedimentological context. The geosystem of coastal desert seems to be quite stable and did not offer appropriate conditions for human activity. The shells of the land snail species may be a consequence of the massive thanatocoenosis which occurred after the population boom triggered by unusual humid conditions during an intensive El Niño episode (see Craig 1992).

We interpret shell sites as a kind of desert pavement which was formed by wind erosion, when finer particles were removed by deflation concentrating coarser material such as shells and ceramic fragments on the surface. Similar sites with desert pavement, formed by fragments of pottery and marine shells brought by humans, were found by Belknap and Sandweiss (2014) on beach ridges in the Chira Valley. Unlike the Chira Valley sites, however, those from Lomas de Lachay are separated from each other by large areas of sands without archaeological material. Moreover, the density of shell fragments and pottery is much smaller in shell sites from Lomas de Lachay than in sites situated on beach ridges in the Chira Valley.

Despite the fact that Lomas de Lachay has been the subject of a number of archaeological studies (Villar 1935; Tello 1943, 1957; Strong and Willey 1943; Kroeber 1944; Maldonaldo 1952; Bonavia 1962; Mármol 1962; Engel 1987; Torreo *et al* 1990; Barraza *et al.* 1994; Shoobridge 2003; Cabrel Palomares 2006; Echavarría Lopez, Ruiz Alba 2006) our understanding of the cultural processes in the region is still in the very early stage. The majority of the investigations, which were aimed at preceramic periods, are partial, incomplete or unpublished. In a number of cases, the research results were interpreted according to old nomenclature, chronology or theories. Unfortunately the published material (*e.g.* Engel 1987) and unpublished manuscripts[2] which the authors had access to usually did not allow for identifying precise sites where previous researchers had worked.

During the survey, only a few Formative sites were detected. In all but one case they were composed of a limited number of pottery fragments. Only one ceramic fragment was highly diagnostic and may be dated to the Early Horizon (800–500 BC). No clear spatial pattern of sites was detected. Due to the scarcity of remains, it seems that from ca 1800 to 100 BC there were no permanently or even seasonally inhabited settlements. The limited number of ceramic fragments presumably document only short-term visits to the lomas to exploit (gathering, hunting) natural resources during the humid season.

The remains of a large structure were discovered (La-266), however, in the middle part of the Doña Maria valley. Pre-Colombian people transformed a natural hill to create a series of platforms and terraces. The main axis of the complex is NW–SE oriented, with a main entrance in the north-western part. After crossing a low, rectangular platform with the remains of stone walls, there are two, several metre wide terraces. There were some small structures on the top of the hill built from irregularly shaped blocks of stone of local origin. Their walls are conserved only to a height of several centimetres. The low, rectangular platform, terraces and the summit were connected by stone staircases, which are still visible at present. Large quantities of irregular blocks of stone suggest that there was also a structure (enclosure wall?) at the foot of the south-eastern slopes of the stack. Nevertheless, the location of stone construction far from agricultural areas, central staircase and the architectural plan composed of a series of low platforms and terraces all suggest a Formative (possibly Early Formative *i.e.* 1800–1200 BC) age of the structure. Certain fragments of late Pre-Colombian pottery were collected, however, from the surface of the site. Engel (1987) claims, that this structure belongs to the Chancay culture and calls it a pyramid, from which the elite were overseeing the work of the commoners. This interpretation seems improbable, because no late Pre-Colombian pottery fragments from the site can be safely assigned to the Chancay culture. As a preliminary hypothesis we would suggest that this pyramid is of a Formative period age and had a public (ceremonial?) function. The dating and function of the site still remains uncertain, however, and must be verified by excavations.

A number of Lima culture sites, inhabited during the Playa Grande ceramic phase (200–500 AD), have been discovered in lomas. Five Lima culture residential sites were detected: La-32 (Quebrada Teatino II), La-49 (Naranjito Bajo); La-180 (Quebrada Teatino II); La-225 (Quebrada Hato Viejo) and La-322 (La Revuelta). Engel (1987) mentions La-322 as "Guayabito" and also associates it with the Lima culture. Three of them are situated in small valleys, which open into quebradas of a second order and two are located on the planation surfaces near inactive water springs. It should be emphasized that the settlements were located in areas where water was present on the surface (springs, small streams particularly during humid periods) or were easily accessible from shallow groundwater aquifers.

The settlements are characterized by small U-shaped walls, which were built of a single row of irregular, angular blocks of local granitoide. Neither the structures, nor their entrances follow any typical orientation. Fragments of the Playa Grande phase pottery and sometimes also grinding stones are scattered on the surface. In a grave robbers' pit in La-180, a thick layer (approximately 50–60 cm) of fragmented marine shells was discovered. This suggests that Lima culture groups from Lomas de Lachay had access to the marine resources of the nearby Pacific Ocean.

In close proximity to the Lima culture sites, vast areas of agricultural terraces were found. Out of the 64 sites with agricultural terraces, almost 80% (51 sites) are channel-in terraces (Figure 9), while slope bench terraces constitute only ca 14% (9 sites) of all the agricultural terrace sites. The terraces were composed of a retaining wall, and a relatively flat surface for cultivation. Depending on the slope gradient, the height of the retaining wall could oscillate between several centimetres and more than 3 metres. In addition, the width of the cultivation space ranged from few metres to several dozen metres depending on the slope gradient. The retaining walls were built of one or two rows of irregular, angular blocks of stone, the dimensions of which decrease with the increasing height of the wall.

The location of the agricultural terraces on the floor of the second order quebradas upper parts, on the floor of the

[2]We would like to thank Don Bernardino Ojeda, co-operator of F. Engel, for providing us with access to an unpublished manuscript from Engel's investigation in Lomas de Lachay.

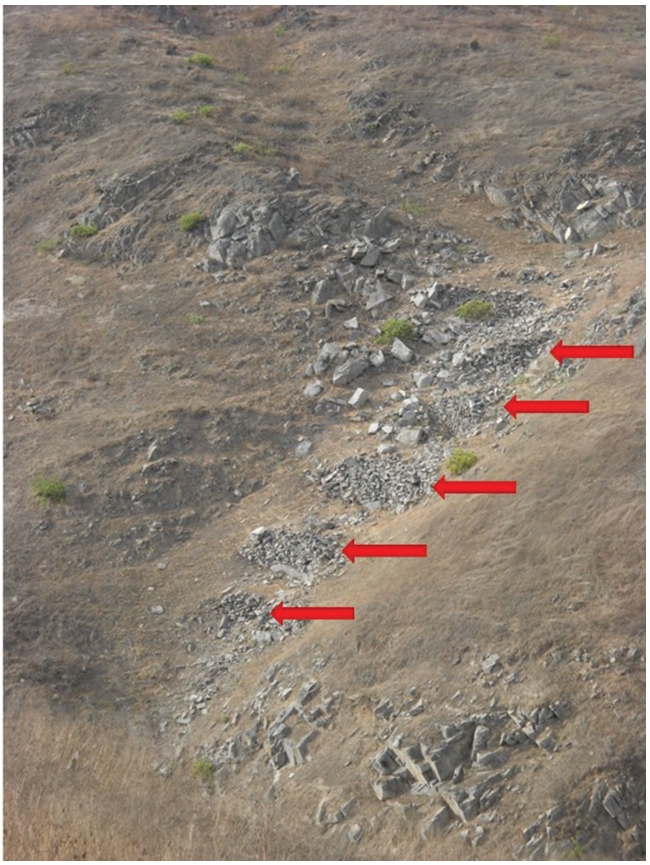

**Figure 9.** Channel-in terraces (marked with red arrows) of Lima culture (La-295 site).

small lateral quebrada tributaries, which open to the second order quebradas or even to the floor of large gullies, suggest that the major concern of the Lima culture farmers was the lack of water. The water table is usually high in such places, so the roots of cultivated plants can absorb water from the ground water. Moreover, during any rain events, water runoff was channelled through concave morphological forms (valleys, quebradas, gullies), so that the soil in these parts of the landscape remained humid longer than anywhere else in lomas. During El Niño episodes, even small streams could exist in the upper parts of the second order quebradas. Agriculture without irrigation could consequently develop in lomas due to the location of agricultural terraces in such places. Brooks (1998) suggests that channel-in type terraces are characteristic for a dry climate conditions.

Slope bench terraces were usually located on southern, south-western or western slopes of ridges, which were exposed toward the fog coming from the Pacific. The agricultural conditions there were much better than on the eastern or northern slopes and allowed for the development of fog-fed agriculture. It nevertheless seems that fog agriculture was never as important as agriculture alimented by runoff and ground water associated with channel-in terraces.

Features associated with water control were detected in quebrada floors. A number of small and relatively deep (1–1.5 m) stone enclosures were detected (*e.g.* La-275, La-296). Their location on the valley floor suggests an association with water storage. They could have functioned as water reservoirs to store water acquired during El Niño episodes or as wells to access ground water. A possible dam was discovered (Figure 10) on the floor of one of the third order quebradas south of Cerro Redondo (La-295). It is composed of the earthen dike faced with stone walls made of irregular blocks of local granitoide on both sides. The structure is about 2.5 m wide, 1 m high and about 10 m long. It has a convex shape of an N–S orientation and a convex side facing west *i.e.* downstream. This structure was probably designed to block the water flow and create a reservoir, where excess water could be stored. It may consequently be interpreted as an infrastructure adapted to a dry climate with a seasonal abundance of water.

In one of the small quebradas, which opens into Quebrada Hato Viejo, the remains of a possible water-control infrastructure were detected (La-223). It consists of low (ca 60 cm high) V-shaped walls on both sides of the quebrada. The structure is narrower in its northern (upstream) part and opens towards the southern (downstream) part. The eastern wall is about 10 m long and has a NE–SW orientation. The western one is about 8 m long and has a NW–SE orientation. The gap between the upper (respectively NE and NW) corners of the walls is about 3 m wide, while between the lower corners


**Figure 10.** Possible dam in II order quebrada near Cerro Redondo (La-296 site).

(respectively SW and SE) it reaches about 6 m of the width. The walls were built of one row of irregular stone blocks. It seems that the possible function of this structure was to reduce the water speed during flash floods, when a relatively large amount of water would descend through the narrow quebrada floor at high speed. Enlarging the valley floor would reduce the velocity of flowing water. It would consequently prevent intensive erosion, which had to be important for ancient human groups, because many channel-in terraces were located immediately downstream of this structure.

Finally, certain sites with rock art should be dated to the Lima culture times. The presence of the ceramic motif of interlocking serpents particularly characteristic for Playa Grande, suggests that sites La-208 and La-344 should be associated with the early phase of the Lima culture.

Settlement phases associated with Lima culture (ca 200–500 AD) and the Middle Horizon (600–900 AD) were presumably separated by a settlement hiatus. The lack of the Lima culture pottery from the Maranga phase (500–700 AD) should probably be interpreted as the abandonment of permanent settlements in this region. It should be noticed, however, that in the same panel with typical Lima culture interlocking serpents found at La-208 site, there is also the motif of a bottle with two spouts. Such ceramic forms appear on the Central Coast only in the first half of the Middle Horizon (ca. 600–850 AD) and may be associated with the Wari imports or the syncretic Nievería style. The presence of such a motif should be interpreted as proof of the slow and gradual process of creation of rock art panels (the minimum duration of the creation of panels at the La-208 site should be estimated at ca 200 years) or alternatively, it may suggest that the Lima culture rock art was reshaped during the Middle Horizon. In both cases, despite the abandonment of settlements and agricultural infrastructure around 500 AD, lomas were visited by human groups of the Lima culture. Such visits were probably associated with the exploitation of the seasonal natural resources of fog oases.

Despite the presence of Middle Horizon materials, almost no settlements were discovered. Only in the abandoned grave robbers' pit at La-322 site (Lima culture settlement) one fragment of Cajamarca III pottery was found. Cajamarca III pottery is a style which developed about 550 km north of the Lomas de Lachay area, thus the fragment from La-322 must be considered as an import. Also described above, the depiction of the bottle with double spouts suggests influences from the Wari culture (direct or indirect via the Nievería style) with its main centre in the Ayacucho region, about 400 km south-east of the Lomas de Lachay area.

The largest site, which may be dated to the Middle Horizon is an extremely large cemetery in Quebrada Teatino (La-26) (known by previous researchers as "Quebrada Teatino", "Pampa Teatino" or "El Teatino"), which was probably established around 650–700 AD. This cemetery is eponymous for the Teatino ceramic style, which was probably developing on the northern part of the Central Coast from about 650/700 to 850/900 AD. The Teatino style was presumably considered an elite style, because Teatino pottery has been found in the Moche elite burials in San José de Moro in the Jequetepeque valley, on the North Coast of Peru (Castillo Butters 2000), about 500 km north of Lomas de Lachay. After the disappearance of the Teatino style, the cemetery continued to be used, as is evidenced by graves with pottery in the Huaura style (850/900–1000 AD).

It seems that despite the lack of permanent settlements in lomas, the inhabitants of Lomas de Lachay participated in an interregional net of exchange of elite goods. These groups seem to be much more mobile than their Lima culture ancestors. We suggest that part of this mobility may be associated with the change in the subsistence economy from plant cultivation to herding of camelids (lama and alpaca).

Evidence, which support this hypothesis, may be found in the geological profile LL-14 discovered in the central part of the Quebrada Hato Viejo western slopes, which are covered with aeolian sand covers. Two buried humic layers (less-developed buried soils), separated by sand layer, occurred in the upper part of the profile (Figure 11). Given the slow pace of soil formation in the dry climate of lomas, it can be estimated that each of those humic layers developed over a period of several dozen years. We suggest that the burial of soil humic horizons is associated with intensive animal grazing on steep slopes (Figure 12) which triggered the mass movements burying the soil. In light of the fact there was intensive grazing of goats and cows in post-contact periods, we conclude that at least one of the buried soils is associated with an episode


**Figure 11.** Geological profile LL-14 of aeolian sand on valley slope with two buried soils.

**Figure 12.** Terracettes, which were formed as a result of intensive grazing of animals.

of intensive Pre-Colombian herding. We tentatively associate this Pre-Colombian episode with the Middle Horizon.

Human activity remains from the Late Intermediate Period are extremely scarce in the study area. Only the Quebrada Teatino cemetery was still in use. A number of fragments of distinctive Chancay Tricolor and Chancay Black-on-White pottery were found on the area of the cemetery. It would seem that cemetery use has been continuous since the Middle Horizon, because not only pottery of the late Middle Horizon (Huaura) style and early Late Intermediate Period (Chancay Tricolor) was found at the site, but it is also often suggested that the Chancay ceramic styles developed from the Teatino and Huaura styles (Krzanowski 2008). The presence of the Chancay settlements in Lomas de Lachay has not, however, been confirmed yet. The settlement hiatus in Lomas de Lachay lasted, in all probability, approximately 450 years from ca 1000 AD to 1450/1470 AD. The remains of the Late Intermediate Period corrals in the nearby Lomas de Iguanil (Kalicki 2014) suggest that during that period transhumance between the highlands and lomas might have developed.

The last pre-Colombian settlement phase was associated with the Late Horizon. All four large settlements were located on the planation surfaces. Interestingly, they were situated extremely close to one other with the distance between them not exceeding 500 metres in a straight line. Moreover, two of the sites which showed traces of Late Horizon human


**Figure 13.** Lima culture and Inka site Naranjito Bajo (La-49 site). Notice the planation surface where the site is located in the centre and the dry channel of a stream flowing from a spring on the right.

occupation (La-49, La-322) were located in the same places where the Lima culture settlements had developed almost 700 years earlier (Figure 13). The location at the same places should, in all probability, be associated with the fact that the springs which provided water for the population were situated nearby. In the case of two other Late Horizon sites, La-329 (Naranjito Alto) and La-38 (Machupicchito), water sources were probably located in the uppermost parts of the nearby quebradas. The extensive site area, the numerous remains of stone residential architecture with *metates* inside, domestic pottery fragments, deposits and possibly also graves indicate that the settlements were permanently inhabited. The settlements were probably abandoned prior to or during the so-called Toledan reductions (ca 1550–1580 AD) since there are no traces of European influences.

Almost no archaeological sites were detected in the mountain desert geosystem. Only a few contemporary or recent corrals for goats and cows were found. The absence of archaeological remains should in all probability be associated with the particular characteristics of this geosystem. There is no water present and vegetation is restricted to only certain cactus during normal and La Niña years. Additionally, during El Niño years torrential rains cause heavy erosion, washing away soil with massive debris flows and flash floods. The mountain desert, being an extremely hostile environment for human activity, has consequently never attracted human groups. Any possible traces of their presence would have in addition been removed by erosion and mass movements.

## 4. Discussion and conclusions

It may be argued that archaeological prospecting only provides us with the image of the last phases of development of the sites. Careful observation of the relics of huaquero pits and the results of environmental research show, however, that slope covers and sediment layers on planation surfaces are extremely thin (Kalicki *et al.* 2013a). We are consequently dealing with a quite paradoxical situation where relics of Pre-Colombian architecture are relatively well-preserved (with the height of the walls even exceeding 2 m at times), while at the same time stratigraphical evidence is very scarce. It would therefore seem that an archaeological survey is the optimal strategy for studying the Lomas de Lachay region.

Our survey indicates that at least 6 main settlement phases can be distinguished during the ceramic periods: Formative

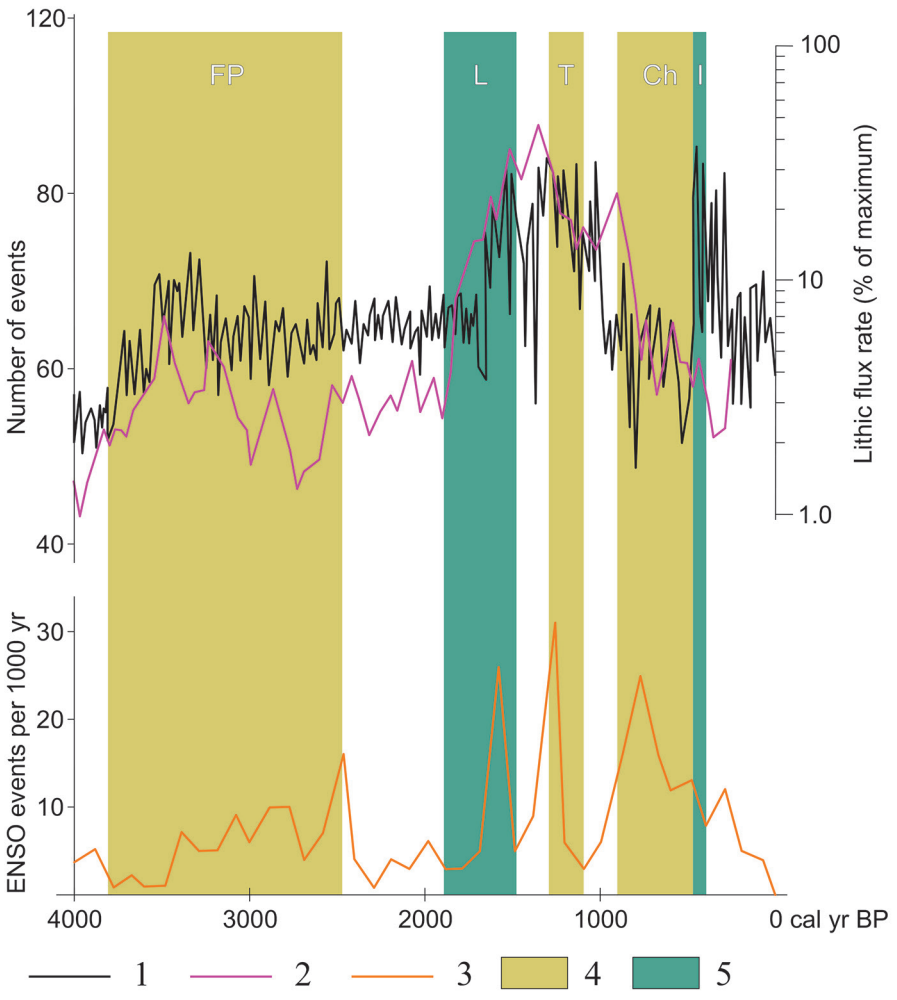


**Figure 14.** Correlation of El Niño frequency and Pre-Columbian settlement phases in Lomas de Lachay. 1 – reconstruction of El Niño frequency based on lithic flux in marine sediments of Peru (Rein *et al.* 2004); 2 – model of El Niño frequency according to Clement *et al.* 2000; 3 – reconstruction of El Niño frequency based on sediment core of Laguna Paucallcocha (Moy *et al.* 2002); 4 – settlement phases with seasonal settlements in Lomas de Lachay; 5 – settlement phases with permanent settlements in Lomas de Lachay; FP – Formative Period; L – Lima culture; T – Teatino; Ch – Chancay; I – Inka.

(ca 1800–100 BC), Lima culture (200–500 AD), the Middle Horizon (600–900 AD), Huaura-Chancay (900–1450 AD), Inka (1450–ca 1550 AD) and historic (1550–1970 AD). There were permanent settlements in the study area during the Lima culture and the Inka times, while the human activity in lomas was not as intensive and in all probability only seasonal during the Formative, Huaura-Chancay and historic phases. Moreover between settlement phases there were certain important hiatuses lasting from at least 100 to 300 years. These gaps are even more pronounced when we realize that at certain phases human activity was only restricted to sporadic, probably seasonal exploitation of lomas (Formative phase) or only to funerary activity (Huaura-Chancay phase).

It would seem that changes in the settlement pattern were strongly influenced by the frequency of El Niño episodes. In periods of high El Niño frequency, due to torrential rains associated with them, slope springs were active throughout the year. The saturation level of the ground waters was presumably near the surface in the upper parts of small, lateral quebradas or even small streams appeared during such periods. Moreover, the sum of the annual precipitation was much higher and the vegetation developed not only during the humid season, but also during the dry season providing rich natural resources to past human groups throughout the year. The vegetation of lomas was also denser after the El Niño episode, although no new plant species appeared (Cano *et al.* 1999). The availability of water throughout the year and the richness of natural resources allowed for development of permanent human settlements. During periods of low El Niño frequency, however, springs and streams were absent and no permanent settlements could develop due to a scarcity of water during the dry season. Lomas were probably only exploited seasonally during the humid season, when advection fogs provided water.

These conclusions are supported by the solid correlation of periods with high El Niño episode frequency with permanent settlement phases (Figure 14). The Lima culture (Playa Grande) and the Inka settlement phases in Lomas de Lachay were coeval with the phase of frequent El Niño episodes. Periods when El Niño episodes were infrequent are contemporary with the settlement hiatus in Lomas de Lachay. The Inka phase correlation with El Niño episode frequency is weaker to some extent and it could be suggested that the appearance of permanent settlements during this phase was connected with both cultural and environmental factors. Similarly, a lack of permanent settlements during Chancay and Teatino settlement phases may be associated both with lower El Niño frequency (particularly in the case of the Chancay phase) and with cultural factors (the Teatino phase). The correlation between El Niño episode frequency and settlement patterns is not as obvious as in the case of the Formative Period but this settlement phase is still poorly defined and dated.

The presented results from Lomas de Lachay contradict the general view of the impact of El Niño on Andean societies as destabilizing and destructive (see *e.g.* Shimada *et al*. 1991; Schimmelman *et al.* 2003; Marchant *et al.* 2004). Our data actually indicate that the impact of frequent El Niño on groups living in the lomas environment (except cacti loma geosystem) seems to have been benevolent. This ambivalent character of El Niño's influence on socio-cultural transformations has also been proposed by Sandweiss *et al.* (2007), who suggest that the reappearance of El Niño ca 5800 cal. BP contributed to the development of early, monumental religious architecture at the beginning of the Formative Period and that the growth in El Niño frequency around 3000 cal. BP caused a dissolution of the Formative cultural tradition. Our results also confirm the hypotheses that the socio-cultural development of the Central Andes was strongly influenced by the environmental changes proposed earlier by a number of archaeologists (*e.g.* Shimada *et al.* 1991, Schimmelman *et al.* 2003; Marchant *et al.* 2004; Sandweiss *et al.* 2007; Sandweiss, Richardson III 2008; Reindel, Wagner 2009; Reindel 2009) and that the effect of large-scale environmental processes on human societies was not uniform (Mächtle, Eitel 2013). Particularly intriguing is the almost simultaneous abandonment of permanent settlements in Lomas de Lachay at the end of the Early Intermediate Period and fall of the Nazca culture on the South Coast of Peru due to an increased variability of precipitation (Fehren-Schmitz *et al.* 2014).

It should also be emphasized that the phase of most intensive exploitation of lomas was connected with the Lima culture people, when agriculture associated with an extensive infrastructure developed. During the next settlement phases, seasonal pastoralism seems to have been the most important aspect of human economic activity in the lomas. Even during the Inka times, when permanent settlements were once more present in the lomas, no agricultural infrastructure was established. This suggests the presence of a gradual, long-term change in the subsistence economy from agriculture to pastoralism. This should presumably be associated both with cultural and environmental factors. An extremely important role was played in all probability by the long-term trend of aridization of the climate in the study area. This kind of trend is suggested by the millennial-scale stability of relief in the lomas. Recent environmental research results suggest that the area of fog oases on the western coast of South America substantially decreased during the Holocene (Engel 1987; Shoobridge 2003).

In conclusion, Pre-Colombian human activity was closely related to the environment. Groups in the past preferred to focus their activity on the lomas geosystem due to the different dynamics of the three basic geosystems of the study area during El Niño episodes. Settlement phases with permanent residential sites are correlated with periods of high El Niño frequency, while periods with low El Niño frequency were characterized by a seasonal exploitation of lomas. A long-term trend involving changes from agriculture to pastoralism in the subsistence economy may also be observed which should in all probability be associated with gradual climate aridization in the study area. The presented research allowed us not only to find correlations between the

increased frequency of El Niño and the settlement phases with permanent settlements, but also to propose the cause-effect relationship which is behind these correlations.

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## References

BARRAZA, S. S., COLINA, E., DEL CARPIO, M., FIGUEROA, A. 1994: Prospección Pampa Doña María y quebradas del Teatino. MS. Deposited: Pontificia Universidad Católica del Perú. Facultad de Letras y Ciencias Humanas.

BELKNAP, F. D., SANDWEISS, H. D. 2014: Effect of the Spanish Conquest on coastal change in Northwestern Peru. *Proceedings of the National Academy of Sciences* 111 (22), 7986–7989.

BONAVIA, D. 1962: *Sobre el estilo Teatino*. Lima.

BROOKS, S. 1998: *Prehistoric agricultural terraces in the Rio Japo Basin, Colca Valley, Peru*. MS. Ph.D. thesis. Deposited: University of Wisconsin-Madison.

CABREL PALOMARES, D. 2006: *Inventario de sitios con manifestaciones rupestres en la Reserva Nacional de Lachay, Lima*. Lima.

CANO, A., ROQUE, J., ARARAKI, M., ARANA, C., LA TORRE, M., LLERENA, N., REFULIO, N. 1999: Diversidad florística de las Lomas de Lachay y (Lima) dirante el evento "El Niño 1997–1998 In: Tarazona, J., Castillo, E. (Eds.): *El Niño 1997–98 y su impacto sobrc los ecosistemas marino y terrestre*. Revista Peruana de Biología, Vol. Extraordinario, 125–l32.

CASTILLO BUTTERS, J. L. 2000: La Presencia de Wari en San José de Moro. In: Makowski, K. (Ed.): *Los dioses del antiguo Perú*. Colección Arte y Tesoros del Perú. Banco de Crédito del Perú, Lima, 103–135.

CLEMENT, A. C., SEAGER, R., CANE, M. A. 2000: Suppression of El Niño during the Mid-Holocene by changes in the Earth's orbit. *Paleoceanography*, 15, 6, 731–737.

CRAIG, A. 1992: Archaeological occurrences of Andean land snails. *Andean Past* 3, 127–135.

ECHAVARRIA LOPEZ, G. T., RUIZ ALBA, E. 2006: Quebrada Palo – Lachay, Perú. La percepción y el registro, un caso de descripción rupestre. *Rupestreweb*: www.rupestreweb.info/lachay.html

ENGEL, A. F., 1987: *De las begonias al maíz: vida y producción en el Perú antiguo*. Lima.

FEHREN-SCHMITZ, L., HAAK, W., MAECHTLE, B., MASCH, F., LLAMAS, B., TOMASTO CAGIGAO, E., SOSSNA, V., SCHITTEK, K., ISLA CUADRADO, J., EITEL, B., REINDEL, M. 2014: Climate change underlies global demographic, genetic, and cultural transitions in pre-Columbian southern Peru. *Proceedings of National Academy of Sciences* 111 (26), 9443–9448.

FERREYRA, R. 1953: Comunidades des vegetales de algunas lomas costaneras del Perú. *Boletín de Estación Experimentaria Agricola "La Molina"* 53, 1–88.

KALICKI, P. 2014: Model of interregional contacts between highland and coastal groups in late Pre-Colombian epochs in lomas of the Central Coast of Peru. *Contributions to New World Archaeology* 6, 83–110.

KALICKI, P., KALICKI, T., KITTEL, P. 2013a: Sediment stratigraphy in Lachay-Iguanil region as record of human impact and environmental change. In: Turek, J. (Ed.): *Abstracts from 19th Annual Meeting of European Association of Archaeologists.* 4–8th September 2013, Pilsen, Czech Republic, 403.

KALICKI, T., KITTEL, P., KALICKI, P 2013: Main stages of the Cenozoic relief evolution of Lomas de Lachay (western slope of Central Andes, Peru). Presented at international conference: Stav geomorfologických výzkumů v roce 2013, Mikulov 24th – 26th May 2013.

KROEBER, A. 1944: *Peruvian archaeology in 1942*. Viking fund publications in anthropology. Number four. New York.

KRZANOWSKI, A. 2008: *Kultura Chancay Środkowe Wybrzeże Peru*, Kraków-Warszawa.

MACHARÉ, J., ORTLIEB, L. 1992: Plio-Quaternary vertical motions and the subduction of the Nazca Ridge, central coast of Peru. *Tectonophysics* 205 (1), 97–108.

MAECHTLE, B., EITEL, B. 2013: Fragile landscapes, fragile civilizations — How climate determined societies in the pre-Columbian south Peruvian Andes. *Caetena* 103, 62–73.

MALDONALDO, A. 1952: Demostrando que en las Lomas de Lachay y adyacentes hubo pastoreo de auquénidos por los antiguos peruanos. *Revista de la Facultad de Farmacia y Bioquímica. UNMSM*. Vol. XIV. Nº 55–56. 53–68.

MARCHANT, R., HOOGHIEMSTRAAND, H., ISLEEBE, G. 2004: The rise and fall of Peruvian and central American civilizations: interconnections with the Holocene climatic change-a necessarily complex model In Yasuda, Y. (Ed.): *Monsoon and civilization*. 351–379.

MARMOL, A. 1962: Los petroglifos o killkarumi de Lachay y su interpretación mesológica y ecológica. In: *Actas y trabajos del II Congreso Nacional de Historia del Perú (época prehispánica). Del 4 al 9 de agosto de 1958*. Vol. II., 339–344.

MARQUARDT, C., LAVENU, A., ORTLIEB, L., GODOY, E., COMTE, D., 2004: Coastal neotectonics in Southern Central Andes: uplift and deformation of marine terraces in Northern Chile (27 S). *Tectonophysics* 394 (3), 193–219.

MOY, C. M., SELTZER, G. O., RODBELL, D. T., ANDERSON, D. M. 2002: Variability of El Niño/Southern Oscillation activity at millennial timescales during the Holocene epoch. *Nature* 420 (6912), 162–165.

ORDOÑEZ J., FAUSTINO J. 1983. Evaluación del Potencial Hídrico en Lomas Costeras del Perú. (Lomas de Lachay e Iguanil*). Zonas Aridas* 3, 29–42.

PINCHE, C. 1994: Estudio de las condiciones climaticas y de la niebla en la costa norte de Lima. *Boletin de Lima* 16, 91–96, 39–43.

PULGAR VIDAL, J. 1987: *Geografía del Perú*. PEISA, Lima.

REIN, B., LÜCKGE, A., REINHARDT, L., SIROCKO, F., WOLF, A., DULLO, W. C. 2005: El Niño variability off Peru during the last 20,000 years. *Paleoceanography* 20, 4.

REINDEL, M. 2009: Life at the edge of the desert – archaeological reconstruction of the settlement history in the valleys of Palpa, Peru. In: *New technologies for archaeology*. Springer, Berlin – Heidelberg, 439–461.

REINDEL, M., WAGNER, G. A. 2009: *New technologies for archaeology: multidisciplinary investigations in Palpa and Nasca, Peru*. Springer.

RUNDEL, P. W., DILLON, M. O., MOONEY, H. A., GULMON, S. L., EHLERINGER, J. R. 1991: The phytogeography and ecology of the coastal Atacama and Peruvian Deserts. *Aliso* 13, 1, 1–50.

SAITO DIAZ, C. 1972. *Base para el establecimiento y manejo de una unidad de conservación en las Lomas de Lachay.* Tesis UNA, Deposited at Ministerio de Agricultura, Dirección General Forestal y de Fauna. Dirección de Conservación, Lima.

SANDWEISS, H. D., MAASCH, A. K., FRED, T. C., ANDRUS, E., REITZ, J., RIEDINGER-WHITMORE, M., RICHARDSON III, J. B., ROLLINS, B. H. 2007: Mid-Holocene climate and culture change in coastal Peru. In: Anderson, G. D., Maasch, A. K., Sandweiss, H. D. (Eds.): *Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions.* Elsevier, 25–51.

SANDWEISS, H. D., RICHARDSON III B. J. 2008: Central Andean Environments In: Silverman, H., Isbell, W. (Eds.): *Handbook of South American archaeology*. Springer, 94–104.

SCHIMMELMANN, A., LANGE, B. C., MEGGERS, J. B. 2003: Palaeoclimatic and archaeological evidence for a 200-yr recurrence of floods and droughts linking California, Mesoamerica and South America over the past 2000 years. *Holocene* 13, 763–780.

SEBRIER, M., LAVENU, A., FORNARI, M., SOULAS, J. P. 1988: Tectonics and uplift of the Central Andes (Peru, Bolivia and Northern

Chile) from Eocene to present. *Géodynamique, Géodynamique des Andes Centrales*. Band 3, 1–2, 85–106.

SHIMADA, I., BARKER-SCHAAF, C., THOMPSON, G. L., MOSELEY-THOMPSON, E. 1991, Cultural impacts of severe droughts in the prehistoric Andes: Application of a 1,500-year ice core precipitation record. *World Archaeology* 22 (3), 247–270.

SHOOBRIDGE, D. 2003: *Lachay National Reserve Park Profile*, ParksWatch – USA.

STRONG, W., WILLEY, G. 1943: Archaeological notes on the Central Coast. *Columbia Studies in Archaeology and Ethnology.* Vol. I., 1. 1–25.

TELLO, J. 1943: Sobre el descubrimiento de la cultura Chavín en el Perú. *Letras. Órgano de la Facultad de Letras y Pedagogía de la UNMSM*. Tercer cuatrimestre, 326–373.

TELLO. J. 1956: *Arqueología del valle de Casma*, UNMSM, Lima.

TORERO, D., NICHO, I., VALLE, F. 1990: *Observaciones arqueológicas en las costas del norte medio (de Chancay a Guaura)*. Universidad Nacional José Faustino Sánchez Carrión, Huacho.

VILLAR, P. 1935: *Las culturas pre-hispánicas del departamento de Lima*. Municipalidad de Lima.