

## The Muralla Pircada—an ancient Andean debris flow retention dam, Santa Rita B archaeological site, Chao Valley, Northern Perú

**Abstract** Debris flows caused by El Niño events, earthquakes, and glacial releases have affected northern Perú for centuries. The Muralla Pircada, a northeast-trending, 2.5 km long stone wall east of the Santa Rita B archaeological site (Moche-Chimú) in the Chao Valley, is field evidence that ancient Andeans recognized and, more importantly, attempted to mitigate the effects of debris flows. The Muralla is upstream from the site and is perpendicular to local drainages. It is 1–2 m high, up to 5 m wide, and is comprised of intentionally-placed, well-sorted, well-rounded, 20–30 cm cobbles and boulders from nearby streams. Long axes of the stones are gently inclined and parallel local drainage. Case-and-fill construction was used with smaller cobbles and pebbles used as fill. Pre-Muralla debris flows are indicated by meter-sized, angular boulders that were incorporated in-place into construction of the dam and are now exposed in breeches in the dam. Post-Muralla debris flows in the Chao Valley are indicated by meter-sized, angular boulders that now abut the retention dam.

**Keywords** Debris flow dam · Mitigation · Natural hazards · Ancient Andean · Perú

### Introduction

The April 10, 2004 debris flow caused by heavy rains near Machu Picchu, a well-known Inca archaeological site (ABC News 2004), the June 23, 2001 earthquake and subsequent tsunami that destroyed parts of Camaná in southern Perú (US Geological Survey 2001), and the January 1998 El Niño floods in northern Perú (CNN 1998) are recent examples of some of the natural hazards that affected modern Perú. Ancient Andeans also felt the effects of hazards such as ground shaking caused by earthquakes and native Peruvian engineers from the Moche (100 B.C.) to the Chimu-Inca (A.D. 1400) built adobe and stone structures, respectively, which withstood the subduction-related tremors of the region. Field studies at the Santa Rita B archaeological site in northern Perú show that ancient people also recognized, but more importantly, attempted to mitigate the effects of El Niño-, earthquake-, or glacial release-related debris flows originating in the Peruvian Andes. The Quechua (a native language of the Andes) word “huayco” is used by Peruvian geologists and highway engineers to refer to a debris flow.

### Review of geologic hazards and society in the Western Andes and Coastal Plain

The location of Santa Rita B in an alluvial environment exposed the settlement to debris flow hazards, or “huaycos”, from El Niño-related flooding, earthquake-induced mass wasting, and periodic glacial-release events originating in the northern Andes. Historical records also show that since 1586 earthquakes off the Peruvian coast have generated 13 tsunamis, five of which were particularly destructive (University of Southern California Tsunami Research Group 1996).

For example, the earthquake-tsunami event that took place in southern Perú on June 23, 2001 indicates ongoing potential for tsunamis in the region.

Written evidence for El Niño events is available only to the time of the Spanish conquest of the region (Quinn et al. 1978); therefore, geochronological evidence must be used to infer the occurrences of these hazards and their impact on pre-Columbian society. Using faunal and other evidence, Rollins et al. (1986) indicate that the El Niño phenomenon did not exist in northern Perú before about 5,000 years before present; however, Wells and Noller (1998) describe north coast flood stratigraphy that indicates that a minimum of 18 major El Niño-generated floods took place during the last 9,500 years.

In the Lurin Valley, central Perú, Burger (2003) describes an Initial Period (2000 B.C.) retention dam built to protect the Manchay Bajo archaeological site from El Niño-related debris flows. This massive dam, which is 745 m long by 12.5 m wide and 5 m high, was strategically placed, much like the Muralla Pircada, between the settlement and drainages that would have channeled debris flow material downslope toward the site.

Catastrophic El Niño rainfall and large-scale flooding from A.D. 500–600 deposited 10 m of fine-grained sediment at the Moche Temples of the Sun and Moon, northern Perú (Moseley and Richardson 1992). El Niño-related flood deposits were described at Batán Grande, northern Perú (Craig and Shimada 1986) and evidence for El Niño events in the geochronological record was the topic of a regional review by Moseley (1987). Sedimentological and geomorphic data indicate that major El Niño rains caused coastal flooding and provided massive pulses of sediment that formed beach ridges correlative with El Niño events in northern Perú (Sandweiss 1986).

Aside from the immediate effects of torrential rain and flooding, the role of El Niño events on the evolution of ancient Andean society in northern Perú may have been even more profound. Studies of Andean glaciers showed evidence for a major El Niño event at A.D. 600–601. This is correlative with evidence of massive human sacrifice preserved in fine-grained sediment washed from the adobe used to build the Temples of the Sun and the Moon by El Niño rains in northern Perú (Steve Bourget, Univ. Texas-Austin, oral commun., 2003). Ceramic evidence indicates that by A.D. 750, the Moche civilization was in decline and Jaime Castillo (Catholic University of Perú, oral commun., 2003) suggests that this decline is due to the ongoing effects of El Niño devastation on Moche society.

Three dated El Niño events occurred at the transition between major archaeological periods and are interpreted to have weakened coastal society which led to vulnerability and invasion by political enemies from outside the region affected by flooding (Craig and Shimada 1986; Wells 1990). By using previously established radiocarbon chronology, Moy et al. (2001) studied lake sediments

in southern Ecuador and showed that El Niños occurred more frequently 1,200 years ago, with a peak in the 9th century, or at end of the Middle Horizon in northern Perú.

Perhaps the most well documented and devastating hazard-related event in the region took place in 1970 when an earthquake-induced rock avalanche originated from Nevados Huascarán (Plafker and Ericksen 1978) and killed more than 20,000 people in the Santa Valley, the next major valley south of the Chao Valley (Fig. 1). Then, in 1972–73, torrential El Niño rains remobilized the 1970 rock avalanche debris which subsequently flowed into the Santa Valley (Moseley and Richardson 1992).

Since 1702, Arnao (1998) identified 22 glacial-release catastrophes that include flooding and ice avalanches, mainly in the Santa Valley. These releases, which are sudden outbursts of water from a glacier-dammed lake, resulted in the destruction of towns and villages and the deaths of tens of thousands of inhabitants.

In southern Perú, Keefer et al. (1996) detailed landslide material entrained in El Niño-induced flood sediment and, by using examples from around the world, demonstrated that even small earthquakes

(magnitude 4) may generate landslides and dislodge rock and sediment that may subsequently be transported toward the alluvial fan by post-earthquake water or debris flows (Keefer 1999). By applying radiocarbon techniques, Keefer et al. (2000) documented the effects of El Niño-related floods in coastal areas of southern Perú from 38.2 Ka to 1998.

El Niño events may occur frequently, sometimes as often as every two to eight years, in Perú (Moy et al. 2001) and the effects of any particular event are typically most severe in the north and diminish to the south (Sandweiss 1986). In 2001, Peruvian President Alejandro Toledo signed an agreement with the Interamerican Development Bank that included a loan destined for public works that would mitigate the centuries-old effects of El Niños on Perú (El Comercio 2001).

#### Setting of Santa Rita B

The Santa Rita B archaeological site is in the Chao Valley (Fig. 1), approximately 65 km southeast of Trujillo, near the village of Chao, and is one of several valleys in northern Perú that is significant to the study of regional archaeological settlement patterns. Location of

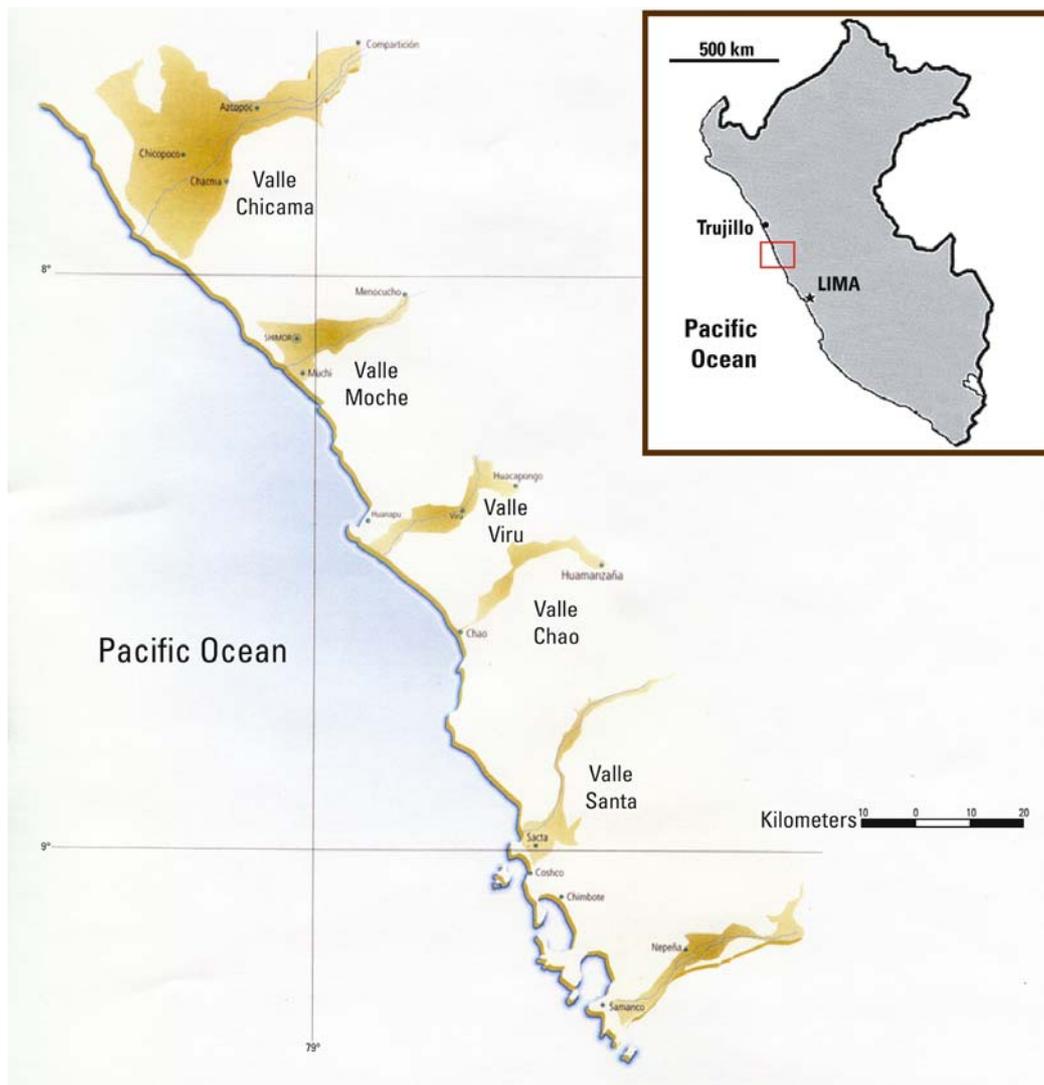
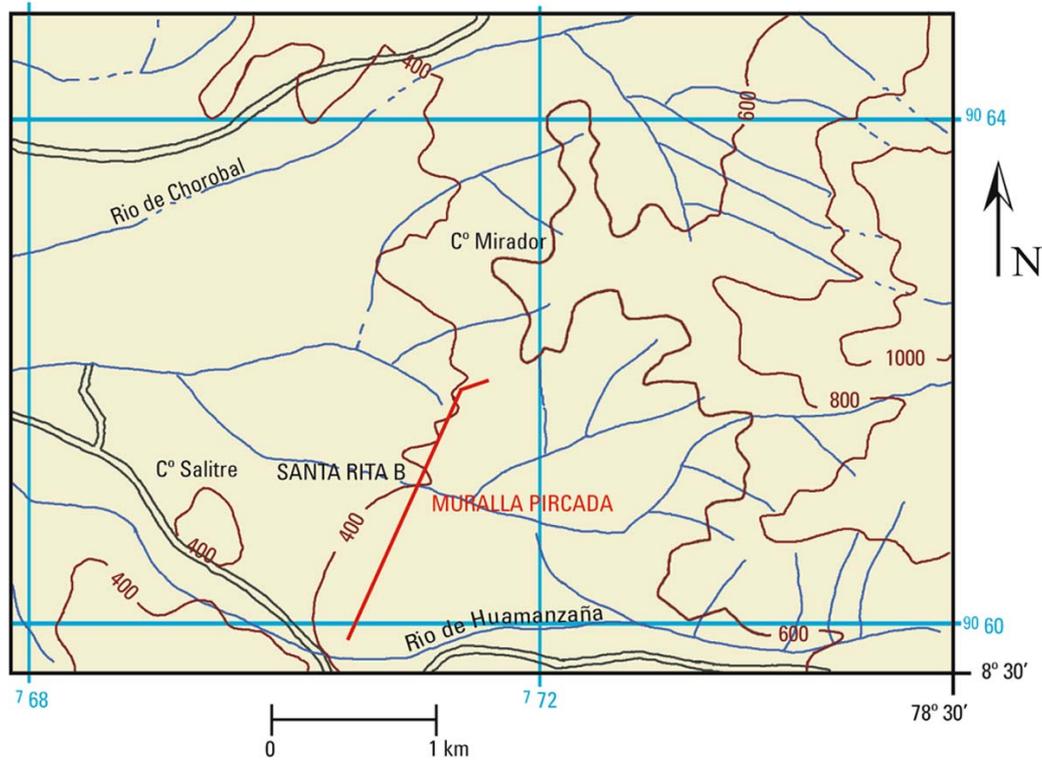


Fig. 1 Location of the Chao Valley, northern Perú (from Larco 2001a)



**Fig. 2** Northeast-trending Muralla Pircada with respect to drainages and the Santa Rita B archaeological site (200 m contour interval, base map from Jaen and Vargas 1967)

Santa Rita B in the Chao Valley provided control of the movement of resources, people, and animals between the Andes and the coast and was an important factor in the almost continuous occupation of the site over the past 2,000 years. Moche and Chimu (Early Intermediate to Late Intermediate Period or approximately 100 B.C. to A.D. 1400) ceramics have been identified from the site (Rosales et al. 2003).

Settlement of Santa Rita B in the Chao Valley (Fig. 1), northern Peru, was also favored by geologic factors that include: (1) location in an alluvial-eolian environment that provided water, specifically in a valley formed by the confluence of several small rivers where they emerge from the Andes; (2) location only a few kilometers from a coastal environment, the Pacific Ocean, that provided food and marine resources; and (3) access to the foothills of the Andes which provided building stone for construction and shelter material (Herz and Garrison 1998). Also, northern Peru is well endowed with placer gold and other mineral, energy, and fertilizer resources that stimulated expansion of pre-Columbian society and were used for craft, trade, and agriculture (Petersen 1970; Noble and Vidal 1994; Brooks et al. 2004).

#### Description of the Muralla Pircada

The Muralla Pircada was first described by Cardenas (1976); however, the purpose of the structure was uncertain. Then, in conjunction with multidisciplinary field studies at Santa Rita B, the structure was interpreted (Brooks et al. 2001). The word “muralla” is Spanish and indicates an extensive wall used to protect a city; however, “pircada” is derived from a Quechua word “pirka” or possibly “pirqua” that indicates a stone fence.

The Muralla Pircada is a north-northeast-trending, ~2.5 km long stone wall east and up-valley from Santa Rita B (Fig. 2) that is con-

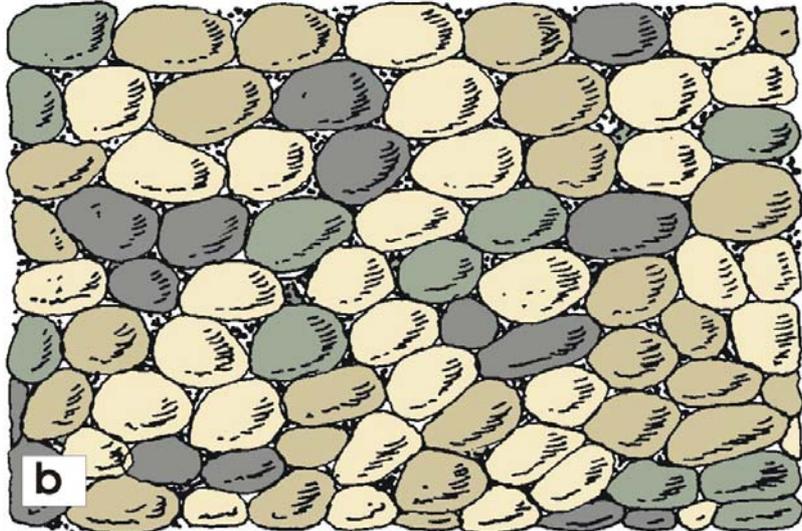
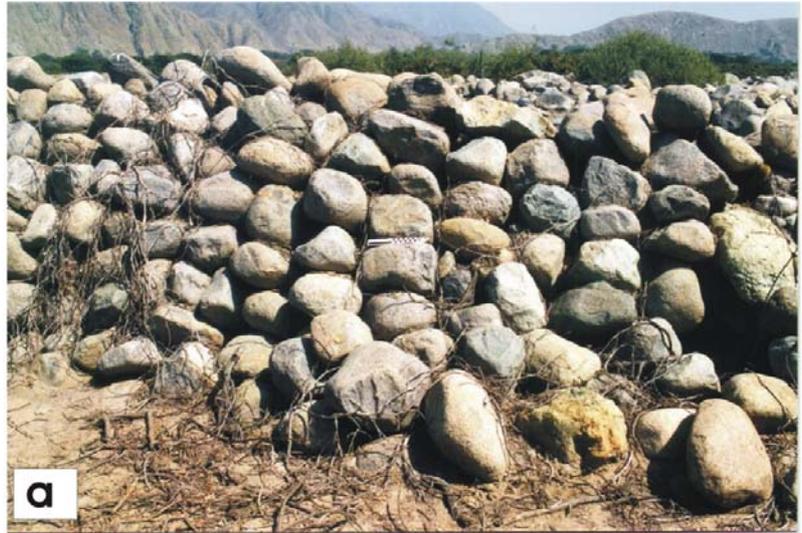
structed of well-sorted, well-rounded, 20–30 cm and larger (Fig. 3a) volcanic cobbles and boulders. The main part of the Muralla is 1–2 m high and is up to 5 m wide. However, the Muralla turns sharply northeast at about 2.2 km and becomes smaller, less than 1 m high and only 0.8–3.0 m wide.

The upstream face of the Muralla is comprised of locally-derived boulders and cobbles that are well-organized and stacked, however, the downstream face is less organized (Fig. 4). Commonly, the long axes of the cobbles and boulders are inclined and perpendicular to the general northeast trend of the structure. And, the long axes of the cobbles and boulders comprising the upstream face of the Muralla are typically parallel with the generally east-west drainage patterns. It is interesting to consider that the pre-Columbian engineers of the Muralla might have attempted to duplicate local stream cobble fabric into construction of the Muralla. These local streams were subjected to periodic torrential currents which would have resulted in orientation of clasts with long axes parallel to stream flow rather than orientation of clasts transverse to stream flow (Pettijohn 1975).

Case-and-fill construction (Fig. 4) was used in wider parts of the Muralla with smaller cobbles and pebbles used as fill. These factors indicate that construction of the Muralla was labor-intensive with a high degree of organization and planning. Additionally, meter-sized angular boulders, exposed in breaches and used in-place for construction, were very likely deposited prior to construction of the Muralla, and are evidence for pre-Muralla mass wasting events in the Chao Valley.

The Muralla Pircada is asymmetrical in cross-section and is thicker, to 5 m, in the downstream direction and tapers to 1 m at the top with a steep, ~70°, upstream face, much like a modern dam. The Muralla

**Fig. 3** **a** Looking west at well-sorted boulders of the Muralla Pircada, Chao Valley, scale is 20 cm. **b** Sketch of rock wall comprised of stream rounded boulders and specifically used for irrigation and protection against erosion caused by running water in northern Perú (from Larco 2001b, aparejo petreo-pirca de canto rodado, pp 213–214, Fig. no. 224)



is perpendicular to and crosses the majority of the now abandoned east-west drainages that traverse the site. At several locations on the ground and perpendicular to the Muralla are clusters of 20–30 cm, rounded, and sorted cobbles (Fig. 5). These clusters are found on both the upstream and downstream sides of the Muralla and are similar in size and composition to the cobbles used in construction of the Muralla. Typically, these features are 1.5 m from the wall and are herein interpreted to have been used as stockpiles for general construction, repairs, or to enlarge the Muralla.

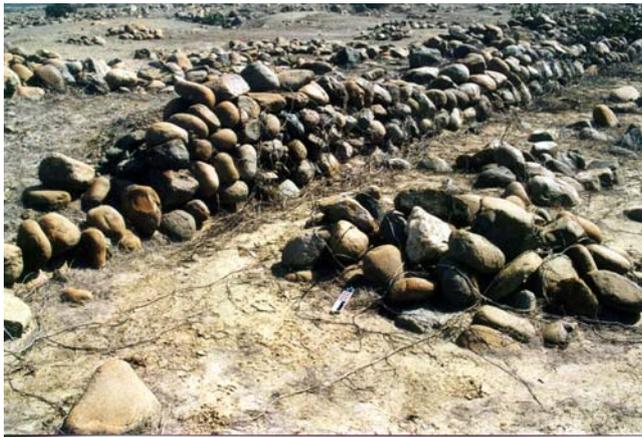
### Discussion

A number of extensive muralla or wall-like features are present near archaeological sites in the coastal areas of northern Perú and Larco (2001a, p. 225) uses “muralla” to describe wall-like structures used for defensive purposes. Other wall-like structures include terraces built by pre-Columbian native society that were called “andines” by the colonial Spaniards, thereby giving the name “Andes” to the mountains in the region. These rock walls were built on contour and filled with soil to gain land for crops or increase settlement area.

The Muralla de la Cumbre is a 10-km long stone wall that is a few kilometers north of Trujillo. It is part of a complex system of retention dams built to protect downstream Chimú settlements, such as Chan Chan, from El Niño floods in the Moche Valley. This muralla and others of similar construction in the Chicama and Moche Valleys are described by Piminchumo and Galvez (2003). The 90 km long Great Wall of Santa (Horkheimer 1965), in the Santa Valley, is perhaps the most well-known, however, it is comprised of adobe blocks that would not have withstood debris flow or El Niño torrents. Other wall-like structures were used in the region as simple boundaries or for water control and Larco (2001b, p. 213) uses the term “aparejo petreo” (rock structure) for these stone features.

There are no features such as ramparts, slingstones, or small watch-towers that would indicate a defensive or military purpose of the Muralla Pircada. Nor is the Muralla constructed around the Santa Rita B settlement which would strongly suggest a defensive or military function. In comparison, however, defensive features such as concentric stone walls with parapets, breastworks, a dry moat, and piles of 5–6 cm rounded stones (slingstones) interpreted as ammunition for

**Fig. 4** Cross-section of the Muralla Pircada showing case-and-fill construction, upstream to the right, approximate width is 4 m, scale is 20 cm



**Fig. 5** Looking downstream at the Muralla Pircada, stockpile of cobbles and boulders in the foreground used for construction or repair, scale is 20 cm



**Fig. 6** Construction of dwelling walls at Santa Rita B, scale is 20 cm



**Fig. 7** Well-rounded, well-sorted, imbricated cobbles used to line the bottom of the reservoir at the Chimú site of Chan Chan, Moche Valley, northern Perú

slingers are described at the Cerro La Cruz archaeological site, also in the Chao Valley (Topic 1990). Therefore, we consider that the Muralla Pircada was not for military defense, as Larco's (2001a) terminology might imply, but for defense and protection of the Santa Rita B settlement from the effects of flooding and mass-wasting that originated in the cordillera. Our interpretation is supported by the following:

- Larco (2001b, p. 210) shows a number of specific stone walls used in northern Perú for varied purposes such as irrigation, tombs, and living quarters; most examples show the use of angular cobbles or blocks. However, the construction style for the Muralla Pircada, which uses only stream-rounded cobbles and boulders (Fig. 3a), is strikingly similar to the description by Larco's (2001b), which says "rock wall of rounded stones (Fig. 3b)...used in irrigation canals...frequently found in (irrigation) canals in the Pampas de Chicama and in the Santa, Virú, Chao, and Moche Valleys...found as a simple covering of the walls of the canals to protect against erosion from running water".



**Fig. 8** Post-Muralla debris flow boulders about the Muralla Pircada, Chao Valley, northern Perú, upstream to the left

- The construction techniques used for dwellings at Santa Rita B were also labor intensive, purposeful, and selective but contrast with the Muralla construction. Specifically, sub-angular boulders of a variety of sizes (poorly-sorted) were used for dwellings. Construction materials used for domestic use were selectively chosen; however, in contrast, these materials were sub-angular, had to be quarried, and transported from nearby hills across drainages that contained abundant, available, and closer, but rounded, construction materials. And, apparently lesser attention was given to the details of organization (Fig. 6), however, the long axes of the sub-angular boulders are commonly parallel to the wall.
- Specific construction techniques and materials are related to pre-Columbian water control engineering technology. For example, construction of the base of the reservoir at the Chimú site of Chan Chan (Fig. 7) in the Moche Valley utilized well-sorted, flattened, sub-rounded construction stones (Squier 1877). These were intentionally imbricated, possibly in an attempt to duplicate the natural imbrication and fabric of stones associated with water courses and shingled beaches in the region.
- At numerous places along the Muralla, meter-sized or larger, sub-angular boulders are deposited directly against (Fig. 8), but are not included in, the Muralla. It is unlikely that the Muralla would have been built in such close proximity to pre-existing boulders and this “contact” demonstrates torrential deposition of these boulders during post-Muralla debris flows in the Chao Valley.
- Meter-sized, sub-angular boulders which are exposed in breaches in the Muralla and were incorporated into construction of the Muralla are evidence for torrential pre-Muralla mass-wasting events in the Chao Valley that would have prompted construction of the dam to mitigate the effects of the debris flows and protect the settlement.
- There is no appreciable thickness of fine-grained sediment or silt on the upstream side of the Muralla as might be expected if the Muralla were a dam constructed mainly for water collection or irrigation with subsequent build-up of sediment on the upstream side.
- Intentional placement of the boulders and cobbles in the Muralla is analogous in appearance and purpose to the modern use of sandbags as a seawall to protect a lighthouse or coastline from erosion, for example, at Cape Hatteras, on one of North Carolina’s barrier islands (see cover, Williams et al. 1995)

## Conclusions

Review of geological and archaeological research indicates that northern Perú has been subjected to debris flows resulting from El Niño floods, earthquake-induced mass-wasting events, and glacial releases originating in the Andes for centuries. Construction of the Muralla Pircada indicates both recognition of these hazards by ancient Andean society and, most importantly, an attempt to mitigate the effects of debris flows affecting the Chao Valley and the Santa Rita B site. The Muralla Pircada is evidence of a natural hazards retention dam built specifically by ancient Andeans in northern Perú to protect their settlement from the effects of debris flows.

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