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**DATING THE ASCOPE CANAL SYSTEM: COMPETITION FOR WATER DURING
THE LATE INTERMEDIATE PERIOD IN THE CHICAMA VALLEY, NORTH COAST
PERU**

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DATING THE ASCOPE CANAL SYSTEM: COMPETITION FOR WATER DURING THE LATE INTERMEDIATE PERIOD IN THE CHICAMA VALLEY, NORTH COAST PERU

[ABSTRACT] Here we present the first ^{14}C ages for the Ascope Canal System (ACS), a large pre-Hispanic hydraulic network in the Chicama Valley on the north coast of Peru. Composed of multiple alignments that irrigated areas north of the river, our results indicate that the ACS was constructed and operated in the Late Intermediate Period, *ca.* A.D. 1000–1400. This overlaps in time with the Chicama-Moche Intervalley Canal that diverted water on the south side of the Chicama River and extended to the city of Chan Chan. Conservative estimates of discharge capacity indicate that the canals combined would have exceeded stream flow in the Chicama River half of the year. The ACS appears to have functioned for several centuries and would have been in direct competition with the Intervalley Canal with, apparently, insufficient water for both systems and other Chicama Valley canals during most of the year. This study underscores the complexities of understanding the operations and histories of irrigation systems in complex societies.

KEYWORDS: Peru, Water Management, Stratigraphy, Chronology, Chimu

Introduction

In this article, we present new data about one of the most impressive, but least known, prehispanic waterworks of the North Coast of Peru, the Ascope Canal System (ACS), and place this new evidence in the context of the well-studied Chicama-Moche Intervalley Canal. New stratigraphic and geoarchaeological data from the ACS, and a re-analysis of ^{14}C ages from the Chicama-Moche Intervalley Canal raise questions about water availability and complicate the presently understood prehistory of the Late Intermediate Period (A.D. 1000–1476) of the Chicama and Moche Valleys of the North Coast. We discuss possible implications of these new data and propose several directions for future research.

The largest indigenous canals in the western hemisphere were constructed along the hyperarid coast of northern Peru (Kosok 1965; Denevan 2001). These canals commonly are associated with prehispanic societies that had engineering skills and political systems sufficient to organize and direct large labor pools to construct and maintain these monumental earthworks. The Chicama-Moche Intervalley Canal, (a.k.a, La Cumbre Canal, hereafter, the Intervalley Canal [Kus 1972:86–87]), beginning on the south side of the Chicama Valley, is perhaps the best known large scale irrigation system on the coast of Peru (FIG. 1). It extends ~74 km over a drainage divide into the next major valley to the south, the Moche Valley, and watered agricultural fields, known as the Three Pampa Field System, north of the ancient city of Chan Chan (Kus 1972:91; Ortloff 1993:328). Most of the main channel is stone-lined, 3–5 m wide and 2 m deep. Along the upper reach where the canal clings to steep bedrock slopes, the Chimu constructed massive buttresses and retaining walls several tens of meters high. Farrington

(1983:370) estimates that 1.1 million worker days were required to complete the canal's construction.

The Intervalley Canal often is cited as evidence that Chimu political organization reached the level of a state or empire, given that it apparently was built to tap the Chicama Valley's water supply in order to water lands to feed the Chimu capital in the neighboring Moche Valley (Keatinge and Day 1973:292–293; Moseley 1983; Billman 2002:384–385). Whether or not it succeeded in delivering water to its terminus has been debated—some segments have positive (uphill) gradients that have been attributed to tectonics (Ortloff *et al.* 1982) or purported errors in construction (Pozorski and Pozorski 1982, 2002; see below)—but its construction alone is seen as indicative of Chan Chan's dominance over the Chicama Valley.

Less studied is the ACS on the north side of the lower Chicama Valley. The ACS main channel diverted water from the Chicama River and conducted it to agricultural fields on the Pampa de Mocán, 45 km away, at the northern margin of the lower Chicama Valley (FIG. 1). Only segments of the upper portion of the ACS are preserved, including the Ascope Aqueduct, a massive earthwork designed to transport water over a large *quebrada* (erosional gully) mouth ~ 3 km west of the modern community of Ascope (FIG. 2). There is no doubt, however, that the ACS successfully delivered water to its terminus as evidenced by agricultural fields and settlements in the Pampa de Mocán (Pozorski 1987:116).

The peak of interest on the Ascope Canal occurred in the 1950s and 60s, in large part inspired by Paul Kosok's revelatory aerial photographs, that brought the monumentality of prehispanic irrigation systems to light. Despite the attention and notoriety it gained, the age of the ACS was uncertain. The literature generally discusses the ACS as a Moche construction (Larco 1946, 1966; Collier 1961; Kosok 1965), but several sub-parallel alignments and

stratigraphic evidence of multiple channels (Watson 1979) indicate a complex history for the aqueduct. Sinuous channel segments north of the Ascope Aqueduct (FIG. 2) that follow mountain toeslopes were likely replaced by the aqueduct. Adding to evidence of a long history of canal remodeling, canals systems and settlements in the Pampa de Mocán contain ceramics dating to the Early Intermediate Period (200 B.C.–A.D. 400), suggesting that these lands were watered prior to the construction of the Late Intermediate Period aqueduct.

Our study demonstrates that 1) the ACS successfully conducted water to the Pampa de Mocán, and 2) preserved channel segments of *both* the ACS *and* the Chicama-Moche Intervalley Canal were constructed during the era of the Chimu as a means of increasing irrigated area and agricultural production. Thus, part of the ACS's operation likely coincided with that of the Intervalley Canal. Intriguingly, simultaneous operation of both canals would have exceeded river discharge volume during half of the year and likewise limited the amount of water available to downstream canal alignments within the Chicama Valley during the majority of the year. These potential limiting factors have implications regarding water control and power relationships between communities within the Chicama Valley and across the larger Chimu polity.

Our work was concentrated on a small but key portion of the ACS in the vicinity of the Ascope Aqueduct where several canal channel segments are preserved (FIG. 2). We examined a stratigraphic exposure of canal channel fill and excavations into El Niño-derived pond deposits formed on the upslope side of canal channels to obtain relative and ^{14}C ages for three alignments within the ACS. We compare our results with ages previously obtained for the Intervalley Canal and consider the hydrological limits of simultaneously supporting both canal systems and the possible socio-political consequences of water scarcity during the Late Intermediate Period.

Irrigation and the Culture History of the North Coast

Canal irrigation is a hallmark of intensive agriculture (Boserup 1965; Kelly 1983). Increasing the amount of watered land increases food production and reduces the risk of crop loss due to drought. Whereas canal irrigation is associated with a wide spectrum of social organization and political power (Lansing 1987; Hunt 1988; Scarborough 2003; Neely et al. 2015), the construction and maintenance of complex hydraulic systems have clear cultural and ecological consequences that extend beyond mere food production and distinguish irrigation farmers from other types of societies. The impressive sizes of many canals in Peru have long been key to identifying complex societies there. The culture history of the North Coast of Peru has been so closely tied to the development of irrigation technology in the region that Farrington (1974:83) proclaimed, “the history of agriculture on the coast of Peru is the history of irrigation.”

Beginning with Gordon Willey’s seminal work in the Virú Valley Project (Willey 1953), a model for irrigation expansion based on the Hydraulic Hypotheses of Wittfogel (1957) and Steward (1955) came to define North Coast socio-economic development. Willey’s model for irrigation expansion has been applied to the Moche Valley, a major religious and political center for both the Moche (A.D. 200–900) and Chimú (A.D. 900–1476) archaeological cultures. The earliest known examples of canals on the North Coast were identified in the Nanchoc Valley in the upper Zaña drainage (Dillehay *et al.* 1997). The canals fed small gardens alongside perennial ravines and dated to the Middle Preceramic Period (6000–3000 B.C.). Brian Billman (2002) proposed societies in the Late Preceramic Period (2500–1800 B.C.) relied on floodplain and water table farming near the coast, later shifting up valley to take advantage of easily irrigable sections of the river terraces during the Initial Period and subsequent Early Horizon (1800–400 B.C.), a model first proposed by Thomas Patterson (1982) for the Central Coast. Park (1983) and

Watson (1979) postulated that salinization and heavy riverine vegetation made areas adjacent to riverbanks unfavorable, and indeed, Billman (2002) found that during the Salinar and Moche Phases (400 B.C.–A.D. 900) irrigation expanded outward from the Moche River, reaching the extent of modern-day irrigation in the valley. Whether catalyzed by the organizational requirements of the irrigation system or by inter-group conflicts over land and water, during the Moche cultural phase, powerful elites emerged who exercised politico-religious power over people, water, land, and other resources.

It was during the Late Intermediate Period under the apparent political direction of the Chimú that technological and environmental parameters appear to have been pushed to their limits. Based on ethnohistorical sources and the impressiveness of large architectural complexes, the Chimú are generally considered to have been a conquest state and the chief rival of the Incas shortly before the arrival of the Spaniards (Rowe 1948; see Moseley and Cordy-Collins 1990). Chimú territorial extent stretched from the Supe Valley of the Central Coast to modern-day Tumbes, with the Chimú capital, Chan Chan, located in the Moche Valley (Moseley and Day 1982; Ortloff 1993:328; FIG. 1). Chan Chan was one of the largest urban settlements in the New World, with a maximum extent of 20 km² and an urban core covering 6 km² (Moore and Mackey 2008: 784). The city depended on expansive underground aquifers and walk-in wells for local water (Day 1974). Although exact population estimates are difficult to make, even with a relatively light occupation the water needs of the city and its supporting hinterland likely would have been significant.

The height of Chimú dominance is exemplified by the Intervalley Canal which was constructed to tap the Chicama River in order to irrigate the desert plains outside, to the north, of Chan Chan although the functionality of this canal has been the subject of debate (Ortloff et al.

1982, 1983; Pozorski and Pozorski 1982; Kus 1984). While the ACS has been known since at least the 18th century, few archaeological investigations have been directed at understanding its function, timing, and cultural affiliations. And yet the construction of the ACS was a prodigious effort. Watson (1979:202–232) pointed out that the length and labor involved in the ACS, especially taking into account the Ascope Aqueduct, is comparable to the Intervalley Canal, and that the former successfully irrigated an area that was 3.6 times as large as the area within the Moche Valley supplied by the Intervalley Canal (Kus 1972:122).

The nature, origins, growth, and eventual collapse of Moche and Chicama Valley canal systems were inextricably linked with the cultural dynamics of societies there. While the construction of the Intervalley Canal has been interpreted as conceived, directed, and built as a project of the Chimu state, the irrigation network of the Chicama Valley has been primarily considered within the framework of a local political system. Using colonial documents, Patricia Netherly (1977, 1984) reconstructed the autochthonous political organization of Early Colonial Chicama. She found that in the 16th century, upon the arrival of the Spaniards, the Chicama was divided into social groups called *parcialedades*, whose political power was reflected in water rights to specific canals. Several 20th century canals in the Chicama Valley (FIG. 3) may follow the alignments of ancient canals supporting these former *parcialedades*. The Chicama Valley and its *parcialedades* were politically divided into two large *repartimientos*, or polities, and the ACS would have corresponded to the ‘Licapa’ polity. We will return to the issue of the socio-political contexts of the canal constructions at the end of this article.

Hydrological Context and Preserved Canal Segments

An understanding of the hydrological regime of the Chicama Valley is crucial to the study of ancient irrigation and canal construction. The perennial Chicama River is located on the western slopes of the Andes in northern Peru at $\sim 8^\circ$ S latitude. The river has a catchment area of ~ 4500 km² with a maximum drainage divide elevation of 4284 m above sea level (asl) (Servicio Nacional de Meteorología e Hidrología 2013). Over 90% of the catchment area is located above 1000 m asl. Mean annual precipitation is strongly influenced by elevation, ranging 15–1500 mm from the coast to the highest uplands. River discharge varies according to precipitation and runoff, which in turn is affected by seasonality, climate change, and human modifications to landscapes. Chicama River discharge varies dramatically within the agricultural year (September – August) and from year to year, which potentially had an enormous effect on canal irrigation and food production in the pre-industrial era.

Chicama River discharge is highly seasonal, with over 80% of the annual streamflow occurring January to May (FIG. 4). Inter-annual variation in river discharge is also a factor in streamflow, owed primarily to the El Niño-Southern Oscillation (ENSO). For example, an analysis of precipitation data (1930–1949; 1961–1960) from Casa Grande (39 m asl) in the Chicama Valley (FIG. 1) indicates a 37.7% increase in rainfall during an El Niño year (Tapley and Waylen 1990:TABLE 1). An analysis of mid-20th century discharge data indicates that the Chicama River mean annual flood increases 77.7% during an El Niño year (Waylen and Caviedes 1986:TABLE 3).

Based on 1931–1970 streamflow records (ONERN 1973), the average monthly discharge of the lower Chicama River between January and May is 55 m³/s; between June and December, the average monthly discharge is only 6 m³/s. Flow seasonality has implications regarding the

allocation and competition for water between canal systems. Although an ethnographic agricultural calendar is not defined specifically for the Chicama Valley, we do know that maize was a key food crop. Along the North Coast, traditional planting of maize occurs May to early June, followed by at least two to three irrigation episodes before the harvest in September and October (Hatch 1974; FIG. 4). Hence, irrigation water demand for maize coincides with a period of relatively low river discharge. In addition to seasonal shortages in river supply, water losses due to evaporation, evapotranspiration from plant growth in and around canals, and seepage all contribute to water shortages, particularly for farmers at the terminus of canal systems. The full extent of the Chicama Valley historic canal systems measures approximately 150 km¹, and given seasonal variability in river discharge, it is likely that much of this system was not watered during a large portion of the year.

Despite major advances in the study of ENSO, the frequency and spatial variability of ENSO events remain extremely difficult to predict. Whereas proxy records indicate increased ENSO activity after ~ 3000 B.P. (Sandweiss *et al.* 2001) historic climatic and hydrological records indicate that spatial and temporal manifestations of ENSO are extremely unpredictable, and may reflect the specific climatic conditions and offshore water temperature of each valley (Tapley and Waylen 1990). As an example, the "mega-El Niño" of 1997–98 resulted in widespread flooding in the Lower Chicama Valley whereas that of 2015–16 did not, although coastal flooding did occur in March, 2017.

Overall, the North Coast typically experiences heavy rainfall during El Niño as the Intertropical Convergence Zone and warm equatorial waters push south allowing for convection of moist air that is drawn inland, resulting in runoff and flooding along normally dry quebradas and peak discharges on the larger perennial rivers. Large floods on the Chicama River would

easily destroy upstream canal intakes (Watson 1979) and potentially alter river channel morphology making subsequent diversions of water increasingly difficult.

Long since destroyed by Chicama River flooding, the intake for the Ascope Canal probably was located at the point where the river first enters the coastal plain across from the community of Sausal on the north side of the valley (FIG. 1). Although exact diversion points for both canals are unknown, the intake for the Intervalley Canal appears to have been upstream of the ACS intake (see Kus 1972:Map 5) and thus would have had the advantage of first access to the water. A few canal segments preserved east of Ascope indicate that the main channel followed the toeslope of mountains in order to maintain a grade that would permit gravitational flow to reach the Pampa de Mocán (FIG. 1) where deep alluvial soils permitted the production of maize, tubers, fruit, and cotton. Since *ca.* A.D. 1920, crop production in the Lower Chicama Valley has been dominated by large industrial sugar cane plantations (Sabogal-Weisse 1975). Twentieth century agriculture, erosion, and deposition obscure and/or have destroyed most of the other pre-Hispanic canal systems in the lower Chicama Valley except on the outermost margins of the valley (FIG. 1).

In addition to intakes on the Chicama River, downstream segments of canal systems were vulnerable to damage where canal channels crossed large quebradas. Indeed, a segment of the Ascope Aqueduct was damaged during the strong 1925 El Niño event (Watson 1979:132). A small lake (laguna) sustained by irrigation runoff occurs today near this damaged segment on the upslope side of the western end of the aqueduct (FIG. 2). Where the Ascope Canal crossed drainages, the canal channels acted as dams, impounding floodwater and resulting in stratigraphic sequences of laminated pond deposits. These pond deposits document past El Niño

events and help define age relationships for what we have identified as the Lower and Upper Ascope Canals (see below).

Three main canal segments associated with the ACS are preserved in the vicinity of the Ascope Aqueduct. One is the aqueduct itself, a 1.2 km long earth construction that crosses a broad *quebrada* separating Cerro Bartolo and Cerro Alto de la Pichona (FIG. 2). Aqueduct height increases *ca.* 12–23 m downstream, and the structure has a basal width of approximately 30–40 m (Watson 1979:154–155) forming a barrier to *quebrada* runoff and excess irrigation waters—resulting in the previously mentioned shallow laguna that seasonally expands and contracts. Within the aqueduct are several pre-Hispanic buried canal channels the dimensions of which are only partly known (Watson 1979:FIG. 8). The aqueduct was remodeled and used in the early 1900s until breached during the 1925 El Niño. The breach was filled sometime after the late 1970s and a canal, cement-lined in segments, was built across the top of the aqueduct; this canal was subsequently damaged again as evidenced by collapsed or broken sections and is currently inoperable.

A main canal occurs north of the Ascope Aqueduct and has a long and sinuous course that follows the base of the mountain. This canal, (hereafter, the Upper Canal), is cut in several places by intersecting side channels (*quebradas*) and can be traced ~ 4 km upstream passing north of Cerro San Bartolo. Where it crosses the mouths of *quebradas* in earthen aqueducts, the Upper Canal acts as a dam to small drainages and hillslope runoff resulting in local accumulations of pond deposits. The Ascope Aqueduct bypasses the circuitous route of the Upper Canal by cutting directly across the *quebrada* separating Cerro San Bartolo and Cerro Alto de la Pichona, suggesting the aqueduct was built to replace the Upper Canal (Watson 1979). The Upper Canal contains berms composed of adobe block and appears to have once joined the

west end of the Ascope Aqueduct. A short segment of the Upper Canal is missing where the two canals merged, but the canal channel elevations are comparable such that the small 20th century canal at the top of the Ascope Aqueduct joined the Upper Canal on the south side of Cerro Alto de la Pichona.

The other main canal is preserved in a 300 m segment where it crosses a small embayment at the southwestern base of Cerro Alto de la Pichona (FIG. 2). Historic (1943) aerial photography shows the channel continuing downstream across another larger embayment to the northwest, beyond which it is not visible. Where preserved, this canal is approximately 25 m wide at the base and 13 m high (FIG. 5). The canal segment is approximately 10 m lower in elevation than the Upper Canal located on the hillslope to the northeast. Referred to here as the Lower Canal, much of this alignment has been destroyed or obscured by subsequent agricultural activities. Extrapolating the Lower Canal gradient upstream places the alignment along the southern toeslope of Cerro Alto de la Pichona, a position currently occupied by a modern canal. Farther upstream, this modern canal follows the base of the Ascope Aqueduct and passes the modern town of Ascope (FIG. 1) on its south side.

Field Methods

Several stratigraphic localities were established during our investigation. Here we focus on three. Ascope Stratigraphic Locality 2 (ASL2) is *ca.* 900 m downstream from where the Ascope Aqueduct joins with the base of Cerro Alto de la Pichona and where the preserved segment of the Lower Canal was cut by water erosion forming a nearly perpendicular exposure of the feature (FIG. 5). This erosional cut is not present on 1943 aerial photography and likely formed sometime in the late 20th century, probably as a result of uncontrolled flooding from an upslope

modern canal. We documented the general stratigraphy of the Lower Canal at ASL2 and collected charcoal from the channel fill for accelerator mass spectrometry (AMS) ^{14}C dating.

The second area of study was Ascope Stratigraphic Locality 7 (ASL7), located next to the Upper Canal north of the modern laguna (FIG. 2). Here the Upper Canal intercepts hillslope runoff during heavy El Niño rainfall events. We placed an excavation unit through stratified deposits in an area of ponding on the upslope side of the canal.

The third study area was Cateo 9, an excavation unit located on the edge of the modern laguna (FIG. 2). This location was selected to see if the transition from alluvial (*quebrada*) to pond deposits as a result of the Ascope Aqueduct could be identified and dated.

Given an absence of visible charcoal, bulk sediments were collected from ASL7 and Cateo 9 for AMS ^{14}C dating. All samples were submitted to Beta Analytic Inc. (Miami); ages are calibrated using OxCal v4.2.1 with the SHCal13 atmospheric curve (Hogg *et al.* 2013) and presented at two sigma error range.

Kus (1972) obtained three ^{14}C dates (UCLA 1711G, UCLA 1711H and UCLA 1711I) for the Intervalley Canal in two excavations: Cross Section 18 and Cross Section 33 (see 1972:Appendix 1). These dates were re-calibrated using SHCal13 following modern standards (see Hogg *et al.* 2013). Finally, Bayesian analysis was applied to two of the Kus dates, UCLA 1711G and UCLA 1711H. Bayesian statistics place parameters on the possible time ranges of ^{14}C calibrations based on the known relationship between the samples – in this case, UCLA 1711H is from a lower stratigraphic layer than UCLA 1711G.

Results

Stratigraphic relationships at ASL2 (FIG. 6) indicate that the Lower Canal is older than the Upper Canal. Upslope from the canal exposure (ASL2c) is an approximately 4 m tall sequence of repeated coarse-to-fine (sand to silt) beds or rhythmites that are overlain by *ca.* 3 m of nonstratified loam deposits (ASL2a; Supplemental TABLE 1). The rhythmite stratigraphy is typical of pond deposition where *quebradas* are dammed and sands settle first followed by silt (e.g., Billman and Huckleberry 2008). However, the quebrada is currently dammed upslope by the Upper Canal, and there is insufficient catchment area between the two canals to generate significant runoff and thick pond deposits. The contact between the rhythmite beds and overlying loam deposits represents the time when the Upper Canal was constructed, thus blocking subsequent *quebrada* floods. The nonstratified loam deposits at the top of the sequence are derived by slopewash off the adobe berms of the Upper Canal.

At least eight nested channels are present within the Lower Canal as viewed at ASL2c (FIG. 5) indicating multiple episodes of remodeling as the canal aggraded. These may relate to eight major canal channels that cross the Pampa de Mocán farther downstream to the north. Other stratigraphic properties at ASL2c commonly associated with functional canals include bedded alluvial sands and silt, iron oxyhydroxides, stone lining of channel banks, and mixed fine-grained bank material derived from repeated channel cleanings (Supplemental FIG 1). Small pieces of charcoal are present within the canal channel fill. A thin lens of charcoal from the base of the lowermost channel (1) yielded a 2-sigma age of 990 ± 40 B.P. (Beta-418226; charcoal; $\delta^{13}\text{C} = -10.9 \text{ ‰}$), which when calibrated yields the date range A.D. 1025–1160 (TABLE 1). An isolated piece of charcoal from higher in the sequence (base of Channel 3) dated 2130 ± 30 B.P. (Beta-418224; charcoal; $\delta^{13}\text{C} = -22.6 \text{ ‰}$) or 205–50 B.C. We favor the younger age from Channel 1 given that the charcoal is from a better stratigraphic context. Isolated charcoal

fragments can be fluvially reworked in canals resulting in ages that predate canal construction (Huckleberry and Rittenour 2014). A lens of concentrated charcoal suggests a more local origin, perhaps related to canal cleaning, i.e., burning of vegetation within the channel.

A full stratigraphic exposure was not available for the Upper Canal. Thus we focused on pond stratigraphy located on the upslope side of the Upper Canal at ASL7 (FIGS 2,7; Supplemental TABLE 2) that provides an indirect age for canal construction. Ascope Stratigraphic Locality 7 contains fine-grained sediments overlying *quebrada* gravels. The fine-grained sediments can be divided into 18 sand-to-silt rhythmites, each interpreted as a single runoff event. The upper four rhythmites are grayish brown, a color that is derived from very fine charred material and ash. A likely source for the burned material is a broad area of industrial sugar cane fields located upwind (southwest) of the study area in the lower Chicama Valley that are regularly burned prior to harvesting. During our fieldwork, we observed air-fall deposition of fine ash and soot in the study area, much of it collecting in localized wind-protected areas on the modern surface. Lower in the stratigraphic sequence, very fine charcoal was retrieved from the bulk sample collected from Stratum 17, the second rhythmite deposited after canal construction. This sample yielded a 2-sigma age of 750 ± 30 B.P. (Beta-418228; charcoal; $\delta^{13}\text{C} = -24.5$ ‰), calibrated to A.D. 1230–1380 (TABLE 1). Given that very strong El Niño events occur every approximately 15–30 years (Ortleib and Macharé 1993), it is likely that Stratum 17 was deposited within 100 years of canal construction. This ^{14}C age is compatible with the relative stratigraphic relationships and chronometry displayed at ASL2, i.e., the Upper Canal is younger than the Lower Canal.

Like the Upper Canal, the Ascope Aqueduct lacks a full stratigraphic exposure of its internal structure. The 1925 breach has been largely filled, although the south side of the breach

is still partly exposed (FIG. 8). Watson (1979:154–156) describes this breach before it was repaired. Although partly covered by vegetation and slump deposits at the time of his visit, he identified several nested channels indicating that the aqueduct was built in several stages. Through time, the channel increased in elevation, in part due to natural canal sedimentation and in part by design in order to bring additional lands under cultivation in the Pampa de Mocán. Watson marks six stratigraphic discontinuities that ostensibly represent separate nested channels beneath the surface historic channel. During a later stage of construction, stone and adobe construction was used to rebuild and stabilize the berms.

The nested channels described by Watson are similar to those seen in the ASL2c exposure of the Lower Canal (FIG. 5) raising the possibility that the Ascope Aqueduct is an overlay upon this older canal. The Lower Canal cannot be traced upstream from the southwest tip of Cerro Alto de la Pichona as the alignment is currently occupied by a modern canal. The alignment of the Lower Canal upstream from this point is unknown although a path along the base of the *cerro* and northeast across the *quebrada* is likely. If true, then the Ascope Aqueduct as defined by its large adobe block construction represents a remodeling of the Lower Canal.

We have no calendrical dates directly associated with the Ascope Aqueduct. Excavations at Cateo 9 located upslope from the aqueduct next to the modern laguna extended *ca.* 2.0 m below the surface and revealed the point in time when the *quebrada* became dammed. Horizontally bedded, fine-grained deposits extend approximately 1.5 m below the modern surface (FIG. 7; Supplemental TABLE 3). Most of these fine-grained deposits are gray (2.5Y hue) with red (5–7.5YR hue) iron mottles (reduction-oxidation features) indicative of fluctuating water tables; less common are thin layers of brown (10YR hue) loamy fine sand. A bucket auger placed at the bottom of the excavation unit confirmed sand and gravel (*quebrada*) deposits 1.6–

2.0 m below the surface. Thus, the fine-textured deposits above 1.5 m depth are related to the damming of the *quebrada* and ponding of water. Efforts to ^{14}C date the fine-grained sediment failed due to insufficient carbon content.

Discussion and Conclusions

Three preserved main canal segments provide insights into the history of the ACS as an important mega-canal system in the Central Andes. Multiple main canal alignments within the upper system indicate repeated episodes of remodeling, possibly related to destructive El Niño floods or political realignments of control over water. The presence of Early Horizon and Early Intermediate Period settlements and field systems located at the terminus of the ACS in the Pampa de Mocán indicate that the system dates earlier than the Late Intermediate Period (see also Chauchat 1998). In areas that have witnessed centuries to millennia of irrigation agriculture, canals and fields tend to become buried and obscured through time (Adams 1965; Kidder *et al.* 2012; Nials 2015). Evidence for earlier canal alignments in the upper part of the ACS is likely to have been buried by sedimentation and obscured or destroyed by later remodeling of the system and 20th century industrial-scale agriculture.

Based on stratigraphic relationships and two ^{14}C ages associated with three preserved main canal segments, the evidence indicates that the Lower Canal in the ACS is the oldest, likely constructed in the A.D. 1000s (FIG. 9) while the Upper Canal was constructed later, probably in the late A.D. 1200s or early 1300s. Our chronology indicates that the three large alignments within the upper ACS were thus remodeled over a period of ~200–300 years. There was an apparent need to increase agricultural production so that the ACS main canals moved upslope through time in an effort to gain a larger irrigable area in the Pampa de Mocán (Watson

1979:202–204). Working against this, however, El Niño flooding likely caused major re-alignments of the Ascope main canals through the destruction of intakes and possible changes to the location and geometry of the Chicama River channel.

Based on geomorphic and stratigraphic evidence, various scholars have suggested that a megaflood impacted parts of the north coast during Chimu time, an event sometimes referred to as Nyamlap's Flood based on ethnohistoric references to such a catastrophe in the early Late Intermediate Period (Donnan 1990). As noted by Wells (1990), the exact age(s) of this fluvial catastrophe remain(s) unclear, ranging from *ca.* A.D. 1000 (Craig and Shimada 1986) to *ca.* A.D. 1350 (Kosok 1965; Pozorski & Pozorski 2002). Nyamlap's Flood may represent different floods in different valleys at different times during the Late Intermediate Period. Regardless, multiple nested channels within single alignments (e.g., FIG. 5) and shifting alignments within the upper part of the ACS likely reflect damage caused by multiple El Niño flood events during that time period.

Similarly, the impressive Ascope Aqueduct ultimately must be understood within the larger context of the canal system of which it is a part. The aqueduct is often mentioned as a Moche engineering feat (Mason 1957; Bennett and Bird 1964; Lumbreras 1974), but the archaeological evidence points to a later construction date (Watson 1979). The Ascope Aqueduct is more closely associated with the Upper Canal given similar elevations and adobe construction. As the Upper Canal has a much more sinuous alignment that follows the base of the mountains, we follow Watson's (1979) interpretation that the Ascope Aqueduct was built to replace the Upper Canal. Moreover, the aqueduct appears to have been constructed along the abandoned alignment of the Lower Canal. If, indeed, constructed to bypass the Upper Canal, then it likely post-dates A.D. 1300.

These considerations of the ACS and the Ascope Aqueduct within it raise issues regarding the general relationships of the major canal systems in the Chicama Valley and, in particular, how this new stratigraphic information relates to previous investigations of the Intervalley Canal. The Intervalley Canal, although not the only intervalley canal on the North Coast (see Hayashida 2006), has been set apart in the archaeological literature because it symbolizes Chimu political dominance from the Moche Valley over the Chicama Valley. As mentioned, opinions on the Intervalley Canal vary widely as expressed in debates in the early 1980s. Thomas and Shelia Pozorski (1982:865; 2002) argued that no part of the system ever functioned due to engineering errors, specifically the construction of segments built with positive (uphill) gradients, by the Chimu, an interpretation shared by Ian Farrington (1983). Ortloff *et al.* (1982, 1983:388) were uncertain, and suggested that gradients may have been altered due to surface deformation associated with subduction of the Nazca Plate. Global positioning networks confirm that a long segment of the northern Peruvian coast (5–10° S) is currently moving coherently 5-6 mm/yr east-southeast relative to the main continent (Nocquet et al. 2014). Such displacement can result in subtle and spatially variable surface deformation without requiring major earthquakes or fault scarps (Perfitini et al. 2010). It is quite plausible that current uphill canal segments were caused by localized crustal bulging or tilting sometime during the past ~700 years. James Kus (1972:144-167; 1984:409) postulated that the area around the site of Quebrada del Oso was in fact watered by the nearby Intervalley Canal and his excavations along that and other channel segments showed evidence of cleaning events (1972: Appendix B; FIG. 1). He (Kus 1984: 415) also suggested that a severe drought impelled the Chimu to start construction on the canal but that the end of the dry period resulted in the abandonment of construction efforts.

While the functionality of the Intervalley Canal has eluded definitive conclusion, there is no doubt that the ACS carried water over multiple centuries to the Pampa de Mocán. Elevation models and topographic mapping of the area, archaeological evidence for both field systems and settlements that span the Early Horizon through the Late Intermediate Period and preliminary microbotanical analysis from samples collected across these fields (FIG. 10) demonstrate that water conducted by the ACS indubitably reached and transformed the Pampa de Mocan.

The Intervalley Canal terminus was the Three Pampa Field System, located just outside the Chimu capital of Chan Chan. The proximity of these fields to the capital has been central in the argument for state-sponsorship of the canal project. If irrigated, the Three Pampa Field System would have resulted in 1600 ha of additional agricultural land (Kus 1972: 26–27; Ortloff 1993:328). But archaeological evidence demonstrates that the Intervalley Canal was not constructed for the sole purpose of irrigating the landscape around Chan Chan. Indeed, an area of the left margin of the Chicama Valley known as Cerro Lescano and Quebrada del Oso (FIG. 1) is the only known location that was successfully watered by the Intervalley Canal, calling into question the single-mindedness of the Canal’s architects and engineers (Kus 1972; Ortloff 1993).

The interpretation of the Intervalley Canal as a project conceived for the direct benefit of the Chimu capital is also closely tied to the chronology of Chan Chan proposed by Topic and Moseley (1983). They held that the Intervalley canal was constructed during Phase 1 or 2 of Chan Chan’s development and therefore essential to the further expansion of the capital (163). Indeed, Kus in his 1972 dissertation, collected three radiocarbon samples (UCLA 1711G, UCLA 1711H, UCLA 1711I) from the berm of the canal in deposits representing construction or maintenance activities, resulting in a date range of A.D.1000–1280 (Kus 1972:113–114). But when those dates were re-calibrated using the SHCal13 curve, the ages expand to a wider and

later period A.D.1030–1410 (TABLE 1), suggesting the Intervalley Canal construction or operation was at some point contemporaneous with ACS constructions and remodelingⁱⁱ. Bayesian modeling of UCLA 1711G and UCLA 1711H from Cross-Section 18 reduced the 2-sigma standard errors, providing an age range of A.D. 1040–1380, but we are still unable to distinguish the exact timing of the construction of the Intervalley Canal in relation to the Lower and Upper Canals of the ACS due to overlapping age uncertainties (FIG. 9).

While our research has been small-scale and focused on short canal segments, the dates we have achieved, so far, suggest that the ACS was being substantially remodeled and extended in the same general time period as the construction or early operation of the Intervalley Canal. However, due to the standard of error, the possibility that the canal systems were built sequentially remains open. Assuming that the canal systems did overlap in their use-lives, these dates are coeval enough that they cover a time when both major canal systems theoretically would have been drawing substantial amounts of water from the same source at the neck of the Chicama Valley. First order estimates of carrying capacity for the ACS suggest that the Chicama River could not have supported both systems during at least half of the year. Using dimensions of Channel 6 in the Lower Canal at Ascope Stratigraphic Locality 2c (FIG. 5), and conservative hydraulic assumptions (see Supplemental FIG. 2; Supplemental TABLE 4), the canal had a discharge of *ca.* 6.8 m³/s at this point in the system, *ca.* 15 km downstream from its likely intake on the Chicama River. The discharge capacity of the Intervalley Canal at a similar distance from its intake on the Chicama River is *ca.* 3.4 m³/s (Farrington 1983:TABLE 1ⁱⁱⁱ). Based on 39 years of historic streamflow records (ONERN 1973), the combined discharge of the two canals exceeds that of the Chicama River during at least half of the year^{iv} (FIG. 4).

Except during the Chicama River peak flow months of February to May, the simultaneous operation of the ACS and Intervalley Canal would significantly limit the delivery of water to other canal systems located farther downstream in the Lower Chicama Valley. This would have deprived water to downstream *parcialadades* for irrigation agriculture during much of the year. Even if the Intervalley Canal did not divert water at the same time as the ACS, its size suggests that it alone would have increased competition for water between the *parcialadades* within the lower Chicama Valley during the months of low river flow, or in years of drought and reduced runoff in the highlands. If the Intervalley Canal did supply water to fields in the adjacent Moche Valley (Ortloff *et al.* 1982, 1983), operation outside the four-month window of abundant river discharge would likely have compromised food production in the lower Chicama Valley.

Evidence suggests that 1) during the occupation of Chan Chan a major canal project in the Chicama Valley (the ACS) was initiated at the same time as or before the construction of the Intervalley Canal; 2) the Intervalley Canal project served not only fields close to Chan Chan, but also a significant area of the Chicama Valley; 3) both systems underwent near constant remodeling in response to floods, gradient change, and agricultural needs; 4) the Chicama River could not meet the water demands of both systems if they were in simultaneous operation for much the year.

The likely contemporaneity of the ACS and Intervalley Canal suggests that regional irrigation systems on the North Coast of Peru during the Late Intermediate Period were on an even larger scale than previously considered. Two longstanding models exist to explain how they were implemented and managed, however. The first is that of state-sponsorship as suggested by various scholars associated with the Chan Chan Moche Valley Project (Moseley

and Day 1982). While clearly a top-down concept, details of how it would have operated have not been proposed. The second model is that of local control through the operation of the *parcialidades* system as documented for the early Colonial Period by Patricia Netherly (1984). Neither model precludes the other, however. A state bureaucracy could easily have appropriated an autochthonously developed *parcialidad* system while it, in turn, could be a survival from a state established bureaucratic system, a still-functioning body that had lost its supervisory head. Indeed, although it is outside the scope of this paper, we propose that the *parcialdiad* system quite likely was the quasi-bureaucratic form under which the Chimú ran its empire albeit a proposal difficult to prove (see Cutright 2009, 2013, 2015).^v

While our work was not directed at issues of the viability of the Intervalley Canal, the Ascope study reopens questions about how engineering, water, and politics were interrelated in late prehistory in these key northern valleys. Although our interpretive reach could be greatly extended with more precise ages for both canal systems and if we could determine with certainty if the Intervalley Canal functioned all the way to Chan Chan, a number of significant points for further consideration have resulted from our work.

There are several possibilities to consider. First, we may be wrong in our estimations: perhaps water availability was greater than we have calculated so that both canal systems would have had enough water to service their areas in critical periods of need. If our water availability calculations are correct, however, this leads to other possibilities contingent upon knowing the amount of area that needed water (irrigation requirement) and population sizes that needed agricultural produce in the Late Intermediate Period. While all of the evidence gathered by extensive research at Chan Chan suggests that it supported one of the highest concentrations of

human habitation in the region, we currently do not have estimations of water demand that could serve to assess whether or not it was fulfilled by known canal systems.

If both canals could not have worked at capacity during the critical months of the year when water was needed to nurture crops, is it possible that the agricultural potential of both valleys was never fully exploited in the Late Intermediate Period? Could the Chicama Valley have been depopulated, perhaps its population relocated to the Moche Valley by Chimu overlords? Then again, if the Intervalley Canal never functioned fully due to engineering or political problems, we return to the issues still unresolved from three decades ago as to the role and purpose of the Intervalley Canal in the first place. Much of trying to determine how the canals may or may not have serviced fields and people in the Chicama and Moche valleys depends on the size of fields and populations in them and the nature of the political system(s) that controlled and distributed water. We know less about these matters than we need in order to fully appreciate the engineering and hydrological issues while the political issues complicate matters further.

On a more focused level of investigation, further research to refine our knowledge of the construction, maintenance, and history of the ACS will better help us understand how it relates to the Intervalley Canal and the allocation of water in the Chicama and Moche valleys. Improved definition of these monumental hydraulic structures elucidates how humans responded to the challenges of making a living on the desert coast of Peru. Those challenges were myriad and included not only how to best utilize limited supplies of water and land but also how to respond to tectonic uplift and the challenges brought about by El Niño. The fact that some of the most vibrant and resilient cultures of the ancient New World were successful for many years in combating those challenges makes the study of these matters both fascinating and valuable as

lessons to be learned as we face our own challenges of water availability and agricultural sustainability.

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Supplemental Materials (linked to the online version of the paper).

Supplemental Table 1. Stratigraphic Description for ASL2a (upslope from Lower Canal).

Supplemental Table 2. Stratigraphic Descriptions for ASL7 (upslope from Upper Canal).

Supplemental Table 3. Stratigraphic Descriptions for Cateo 9 (upslope from Ascope Aqueduct)

Supplemental Table 4. Hydraulic Calculations for Ascope Lower Canal, Channel 6.

Supplemental Table 5. Bayesian Analysis Data for Contiguous Sequence entered into OxCal v4.2.4.

Supplemental Figure 1. Examples of stratigraphic features associated with functional canal operation present at Ascope Stratigraphic Locality 2.

Supplemental Figure 2. Channel dimensions and hydraulic calculations for Lower Ascope Canal, Channel 6.

Supplemental Figure 3. Multiple plot of probability distributions for Intervalley Canal ¹⁴C samples (Kus 1972) 1711H, 1711G and 1711I and Ascope Canal System ¹⁴C samples from ASL2c and ASL7. Graph created in OxCal v4.2.4 using the SHCal13 atmospheric curve.

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Table 1 Radiocarbon Ages for (a) Ascope Canal System and (b) Intervalley Canal. Intervalley Canal ages courtesy of Kus (1972:Appendix A).

Locality	Beta #	Material	¹⁴ C yr BP	δ13C (‰)	Calibration (2 σ) [*]	Bayesian Model Age Range (2 σ) [†]	Notes & Interpretations
ASL2c	418224	charcoal	2130 $\pm$ 30	-22.6	205–48 B.C. ($p = 0.951$) A.D. 4–9 ($p = 0.004$)	-	Isolated detrital charcoal from upper channel fill of Lower Ascope Canal; reworked from older context
ASL2c	418226	charcoal	990 $\pm$ 30	-10.9	A.D. 1025–1160 ($p = 0.954$)	-	Thin, continuous layer of charcoal near base of lowermost channel of Lower Ascope Canal
ASL7	418228	charcoal	750 $\pm$ 30	-24.5	A.D. 1231–1248 ($p = 0.030$) A.D. 1262–1320 ($p = 0.689$)	-	Silt cap of rhythmite (17) in pond deposits upslope from Upper Ascope Canal; charcoal not identified in field but recovered

A.D. 1351–1385 ($p = 0.235$)

during pretreatment by Beta Analytic, Inc.

(a)

Near Quemazon Cross Section 18	Sample 7 (UCLA 1711G)	Carbonized plant material	820 ± 60	-	Original: A.D. 1130 $\pm$ 60; Corrected with SHCal13, 2 σ : A.D. 1150–1317 ($p = 0.915$) A.D. 1354–1383 ($p = 0.039$)	A.D. 1164–1378 ($p = 0.954$)	Burnt straw, twigs and plant remains possibly maize, from distinct layer of burned material 20 cm below the surface of outside of canal bank, below two other distinct layers; apparently intentional, in situ burning
Near Quemazon Cross Section 18	Sample 8 (UCLA 1711H)	Carbonized plant remains	870 ± 80	-	Original A.D. 1080 $\pm$ 80; Corrected with SHCal13, 2 σ : A.D. 1027–1300 ($p = 0.954$)	A.D. 1044–1275 ($p = 0.954$)	40 cm below level of surface of outer canal bank.
Quebrada del Oso Cross	Kus Sample 9 (UCLA	Charcoal	780 ± 110	-	Original A.D. 1170 $\pm$ 110; Corrected with SHCal13,	-	110 cm from surface of center of canal

Section 33 1711I)

2 σ : A.D. 1045–1097 (p

= 0.054)

A.D. 1106–1413 (p =

0.900)

(b)

*Calibrated with OxCal v4.2.4 and the SHCal13 database (Hogg *et al.* 2013).

†Details on Bayesian model in Supplemental Table 5.

FIGURES

Figure 1. Chicama Valley and Ascope Canal (adapted from Watson 1979).

Figure 2. Google Earth image of Ascope Aqueduct area showing canal alignments and stratigraphic localities.

Figure 3. Late 20th century canal systems within the lower Chicama Valley; adapted from Netherly (1977:Figure VI.2).

Figure 4. A. Proposed agricultural calendar for traditional winter maize production in Chicama Valley adapted from Hatch (1974). B. Hydrograph of mean monthly discharge (1931–1970) and 1964 daily discharge of the Chicama River measured at the Salinar hydrological station. Chicama River discharge data from Oficina Nacional de Evaluación de Recursos Naturales (1973: Cuadro no. 2-RH, p. 1999); adapted from Watson (1979:Figure 1).

Figure 5. Lower Canal exposure at Ascope Stratigraphic Locality 2 with location of ^{14}C ages. A minimum of eight nested channels are visible. Person at base of exposure for scale.

Figure 6. Stratigraphic relationships between Upper and Lower Canals at ASL2.

Figure 7. Ascope Stratigraphic Locality 7 and Cateo 9 stratigraphy. Stratigraphic descriptions in Supplemental Tables 1–3.

Figure 8. Photograph taken in 2014 and sketch profile (adapted from Watson 1979:157) of Ascope Aqueduct exposure at former breach. Photo faces east and shows southern (right) part of profile sketched by Watson.

Figure 9. Proposed timeline of canal operation for Upper and Lower Canals and the Ascope Aqueduct.

Figure 10. Relict canals and agricultural fields in the Pampa de Mocán supplied by the Ascope Canal System. a) Location of fields at terminus of the system in the Pampa de Mocán; b) Pampa de Mocán elevation model; c) aerial image of agricultural field containing diatoms (d) indicative of irrigation. Imagery in c) courtesy of Luis Jaime Castillo Butters; altitude 50 m.

TABLES

Table 1. Radiocarbon Ages for (a) Ascope Canal System and (b) Intervalley Canal.

Intervalley Canal ages courtesy of Kus (1972:Appendix A).

ENDNOTES

ⁱ System length based on Figure 2 from Netherly 1984:232.

ⁱⁱ We recognize that recalibrating dates for Chan Chan, itself, might shift the timing of many events including the relations between the timing of city growth and canal construction. As that is beyond our purpose here, however, we refrain from straying too far into this issue.

ⁱⁱⁱ Here we conservatively use Farrington's (1983:Table 1) estimate of discharge based on the average of Locations A and B. Ortloff *et al.* (1982: Table 1) present a larger discharge estimate (4.7 m³/s) for the Intervalley Canal.

^{iv} Mean daily discharge plot for the Chicama River in 1964 (Figure 4) coincides with ENSO neutral to slightly warm phase conditions (http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml).

^v If it was an empire, run by a centralized government.

Figure 1.

Figure 2

Figure 3

Figure 4

Ascope Stratigraphic Locality (ASL) 2

Figure 5

Figure 6

ASL7

750±30 B.P. (microcharcoal)

Cateo 9

Figure 7

Figure 8

Figure 9

Figure 10

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Supplementary material

Ascope Supplemental Tables and Refs Cited.docx

Features associated with canal operation:

- 1) Bedded alluvial sands and silts
- 2) Iron oxyhydroxides
- 3) Multiple stone linings for channel stabilization
- 4) Mixed, loamy bank material (dredged sediment)

Supplemental Figure 1. Examples of stratigraphic features associated with functional canal operation present at Ascope Stratigraphic Locality 2.

1/2 Full Dimensions: Top Width = 6.8 m; Depth = 1.5 m; $A = 6.8 \text{ m}^2$

Supplemental Figure 2. Channel dimensions used in hydraulic calculations for Lower Ascope Canal, Channel 6.

Supplemental Figure 3: Multiple plot of probability distributions for Intervalley Canal ^{14}C samples (Kus 1972) 1711H, 1711G and 1711I and Ascope Canal System ^{14}C samples from ASL2c and ASL7. Graph created in OxCal v4.2.4 using the SHCal13 atmospheric curve.

Author Biographies

Gary Huckleberry (Ph.D. 1993, University of Arizona) is a consultant and Adjunct Research Associate in the Department of Geosciences at the University of Arizona. He has conducted 30 years of consulting and research in western North America, Peru, and Chile. His research interests include geoarchaeology, geomorphology, soils, and climate change. He is currently Co-Editor of *Geoarchaeology: An International Journal*.

Ari Caramanica (M.A. 2013, Harvard University) is a PhD candidate in the Anthropology Department at Harvard University. Her research focuses on pre-Columbian agricultural landscapes, water management and environmental change in the Chicama Valley of North Coast of Peru.

Jeffrey Quilter (Ph.D. 1981, University of California, Santa Barbara) is the William & Muriel Seabury Howells Director of the Peabody Museum of Archaeology & Ethnology at Harvard University. His research interests concern ancient political systems in the Central Andes and southern Central America. His most recent book is *The Ancient Central Andes*.

We thank the reviewers for their constructive comments regarding our manuscript titled "DATING THE ASCOPE CANAL SYSTEM: COMPETITION FOR WATER DURING THE LATE INTERMEDIATE PERIOD IN THE CHICAMA VALLEY, NORTH COAST PERU".

We will respond to the reviewers' comments in order:

Reviewer #1: In general, I think that this is quite a good, interesting and useful article. The dating of the Ascope system and the discussion of the Intervalley system is well done and raises interesting questions. The author(s) are aware of the debates surrounding the functioning of the Intervalley system and also surrounding the degree to which a bureaucratic state government might have been necessary for the construction of large-scale irrigation systems.

The conclusions that are listed concisely on page 21 (Evidence suggests that 1) . . .) are well supported by the earlier discussion.

On the other hand, the conjectures about Chan Chan on pages 22-23 (As noted at . . . perhaps its population relocated to the Moche Valley by Chimú overlords?) do not seem to me to be well supported at all. In particular, I think that we have a better understanding of the population history of the site than the author(s) suggest, that the site did not extend under what is now the modern city of Trujillo and that it was not a pilgrimage destination. There is, to my knowledge, no evidence that the Chicama valley was depopulated by the Chimú. No citations are provided for any of these statements.

Reply: We concede the reviewer's point regarding the conjectures about Chan Chan as stated in our earlier draft. We have deleted the speculations and substituted a single sentence that states that we do not have accurate information on what the water needs of Chan Chan might have been.

There was little discussion of the boca tomas (or canal intakes) for the two systems. Figure 1 suggests that the boca toma for the Intervalley canal system would have been somewhat upstream from the boca toma for the Ascope system (possibly 2-3 km upstream?). One might infer from this that the Intervalley system might have been able to have first call on water flowing down the Chicama river. Also, then, this narrow portion of the valley might have been a zone of contention and/or cooperation, and, at the least, a zone of interest for future investigation.

Reply: The reviewer raises a good point regarding the canal intakes. We inserted a sentence that notes that although we do not know the exact locations of the boca tomas for both canals; they have been destroyed by river flooding and it appears that the Intervalley Canal intake was located farther upstream and had the advantage of first access to the water.

Reviewer #2: When I first saw the name of the manuscript, I thought "Great! Someone has finally looked at this canal system in detail." After reading the manuscript, however, I was disappointed. I do not want to discourage scholarship by seeming heavy handed, but I have serious reservations about the conclusions drawn by the author. My assessment of the data presented and the conclusions derived from those data are based on my experience working on the Moche Valley canal system, the Chicama-Moche Intervalley Valley canal, and a familiarity with the Ascope Aqueduct and the associated canal system on Pampa Mocan.

First, the author spends an inordinate amount of time on the Chicama-Moche Intervalley Canal. Certainly this is an impressive-looking construction, but the discussion should have stopped there. The author cites Pozorski and Pozorski 1982, but did not read it very carefully. Had the author done this, it would have been very clear that the Chicama-Moche Intervalley Canal never carried any canal water, not even to Quebrada del Oso. Figures 1 and 2 and Table 1 in that article clearly show that the canal has many uphill segments along its entire length, including eight segments before the canal

reaches Quebrada del Oso, that are not due to tectonic uplift. Thus, the conclusion that the canal never carried any water is not just an opinion, but a conclusion based on incontrovertible evidence. So, the extended discussion on the impact of the Chicama-Moche Intervalley Canal on the water availability in the Chicama Valley is irrelevant and unnecessary.

Reply: We have described characteristics and competing ideas regarding the history of the Intervalley Canal because one of the important points we make in our paper is that the Ascope Canal System and the Intervalley Canal appear to be contemporaneous, at least at the resolution of current radiocarbon dating. This is new information and it has implications regarding water availability during parts of the year if both canals were competing for Chicama River discharge.

The reviewer is correct that we should have included the fact that the Pozorskis' documented canal segments with positive (uphill) gradients upstream from Quebrada del Oso. However, we disagree that this represents incontrovertible evidence that the canal never operated. We stressed in the original manuscript that there is the possibility that the gradient has been altered by tectonic events, as noted by Ortloff and colleagues (Ortloff et al. 1982. *American Antiquity* 47:572–595). In the current revision, we strengthen that argument by discussing and citing new evidence for crustal movement along this portion of the Peruvian Coast that can easily manifest itself by localized deformation of the crust. Only slight tilting would be necessary to alter canal gradients from negative (downslope) to positive (upslope).

Second, the author has not demonstrated that the Ascope Canal System was ever really functional. The author has assumed, like many investigators of ancient Peruvian canal systems going all the way back to Kosok, that if canals and field systems are present, then they must have been functional. This is a faulty assumption. During the study of the irrigation in the Moche Valley, some canals and fields were visible on the surface but upon careful investigation were shown to have never been used. This was demonstrated by excavation of canal cross sections and by theodolite measurements of canal slopes. Along the Chicama-Moche Intervalley Canal, there are similar unused field systems and unused canal channels. At Quebrada del Oso, aqueduct cross sections show multiple canal constructions superimposed one on top of another, just as seen in the author's photos of the Ascope Aqueduct (Figure 8) and the Lower Canal (Figure 5). However, none of the canals in the cross sections at Quebrada del Oso show evidence of water laminae or soil oxidation, an essential indicator of significant canal use.

Reply: We are confident that our stratigraphic evidence indicates that the Ascope Canal System was indeed functional. To better support our argument, we have provided additional evidence including diatoms (an indication of irrigation waters) from agricultural fields located at the terminus of the canal system, and additional stratigraphic descriptions of the Ascope Lower Canal exposure (see additional text and new Supplemental Figure 1).

The profiles presented in the manuscript are not of actual canals but rather of sedimentary deposits accumulated up slope of actual canals. I am not sure why the author did not clear off the actual canals at existing break points. It seems to me that this could have been done on both the Upper Canal and the Lower Canal and probably on the Ascope Aqueduct itself. The photos of the Lower Canal (Figure 5) and the Ascope Aqueduct (Figure 8) are not clear enough to determine if the channels within each contain water laminae and oxidation indicative of canal use. Are there more detailed, close up photos of these canals? No slope data are provided between the main Ascope canals and the field systems present on Pampa Mocan. Those data would help in determining whether or not the slope is consistently downhill going toward the fields, and, as such, provide supporting evidence of field use.

Reply: Our study focused on ponded sediments on the upslope side of the Ascope Canal to help date the system and reconstruct the frequency of El Nino rains. During this investigation, we encountered the natural stream cut of the Lower Ascope Canal (ASL2c). Ideally, it would have been advantageous for our study to face this canal exposure but the logistics would have been daunting (the great height of the exposure; Africanized bee nests within the exposure). But enough stratigraphic detail is revealed to demonstrate with high confidence that the canal operated and was remodeled multiple times (see Figure 5; Supplemental Figure 1). In the new Supplemental Figure we point out stratigraphic features commonly associated with canal use: e.g., bedded silts and sands, iron oxyhydroxides indicative of saturated sediments, stone work used in remodeling channels, and mixed (dredged) sediment on the banks.

We agree with the reviewer that slope data, which we did not collect, would be an additional line of evidence supporting our claim that the canal functioned. Nevertheless, we believe that the stratigraphic features revealed as ASL2c and the agricultural evidence (fields, farming settlements) at the terminus of the system are adequate evidence that this monumental construction indeed provided water to the Pampa de Mocán A.D. 1000-1400 during the Late Intermediate Period.

What is provided in the manuscript are profiles and detailed descriptions of excavations on the up slope sides of the Lower Canal and the Upper Canal which are used, along with some radiocarbon dates to quite effectively demonstrate that the Ascope Canal System dates to the Late Intermediate Period. This discussion represents the heart of the paper; if the manuscript is modified to concentrate on this information, then the reworked manuscript would be a valuable contribution to the literature on ancient Peruvian irrigation systems.

Reply: We agree that the new ^{14}C ages are the heart of this study, but that it behooves us to place this new information into larger environmental and cultural contexts. Thus, our discussion of possible water competition between the Ascope Canal System and the Intervalley Canal.

We hope that these revisions address the concerns of the two external reviewers. If you have any questions or concerns, please do not hesitate to contact us.

Sincerely,

Gary Huckleberry
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