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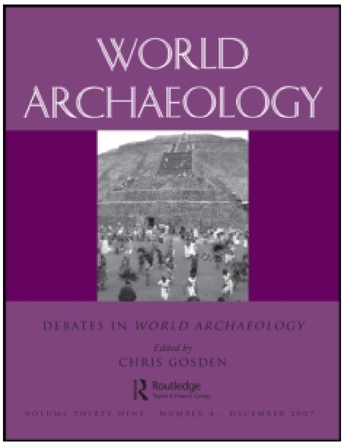

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Rethinking disaster-induced collapse in the demise of the Andean highland states: Wari and Tiwanaku

Patrick Ryan Williams

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Abstract

The role of drought in the collapse of the ancient states of the Andean Middle Horizon has received a great deal of attention in recent years. The only Andean valley where both principal states of this time period, Wari and Tiwanaku, had established settlements is in Moquegua, Peru. Based on a GIS network analysis of ancient irrigation systems and detailed palaeoclimatic data, I assess the assertion that a centuries-long drought caused the collapse of state colonies in this valley circa AD 1000. I conclude that the onset of the drought significantly postdated collapse and suggest that factions of Tiwanaku social groups who allied themselves with Wari settlers upset the ecological balance of water use in the valley prior to the end of the first millennium AD. The increase in agricultural activity in the upper sierra in conjunction with the political instability caused by the fissioning of Tiwanaku political power in the valley created an environment of vulnerability for the Tiwanaku state colonies. It was the complex interaction of social and ecological factors that led to the collapse of the largest western colony of the Tiwanaku state. The Wari imperial colony played a pivotal role in this collapse by establishing an administrative center in the upper valley that drew away resources from the Tiwanaku state below. Ironically, the political instability caused by the Tiwanaku colonial collapse may have been instrumental in the downfall of the Wari colony as well.

Keywords

Irrigation agriculture; drought; Peru; landscape ecology; GIS network analysis; Wari; Tiwanaku.

Introduction

The relationship between disaster-induced sociopolitical collapse and social evolution has a long history in archaeology. In the Andes, one of the major world regions in which the pristine state developed, environmental explanations have dominated the discussion of state collapse and long-term social evolution in recent years. The Andean Middle Horizon (c. AD 600–1000) provides an excellent opportunity to assess models of disaster and collapse. The inception of the Middle Horizon has been linked to a long drought

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from AD 562 to 594 (Shimada et al. 1991) and Moseley (1992) argues that the expansion of the empire of Wari was tied to its successful economic adaptation to this drought. Kolata and colleagues (Ortloff and Kolata 1993) maintain that the collapse of Tiwanaku in the Bolivian altiplano, the other great highland state, was caused by a centuries-long drought beginning around AD 1100. Many of the catastrophic explanations therefore involve the two predominant Middle Horizon highland cultures, Wari and Tiwanaku.

The only common frontier between these two polities was in the Moquegua Valley of southern Peru (Fig. 1). Here they established imperial colonies within sight of each other that coexisted for some 400 years. This small valley is therefore the ideal place to view the interactions between them and assess their rise and collapse. In the following, I evaluate the impact of drought on social interactions between them, and on their eventual collapse. Irrigation agriculture was the economic mainstay in the dry, rugged south-central Andean sierra, and I argue that changes in irrigation infrastructure reflect the economic impacts of water shortages.

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Tiwanaku colonization in the seventh century AD

The midvalley zone (1000–1500 meters above sea level) of the Moquegua valley was intensely populated in the Formative Period, immediately prior to the Middle Horizon. There was however little sociopolitical integration and no settlement hierarchy; the inhabitants farmed the valley floodplain from settlements on the low foothills next to the rivers (Goldstein 2000).

At the beginning of the Middle Horizon, c. AD 600, the first Tiwanaku colonies were established in Moquegua. Represented by Tiwanaku IV style ceramics, they represent a major change in the political control of the valley. The site of Omo (Fig. 1) is a principal focus of Tiwanaku settlement. Goldstein characterizes the initial Tiwanaku occupation in the Omo phase as an intrusive imperial colony. Imported ceramics in utilitarian contexts suggest that the population was ethnically Tiwanaku, not local people subjugated by the altiplano polity. House forms resemble those of the altiplano, not the local cultural traditions (Goldstein 1989).

In the Tiwanaku heartland, the nature of Tiwanaku control has been documented at the site of Lukurmata by Bermann (1993). A special purpose domestic architectural form, probably designed for storage, appears in the seventh century AD contemporary with an increase in Tiwanaku prestige items. This could denote coerced production for export. At Omo during the initial Tiwanaku phase, individual housing complexes are organized in plaza communities that do not contain any storage structures. Goldstein (1989) suggests that this indicates the presence of a supra-household storage facility, and that the lack of craft specialization indicates that the primary purpose of the colony was agricultural production for export – especially for maize which could not be grown in the Tiwanaku heartland. Kolata (1994) argues that at Tiwanaku from c. AD 500, agricultural systems were constructed using state control of local elites. While these local elites may have been fairly autonomous, they were constrained and motivated by the needs and demands of the state elite in the capital. These convergent reconstructions suggest that the agricultural colonies of Moquegua provided the state with exotic staple products not obtainable in the

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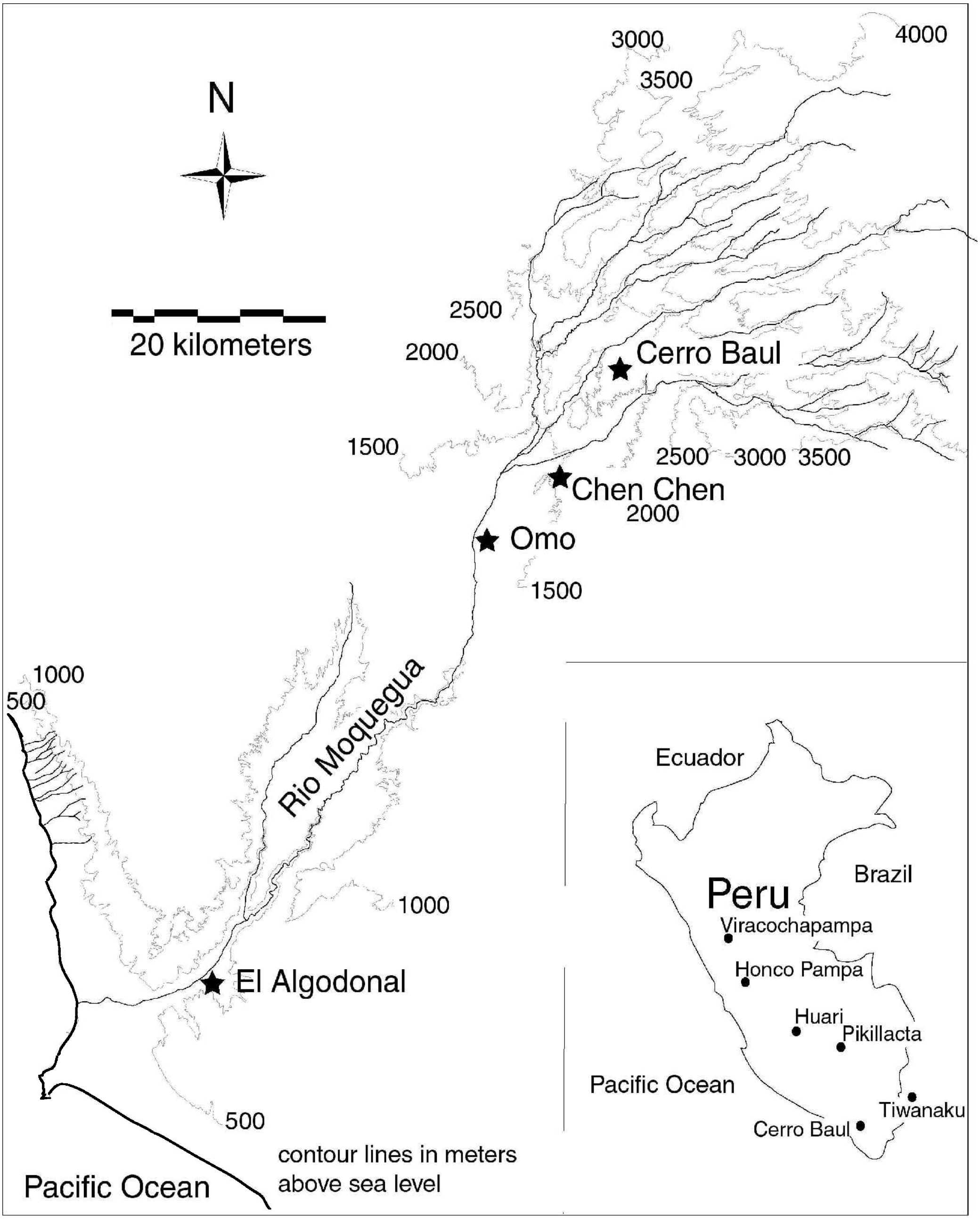

Figure 1 Location of the Wari-Tiwanaku interaction in the Moquegua Valley, Peru.

altiplano heartland. The state had a vested interest in the continuance of production of the Moquegua colony, although day-to-day decisions were most likely left to the colonists.

Regarding vulnerability to disaster, some factors might have hindered an effective response by the Omo colony. The colonists were highly dependent on extra-local power structures predicated on wealth objects from the Tiwanaku heartland. Status differentiation at Omo is distinguished by preferential access to items such as imported redware ceramics and warp face polychrome striped textiles (Goldstein 1989). The large-scale presence of these bulky status goods suggests a well-developed caravan system – a form of communication network (ibid.). Yet this was designed to move goods, not information. Communication between Moquegua and the altiplano heartland would have taken about a week, which would prohibit effective disaster response given the degree of interdependence between center and periphery.

In addition to these social factors, the Omo economic infrastructure – the hydraulic organization of agriculture – is also prone to collapse when faced with water shortage. I now examine that economic infrastructure. It was focused on middle valley floodplain farming. There was no great investment in extensive terrace systems like those of the upper portion of the valley, nor do the canals cross extremely steep and rugged terrain for great distances. The technological aspects of irrigation are not very complex. Given the very different hydrological regimes of the altiplano and the western valleys, Tiwanaku hydraulic technologies would not be applicable to the environment of the Omo colony.

The Omo agrarian environment could cope with minor tectonic activity. Adjusting to changes in surficial topography does not require great amounts of human labor. Likewise, while extreme flood events could destroy canal intakes and inundate fields, recovery of the Omo agrarian infrastructure from this sort of event could be accomplished rather quickly. Short-term productivity losses might be intense, but would be limited to months, rather than years.

However, the low-lying valley bottom systems were particularly vulnerable to drought. Upvalley agrarian systems, evaporation and seepage will all diminish the available water. When rainfall decreases and upvalley fields nevertheless continue to produce at pre-drought levels, lower valley fields will suffer the entire effects of water shortages. Since the Omo fields are closer to the lower end of the hydraulic system, they are more prone to water shortages. Modern farmers in most of the Omo agricultural area rely on mechanical pumping from subterranean aquifers to provide sufficient water for their fields (Moquegua Ministry of Agriculture 1983) – a technology not available to the prehistoric inhabitants.

Thus, both social vulnerability to crisis and technological vulnerability to certain natural hazards would have plagued the Omo colonists of Moquegua. As discussed above, this vulnerability would be especially pronounced should upstream agricultural systems begin to use more water at a time when highland rainfall was decreasing. This is exactly what happened in the seventh century AD, with the intrusion of the Wari colony.

The rise of the Wari colony in the seventh and eighth centuries AD

The Wari expansion led to the introduction of a new agricultural technology of profound importance to many parts of the Andes: terraced agriculture in the high sierra. Although terraces were utilized centuries earlier in the Early Horizon, as evidenced at Chavin (Burger 1992), in many regions of the Peruvian Andes, especially the desert south, it was

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Wari's expansion which first opened the high sierra to agriculture. In Moquegua, there was little or no occupation of the high sierra until the Wari intrusion (Owen 1994).

The Wari expansion around AD 600 occurred after thirty years of 20–30 per cent below normal precipitation (Shimada et al. 1991). High sierra farming radically improved the efficient use of water by decreasing the amount of water lost to evaporation and seepage in transport from the rainfall areas. In Moquegua, I estimate that the Wari canals could irrigate 2.5 times the area per volume irrigated by the Tiwanaku systems, due to their closer proximity to the highland rains above 3500 masl and the use of stone masonry terracing. That is, Wari agriculture was more than twice as efficient in the use of water. Since there was little pre-Wari occupation of the high sierra (Owen 1994), Wari was apparently not trying to incorporate a local population; rather, the Wari settlement in Moquegua was a colony, designed perhaps for political or defensive purposes, but with a strong agricultural foundation to support the colonial infrastructure.

The Wari occupation of Moquegua was centered on the Torata valley, one of the high sierra tributaries of the Moquegua River. Recent fieldwork in the area has documented six architectural sites and a canal system connecting them all (Moseley et al. 1991a; Owen 1994; Williams 1997). The Wari settlement is centered at Cerro Baúl, an impressive mesa with sheer sided cliffs. Excavations indicate that this colonial capital was an administrative/ceremonial site with a relatively long occupation (Fig. 2). Calibrated radiocarbon dates from the site span the period AD 620–1120, placing Cerro Baúl's occupation contemporary with the entire Tiwanaku occupation of the middle valley (Williams 2001). Excavations on Cerro Baúl have revealed Tiwanaku and Wari-Tiwanaku hybrid ceramic forms,

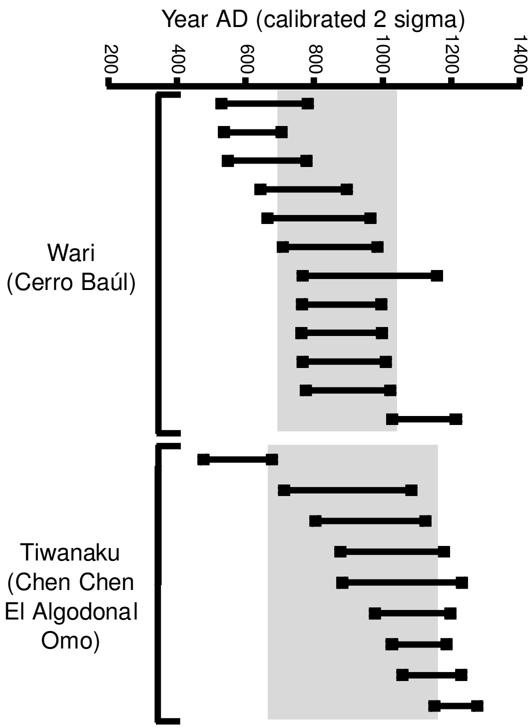

Figure 2 Comparison of Wari and Tiwanaku calibrated radiocarbon dates from Moquegua. Shading indicates 95 per cent confidence range of occupation based on all dates for each group. (After Goldstein 1989; Moseley et al. 1991; Owen 1993; Williams 2001.)

suggesting some interaction between the two polities (Moseley et al. 1991a; Williams et al. 2000).

The other Wari sites are on the 13 km Wari canal upstream and downstream of Cerro Baúl. They are all architecturally differentiated, suggesting a possible administrative site hierarchy (Nash 1996). Associated with the canal are several remnant agricultural terrace groups, which are highly eroded in some areas and superficially do not appear to reflect the work of a central authority. However, there are several lines of evidence suggesting that Wari agricultural works were much more extensive than they now appear.

First, these scattered agricultural works could not have supported the populations of the Wari colony. The ratios of settlement habitation area to cultivation area for several contemporary 'subsistence' economies in the Moquegua sierra support this argument. These range from 1:600 to 1:1000, with an average of 1:750. The Cerro Baúl colony, being part of an expansive state, should have had needs at least as great as these, yet the ratio of Wari habitation areas to the scattered terrace remnants is only 1:100. This suggests that there must have been at least six times as much irrigable land as the remnant traces indicate (Williams 1997).

Second, a hydraulic analysis of the principal Wari canal supports this hypothesis. A trench excavated through this canal at the site of El Paso indicates that the canal had a maximum discharge of 400 liters per second at this point. A canal of this size could irrigate an area in excess of 65 hectares (Williams 1997). The terrace remnants below El Paso measure only 25 hectares, and so the area actually irrigated was probably much greater than can be seen on the surface today.

Finally, it is probable that some of the modern canals in the Torata Valley were originally built by Wari, especially those on the river's south-east banks. One of the main Wari sites, Cerro Petroglifo is located within 200 meters of a modern Torata valley canal (Nash 1996). I therefore suggest that Wari land use included all modern irrigated lands in the lower Torata district and the terrace remnants associated with the Wari canal. This is probably a conservative yet accurate estimate of the actual land use in Wari times.

The impact of this Wari intrusion on Omo settlements lower down the valley is debated. One hypothesis holds that the Wari intrusion drove Tiwanaku from the valley (Goldstein 1989), suggesting a violent military confrontation. But another hypothesis argues for a decline in Tiwanaku agriculture in Moquegua due to productivity stress caused by Wari hydraulic investment in the upper drainage.

This hypothesis is tested by analysing water availability and agricultural land use during the established Wari occupation after 640 AD, when there was a decade-long drought involving an average 25 per cent decrease in precipitation (Shimada et al. 1991). Wari agricultural fields would need a minimum of 25 million cubic meters of annual discharge to support their irrigation fields, which represents 10 per cent of the water needed to irrigate Omo fields. Thus, the opening of the high sierra to agriculture by the Wari empire in conjunction with the decade-long drought would have reduced the water available to Omo fields by over 35 per cent. This would have decimated Omo agricultural production in the middle valley.

The Wari investment in agricultural infrastructure is a conquest by hydraulic superiority, accomplished through economic rather than military means. The hydraulic model provides a plausible, even convincing insight into relations between the Tiwanaku and

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Wari groups in the valley. It suggests an escalating conflict over water rights towards the end of the seventh century as water scarcity became more pronounced.

Two disasters thus converged: a drought-induced decline in productivity and the usurpation of water rights by a powerful intruder. They may have affected the nature of Tiwanaku Omo control in the region. Centralized decision making by, and economic dependence on, the Tiwanaku core area may have contributed to the failure of traditional authority to legitimize effective response to the disaster. The psychological impact of a competing empire establishing itself on a highly defensible and ritually charged mountain peak, co-opting local sources of water and spiritual power, may also have constrained effective response. The impact of the convergent disasters drastically altered the Moqueguan political and economic landscape. The political and economic power focus shifted from the middle to the upper valley during the early eighth century AD. Later effects of the tense relations are evident in the reorganization of provincial administration in the succeeding Tiwanaku phase.

The mature colonies of the ninth century AD

Late Middle Horizon Tiwanaku settlement is characterized by a politico-religious center at Omo, and a demographic-economic center at Chen Chen (Fig. 1). In terms of adaptive response to the Wari intrusion, the politico-religious center attempted to solidify control of the valley through ideological means, along with the establishment of more population centers and investment in agrarian infrastructure. At Omo, provincial administrators constructed a ceremonial complex based on the Akapana temple at Tiwanaku. It mirrored the three-tiered platform of altiplano temple centers, and is the only such complex constructed outside the Titicaca Basin (Goldstein 1993). The symbolic significance relates to the forward-facing deity on the Gateway of the Sun, arguably the most important figure in the Tiwanaku pantheon. This figure stands upon a three-tiered platform flanked by side-profile attendants (Goldstein 1993); we can thus argue that the three-tiered platform was a portrayal of power structures, relating humans to gods and reinforcing the social hierarchy as an extension of the earthly and supernatural world order.

This incorporation of Moquegua as an administered province during the Tiwanaku V period may be a reflection of a larger reorganization of the Tiwanaku state at this time (Browman 1981). This may have involved regional centralization of administration to Tiwanaku itself, reflected by a decline in the domestic and ritual complex at Lukurmata and a corresponding increase in centralized control of production and ritual at the capital (Bermann 1993). This is also evident in changes in settlement hierarchy and agricultural production in the Tiwanaku Valley region at this time (Albarracin-Jordan and Mathews 1990).

The establishment of Omo as a provincial administrative center is in stark contrast to this centralizing process. It may partially be explained by its distance from the capital and the need to incorporate Moqueguan inhabitants more directly into the rituals of the state. The evidence seems to indicate the development of a hierarchy within Moquegua and perhaps less centralized control of the Moquegua household by the state administrators in the altiplano. However, investigations at Omo's Chen Chen style site of M10 argue for the integration of households into the state economy, with regard to both staples and wealth items (see D'Altroy and Earle 1985). The frequency of redware ceramics, most likely imported from the altiplano, surpassed the fineware frequencies from earlier phase excavations (Goldstein 1989). Both finely crafted and coarse utilitarian textiles were recovered from Omo M10, and their likely manufacture in the altiplano may have been even more important to the integration of Moquegua into the state economy. Staples such as llama and *chu o*, a freeze-dried potato which can be produced only in the cold altiplano, were found in domestic contexts (Goldstein 1989), indicating that such staples moved between Tiwanaku and her provincial daughter.

The strongest evidence for staple interdependence between core and periphery is that which indicates maize production for export. New varieties of maize with a larger cob were introduced, suggesting selection for increased production. The many *taclla* (stone hoes) and *batanes* (ground stone implements used in mass producing maize) found in domestic contexts at Omo M10 also indicate agriculture geared toward surplus production (Goldstein 1989). Recent evidence from Chen Chen compellingly suggests that massive storage facilities were constructed at this time (Bandy et al. 1996). Surplus production for extra-local exchange, the expansion of the agrarian landscape and the increase in associated Chen Chen Phase settlements all argue for state investment in the agrarian infrastructure geared specifically for maize production and export. The development of a site size hierarchy also argues for incorporation of the valley as an integrated economic province of the Tiwanaku state at this time (McAndrews 1995).

This increase in sites occurred throughout the middle valley, but the greatest population focus and agrarian investment was in the upper portion of the middle valley at Chen Chen. Here the river valley narrows significantly, so the area is important for the control of water. This upvalley movement of agricultural lands constructed for state production was adaptive in mitigating the effects of water availability on agricultural production.

Meanwhile, the Wari colony in the high sierra continued to thrive. The increase in rainfall in the eighth and ninth centuries AD provided enough water, so droughts would not have curtailed Tiwanaku agrarian expansion despite the Wari success. In fact, there is some evidence that Wari and Tiwanaku interaction had become more extensive, suggesting relations may even have been amicable (Williams et al. 2000).

I have elsewhere argued that a major institutional restructuring took place at the colonial capital Cerro Baúl in the late ninth century AD (Williams 2001). This does not appear to result from a natural catastrophe, but probably represents a reorganization of the Wari colonial presence. Several large plaza complexes were constructed, each between 500 and 1000 square meters. Earlier monumental architecture was at its largest around 100 square meters. Furthermore, the associated buildings contain no evidence for domestic activities, such as food preparation and consumption, household craft production or sleeping areas. My interpretation is that these are buildings in which the colonial governors maintained administrative offices and reception halls, but were not residential. This reconstruction transformed the nature of interactions between elite governors, their subjects and outside groups.

This restructuring may be a reaction to the consolidation of Tiwanaku settlements in the middle valley a few decades earlier. Nevertheless, in this dynamic social environment,

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the status quo was never preserved for long, and there is ample evidence for rapid changes in the latter stages of the tenth century AD, despite the fact that rainfall remained above normal, and would not decrease for at least another 100 years.

Tiwanaku factionalization and collapse in the tenth century AD

The collapse of the Tiwanaku state has been attributed to a number of causes. Especially in provincial areas such as Moquegua, none of these mechanisms is well understood. Kolata (1994) argues for a pan-Andean drought in the eleventh century AD. Others have argued for an independent collapse of the Tiwanaku administrative hierarchy. The site of Chen Chen is an ideal location in which to study agricultural development during the terminal Tiwanaku period (850–1050 AD). An hydraulic analysis of this site provides the data to test these hypotheses.

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Chen Chen is located at the upper limits of imperial presence in the region. It is the largest Tiwanaku V occupation of the area. A set of irrigation canals, which drew water from the Tumilaca River, are well preserved, as are the associated fields, and individual irrigation furrows are visible on the surface. Furthermore, Chen Chen is a single component site with radiocarbon dates falling solely in the Late Tiwanaku period.

There was an upslope shift in the principal irrigation canal through time, and a precipitous decline in irrigated areas and canal capacity at the end of the period (Fig. 3). Mapping and reconnaissance indicate the existence of three principal canals. Their temporal sequence from lower to higher is based on the following superposition evidence. The lowest canal lies below several cemetery and domestic sectors, and is crossed by feeders and furrows from the middle canal. This securely dates the lowest canal's abandonment to before the maximum expansion of middle canal agriculture and well before the abandonment of the site. The middle canal also lies below some cemetery and domestic sectors, and is crossed by a feeder from the upper canal. Tombs lie directly in the course of both these canals, showing canal abandonment before cemetery construction. Superposition evidence also indicates that the middle canal was abandoned well before the site was abandoned, and fell out of use before the upper canal. The upper canal is the only one compatible with all cemeteries and domestic sectors at the site. It is therefore the only canal that could have brought water to the site in its terminal phases. The superposition of the upper canal over the middle canal also indicates that this was the last functioning canal at the site.

Given this canal sequence, maximum cultivation areas under each canal system can be mapped (Fig. 3). As is evident from the maps, there was a precipitous decline in cultivation area from 93 to 70 to 15 hectares. Excavations of the principal canals confirm this: estimated discharge capacities of the successive canals declined from 81.5 to 63.5 to 58.1 liters per second. The irrigation authorities at Chen Chen were clearly restructuring the agrarian landscape in a dynamic manner. This restructuring could be due to a decline of water resources, pressures forcing increased agrarian production, political manipulations of agrarian infrastructure, or a combination of these. Whatever the impetus, the result was a decline in production and the abandonment of the settlement. At the same time, the administrative networks of state domination of the region collapsed (Bermann et al. 1989).

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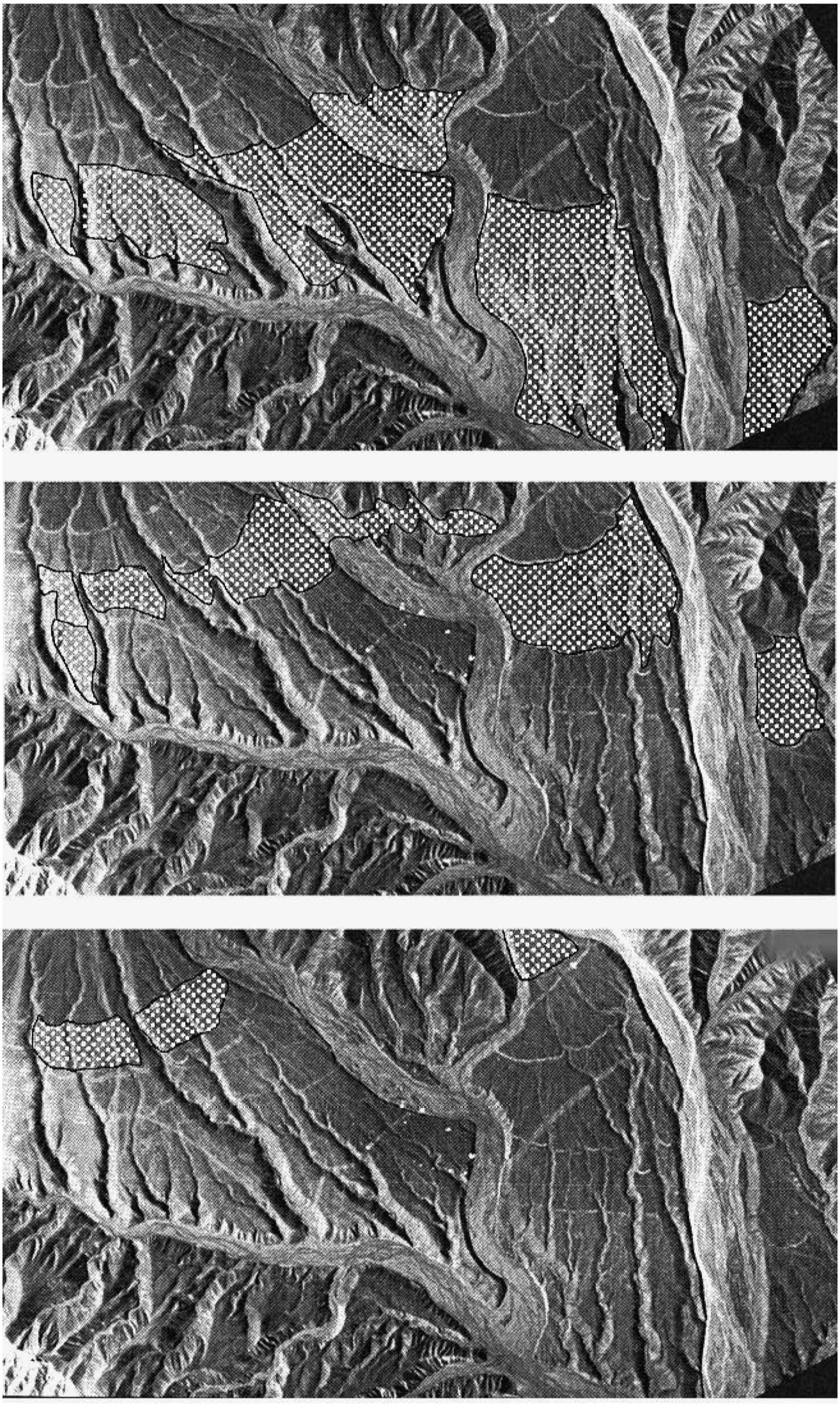

Figure 3 Evolution of agricultural systems near Chen Chen, AD 800–1000, showing the three successive phases of agricultural retraction (oldest at top). Shading indicates field areas. (Williams 1997)

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Probably at this time, Chen Chen was also sacked and destroyed. Several possible sources have been advanced, likely candidates being a Wari intrusion or a revolt by the local population against state rule (Moseley et al. 1991a). Little evidence exists for a direct overthrow of Tiwanaku by Wari – no implements of war or other evidence of direct Wari conquest has been recovered from extensive excavations at Tiwanaku sites in the valley. This leaves the revolt of the local inhabitants as the most plausible explanation.

Early in the Late Middle Horizon Period (*c*. 850–950 AD), drought did not play the same role as in the earlier Tiwanaku-Wari tensions of the seventh century AD. In fact, the long drought of the first half of the second millennium AD did not significantly affect the water supply until the twelfth century AD. The average water available during the main Chen Chen occupation (850–950 AD) was 245 million cubic meters of annual discharge. The range in decadal averages was 225 to 265 million cubic meters, with a standard deviation of decadal averages of 12. This indicates that the period was characterized by low variation in rainfall and normal to wet conditions when compared to the 1500-year average.

The Chen Chen field systems needed an estimated 250 million cubic meters to sustain production in all fields, which is within the range of availability during this period. In the succeeding century (AD 950–1050), water statistics are very similar, with a period average of 240 million cubic liters of annual discharge; decadal average ranged from 220 to 260 million cubic liters, and the standard deviation for the period was 13. There was thus little change throughout the period AD 850–1050.

A natural change in hydraulic conditions cannot therefore account for the Chen Chen collapse prior to AD 1050. However, a crucial factor is that the full component of Wari fields upstream of Chen Chen would have required 50 million cubic meters of water annually. If water shortage contributed to the decline of Chen Chen, it would have been a result of development of the upper valley by Wari and their Tiwanaku associates, the Tumilaca (Williams and Nash 2002). It is therefore argued here that control of water resources, and control of production and distribution of agrarian goods, were the impetus for an independence movement by the Tumilaca at AD 950. A revolutionary movement within the province could be manifested in the destruction of sites that exemplify state control. The lack of foreign materials on these sites suggests that the looting was probably undertaken by members of the same society.

Cultural continuity between Chen Chen and Tumilaca suggests links to the Tiwanaku heritage, but the absence of the Gateway God motif, conspicuously present in Tiwanaku IV and V iconography, may suggest a rejection of state control if this figure is emblematic of the state (Goldstein 1989). In addition, the large Tumilaca/Chiribaya canal in the coastal valley was most likely constructed before AD 1000 (Satterlee et al. 2000; Owen 1993). In order for water to reach this canal on a year-round basis, the irrigated lands at Chen Chen would have had to have been abandoned, because these fields would have used practically all the water available at that time.

Conclusions

The analysis of ecological effects of drought in the Titicaca heartland does not seem to indicate severe water shortages until the end of the eleventh century AD (Kolata 1994).

The hydraulic analysis of Moquegua agriculture presented here also rules out a disaster caused by environmentally induced water shortages. Instead, it seems more likely that local factions within the Moquegua Tiwanaku populations were developing, perhaps in response to the high degree of economic interdependence forced on them by the state. Once the Moquegua revolution had gained enough momentum, it began to follow its own course; the ramifications of losing one of its prime maize-producing regions may have further destabilized the authority structure of the state in the heartland itself, but this hypothesis requires testing at Tiwanaku itself.

The Wari colony at Cerro Baúl also appears to have been abandoned in the eleventh century AD. While hydraulic analyses of Wari field systems do not indicate the hydraulic mismanagement that characterized the late Tiwanaku field systems in Moquegua, the abandonment of Cerro Baúl and the probable collapse of the Wari state at this time (see Williams 2001 on revising the date of this event) are likely more than coincidence. The events precipitating the local Tiwanaku collapse inevitably affected the politics of Wari control in the drainage. Perhaps with the demise of Tiwanaku state presence, the principal reason for the Wari occupation of Moquegua – to contain and interact with the Tiwanaku frontier – was no longer an issue. Ongoing research at Cerro Baúl will certainly illuminate these issues. Nevertheless, the end of the Middle Horizon dominion by the two principal states is an extremely complex social process. In Moquegua, water and social dynamics very likely played a crucial role in the abandonment of the only known frontier of direct interaction, with social vulnerability to certain natural and political stresses a primal factor. The ramifications of losing an important colony may have increased social susceptibility in the Tiwanaku heartland to severe resource stress that the later drought brought forth.

The competing agricultural dynamics of the Middle Horizon influenced the development of the landscape of Moquegua over the next millennium. Post-collapse societies were embroiled in a centuries-long drought that gave the competitive edge to those who elaborated Wari's high sierra agrarian technology. Developed to its penultimate by the Inca empire in the fifteenth and sixteenth centuries AD, high elevation terraced agriculture is still a traditional mainstay in the Andean sierra today. Thus, the response to competing political forces and ecological conditions has drastically altered the ecological dynamics of the western Andean watersheds up to the present day.

The magnitude of a natural hazard cannot be equated with the magnitude of its social impact. Collapse and survival are social processes, affected by but not driven by their environments. The explanatory focus on disaster agents, rather than the process of coping with disaster and the inherent vulnerabilities in social systems, has reduced the explanatory strength of archaeological models. By incorporating social elements into the equation, we arrive at much more powerful explanatory devices that do not depict human societies as the recipients of environmentally prescribed collapses, but as active agents in the construction of the environment and in their own development. Environmental reconstructions will continue to play an increasingly important role in archaeological models, and archaeology must continue to utilize both social and environmental data in order to understand the long-term impacts of ecodisasters on the landscapes humans inhabit.

Department of Anthropology, The Field Museum of Natural History,
1400 S. Lake Shore Dr., Chicago, IL 60605, USA

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