
Water, Silt and Dams: Prehispanic Geological Storage in the Cordillera Negra, North-Central Andes, Peru

Agua, Limo y Represas: Almacenaje Geológico Prehispánico en la Cordillera Negra, Andes Norcentrales, Perú

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...Y después mandó los señores reyes ingas guardar la costumbre y ley de que no meneasen todas las dichas acequias, agua de regar las dichas sementeras, hasta los pastos de ganado regaban en los altos y quebradas...

(Guaman Poma de Ayala, 1993 [1615], 780)

Abstract

Over the past few decades there has been an increasing interest in building micro-dams across the whole of the Cordillera Negra, North-Central Andes, Peru. Given the difficulties in maintaining a regular flow of water, especially during the dry season, it is a logical response to a pressing need. Yet, lack of water is not a modern phenomenon, it is a long-standing problem that was tackled in a similar fashion in the past. Then, indigenous skill and landscape knowhow informed the selection of sites for damming.

Modern engineers have followed their lead, such that present-day micro-dams often occupy the same space as the prehispanic ones. Aside from the obvious destruction of cultural heritage – usually without a proper archaeological survey – there is one other problem with this policy: not all the old dams which are now being reconstructed were built for retaining just water. With an intimate knowledge of their Andean environment, humans adapted and altered the land around them. To this end, alongside water dams, other structures were built, such as silt dams.

Although outwardly like water dams, silt dams evinced a very different purpose. These structures acted as large check dams which accumulated run-off silt and other sediments, fostering a *bofedal*-type microclimate, while likewise trapping and purifying water within the silt. Nowadays, these unique structures are under threat from engineers with little understanding of the true purpose of these hydraulic monuments. This article describes these silt dams, using a case-study from the Upper Nepeña Valley, their form and function.

Keywords: *Ancash, silt dams, geological storage, prehispanic, bofedales*

Resumen

En las últimas décadas, hubo un importante incremento en la construcción de microrepresas a lo largo de la Cordillera Negra, Andes Norcentrales del Perú. Debido

a las dificultades en mantener un flujo regular de agua, especialmente durante la estación seca, esto constituye una respuesta lógica a una necesidad urgente. Sin embargo, la falta de agua no es un fenómeno moderno, es un problema de larga data que se abordó de forma similar en el pasado. Por lo tanto, el conocimiento del paisaje y las habilidades indígenas llevaron a la selección de sitios para hacer represas.

Los ingenieros modernos han seguido su ejemplo, de modo que las microrepresas usualmente ocupan los mismos espacios que las que fueron realizadas en contextos prehispánicos. Además de la obvia destrucción del patrimonio cultural – generalmente sin un estudio arqueológico apropiado – existe otro problema con esta política: no todas las antiguas represas reconstruidas en la actualidad fueron originalmente hechas para retener solamente agua. A partir de un profundo conocimiento del ambiente andino, las poblaciones humanas adaptaron y alteraron la tierra que los rodeaba. Con este objetivo, además de las represas para contener el agua, se construyeron otras estructuras como las represas para retener limo.

Si bien son exteriormente similares a las represas hidráulicas, las estructuras para contener limo tuvieron un propósito muy distinto. Estas represas permitieron controlar y acumular flujos de limo y otros sedimentos, lo cual fomentó un microclima de tipo *bofedal*, al mismo tiempo que retenían y purificaban el agua contenida en el limo. Actualmente, estas estructuras únicas se encuentran amenazadas por ingenieros con escasa comprensión del verdadero propósito de estos monumentos hidráulicos. Este artículo describe estas represas para controlar y acumular limo, usando un caso de estudio del valle alto de Nepeña, principalmente su forma y función.

Palabras clave: *Ancash, represas de limo, almacenaje geológico, prehispánico, bofedales*

Introduction

Over the past few decades, the complexity and diversity of Andean hydraulic engineering have been studied and highlighted as never before (Denevan, 2001; Herrera, 2011; Lane, 2014; Orloff, 2009). This is especially true of the highlands, which until recently were singularly under-researched. Nevertheless, there is still much new material to be investigated and assimilated, as studies into the *amunas* systems of the Central Andes demonstrate (Alencastre, 2012; Apaza, Hurtado and Alencastre, 2006).

This study presents and describes a series of structures known as *represas de limo* or silt dams. Silt dams were structures primarily built to contain erosion (a sort of massive check dam), while concomitantly providing a stable platform for the creation of artificial *bofedales* (irrigated moorland). Although initially identified for the Cordillera Negra, Ancash, new research has uncovered evidence of similar constructions in the Upper Ica Basin (Huamán and Lane, 2014), suggesting that these type-sites were more common across the Andes than originally envisaged (Figure 1).

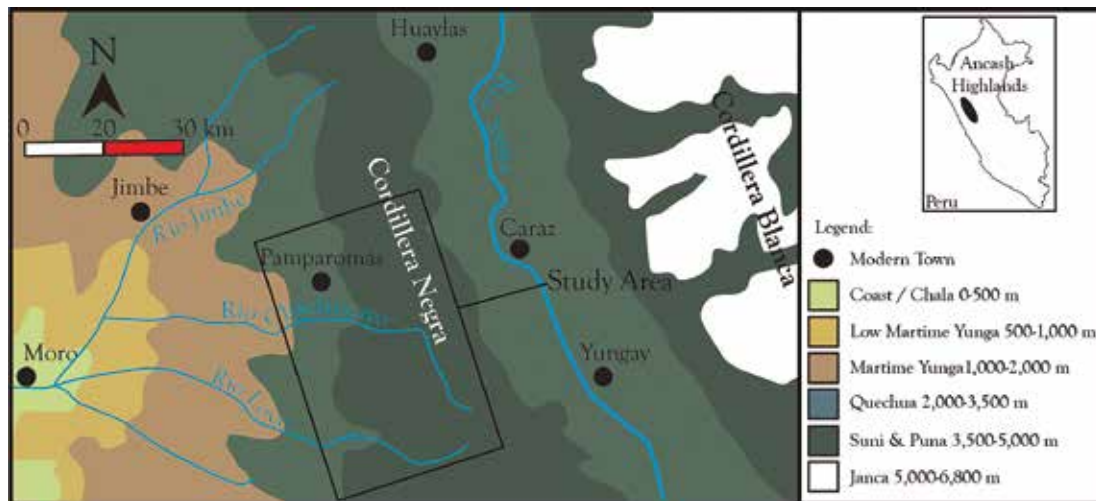


Figure 1. Map of study area – Pamparomás District, Huaylas Province, Ancash.

Although outwardly similar to prehispanic water dams, these silt dams were very different in their use and location. Nevertheless, the general similarities in structure and construction have led to misidentification of these features as water dams, in turn leading to the destruction of some of them (Lane, 2013). In this article, we describe these silt dams – their state of preservation, form and function – in the Cordillera Negra, Department of Ancash.

Silt Dams

Silt dams are large stone and fill structures that essentially serve three basic functions:

1. Accumulate silts and sediments that erode from the mountain slopes;
2. Retain and store water within the trapped silts and sediments;
3. Provide a rich soil matrix platform for the creation of an artificial *bofedal*.

These three functions are obviously interlinked. In addressing the first function, given the annual high-energy water discharge associated with the austral summer rains and therefore the propensity for landslides and avalanches (*huaicos*), it makes logical sense to construct barriers to halt and control the flow of water and sediment. In this remit, silt dams act like large check dams which cut across the path of main water flow (Denevan, 2001). While the features described by Denevan (2001: 171-185) were

grouped and stepped, built across very narrow ravines – and therefore more analogous to the silt reservoirs described for the Ancash region (Lane, 2009) – these silt dams are large constructions (usually over 80 m in length) spanning across a whole valley or side-valley floor.

Indeed, this function was highlighted by Freisem (1998), who identified them as *secondary erosion dams*, which ameliorate the effects of *huaicos* and thereby protect the lower-lying cultivation fields and settlements. Yet this is only part of the story. Silt dams, like the silt reservoirs, were more than just devices to prevent erosion flooding. The sediment generated by hill-wash and general erosion provided an important platform for pasture, and retained mineral salts that were in turn consumed by animals.

Likewise, the function of trapping silts and sediments (Point 2 above) does not preclude the fact that these structures also store and contain water. In this case, silt dams act not so much as dams but rather sieves that filter hydraulic overflow while maintaining the trapped sediments behind the wall structure saturated with water. In so doing, these features act to store water and help in replenishing underground aquifers (*sensu* Fairley, 2003). Finally, (Point 3 above) the dual accumulation of sediments and water creates the conditions for *bofedales* (moorland ecotone).

Bofedales are important highland ecotones that help create and sustain particular niche habitats. In this case,

bofedales provide optimum pasture conditions for use by herd animals (Maldonado, 2014/15). While these occur naturally, there is a long pedigree in the Andean highlands of human-made *bofedales* (e.g. Flores and Paz, 1986; Flores, Paz and Rozas, 1996; Palacios, 1977, 1981, 1996). To these systems can now be added that of silt dams first identified for the North-Central Andes (Lane, 2006, 2009), and subsequently found in other parts of the Andean highlands (Huamán and Lane, 2014).

A thorough survey of the Upper Nepeña drainage (1999-2008) – the Loco River and Chaclancayo River – revealed twenty-nine sites with hydraulic features, ranging from major dams to water reservoirs, small check dams and large silt dams (Figure 2). Five of these were silt dams. In turn, these various water and/or silt storage structures combine with fields, terraces and canals to create complex hydraulic systems that can encompass whole valleys. This systemic control of water emphasizes the highly-specialized relationship that existed between people, water and technology in the past. It was this syncretic relationship that underpinned the development of novel hydraulic constructions, such as silt dams.

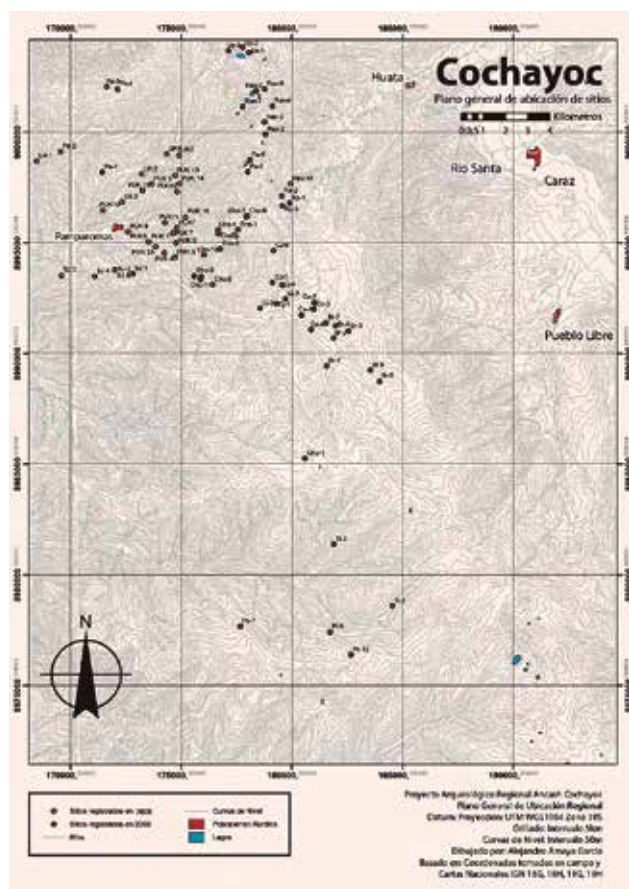


Figure 2. Detailed map of survey area.

In the study area, two types of hydraulic features were primarily used for the creation and maintenance of *bofedales* – silt dams and the smaller check dams – here

we concentrate on the former. The scale of these features precludes them being managed at the household (see Aldenderfer, 1998; Carhuallanqui, 1998; Kuznar, 1995), rather it is more in keeping with the large moorlands created and nurtured by the Chichillapi herders of Puno (Palacios, 1977, 1981, 1996). In this community, a complex system of canals was used to irrigate high altitude pastures creating *bofedales*. In the Cordillera Negra highlands with the construction of silt dams and check dams, large areas of the *puna* were turned into a rich plant biota for camelids, especially the less robust alpaca (*Lama pacos*).

The five silt dams identified for the study area combine to cover an area totalling 372,027 m² of artificial *bofedal*, and include Oleron Cochauri [Cho 2], Collpacocha [Co 1], Tsaquicocha [Pa 5], Huancacocha [Rac 1], and Tsaquicocha [Uc 3]. As calculated by Browman (1990), these more than 372 ha of deposited silts and moor-like environments would have supplied forage for an extra 1200 animals, calculating at 3.25 animals per hectare of *bofedal*. While this might seem a paltry sum, one also has to consider the already existing natural areas of *bofedal*, as well as those created by the silt reservoirs. Jointly, all these areas would have provided an important mosaic of herding options within the *suní-puna* environment.

Structurally, silt dams are strikingly similar to the normal water dams in that they were constructed of double-faced walls, in-filled with compacted earth, stone and clay, making an almost impermeable barrier behind which sediment and water were stored.² Like the water dams, these constructions were gravity structures, in that their solidity and weight is what anchors them in place. The central part of many of the dams was reinforced by step-like walling, given the added soil and water pressure present in this area of the structure.

Unlike water dams, silt dams were not necessarily anchored onto rock, given that water overflow along the sides of the structure was not an issue. They also usually had only one discernible outtake sluice located along the base of the structure, usually at its center. The basic principle governing the silt dam was that of geologic water storage (Fairley, 2003); in this case the accumulated soil basin acted as an aquifer in which water was both stored and purified through the soil. Since the soil also acted as a barrier to water seepage, the sluice should be viewed rather as a 'sieve' which siphons excess water out of the dammed basin while the soil retains enough moisture for the growth of a *bofedal*-type micro-environment.

Also, unlike water dams, the silt dams are located much lower down in altitude, occurring between 3825 and 4425 m (as opposed to 4600-5200 m). The only exception to this is the small silt dam at Tsaquicocha [Pa 5], located at 4625 m. The local geology of loose and eroded earthen hills probably occasioned the swift silting of this basin, which

²These stone and earth walls were never meant to be completely impermeable. These structures can shift during tremors and earthquakes, usually settling back in with minimal damage to the structure. In contrast, modern rigid concrete dams tend to crack.

made the creation of a silt dam at this location desirable. In the other instances, they are located sufficiently low enough in a valley to best trap hill-wash and silt from the surrounding area. Currently for the area, elevations above 4200 m are rarely visited by modern goat and sheep herders. Therefore, these abandoned silt dams are used by the few cattle and donkeys that roam semi-wild in the *sierra*.

More commonly, the silt dams were located downriver from one or more larger bodies of water and dams. In these circumstances Tsauicocha [Uc 3] is set below the large water dam of Agococha/Negrahucanan [Uc 2]. The silt dam of Oleron Cocharuri [Cho 2] is likewise sited below the water dams of Yanacocha [Cho 1] and Orconcocha [Cho 6], while the silt dam of Huancacocha [Rac 1] is located below Sacracocha [Rac 2]. The large silt dam of Collpacocha [Co 1 at 3950 m] accumulates the sediment discharge from the source of the Chaclancayo River located upslope in the puna.

Silt dams are the result of a long process of construction and years of careful management. In the main, the initial silt basin was probably small and would have grown slowly through silt accretion during the annual rains. This system of accretion is sometimes known as varve-formation (Leet, Judson and Kauffman, 1982). The overflow and eroded conditions seen today on many of these silt dams, such as Collpacocha [Co 1] and Huancacocha [Rac 1], are not indicative of how these dams would have looked and functioned in the past. It is probable that, in the past, parts of these structures were periodically de-silted. This occurred with the Indian *gababand* silt-traps (Possehl, 1975). It is possible that the excess silt thus recovered was relocated to nearby terraces and cultivation fields. Below we describe the five silt dams present in the study area.

Oleron Cocharuri [Cho 2] Silt Dam

Cho 2 is located in the Chorrillos Valley, which branches out to the north from the main Chaclancayo Valley. The site itself is composed of three sectors (A-C) between 4185 m and 4220 m and lies altitudinally 450 m below the water dam of Yanacocha [Cho 1] on a type of natural platform (Figure 3).

Sector A is the main silt dam itself and describes a C-shaped walled structure about 76 m long (Figure 4). The wall is composed of two parallel stone walls, infilled with packed earth and stone, with a width that varies between 2.15 m and 4.30 m. The height varies between 0.50 m and 0.57 m at the extremities, rising to a maximum of 2.50 m along the central part. Part of the height discrepancy is due to the V-shape of valley itself, which makes the central section higher while maintaining an almost level dam crest. The dam uses large, naturally occurring rock outcrops as integral parts of the structure. The dam is in a good state of preservation, with only the center having partially collapsed. The Chorrillos stream flows through this eroded center. The two ends of the dam are anchored onto the valley flanks, a clear indication that this is a silt



Figure 3. Photograph of Cho 2 – Oleron Cocharuri, Chorrillos River. Observe *bofedal* behind dam wall.
Photo: K. Lane, 2002.

dam. A single sluice located at the base of the center of the structure drains excess water. The level area behind the dam wall recreates a *bofedal*-type environment of 53,125 m².

Sector B is located approximately 350 m upstream to the north of Sector A. It comprises a seasonal natural pool (*ojo de agua*) circular in shape, and approximately 4 m in diameter. It is located on a bedrock outcrop that stands about 8 m in height. It does not seem to have been artificially modified, and it feeds into Cho 1. Finally, Sector C (Patoparanán) is located downstream from Sector A comprising the edge of the natural platform on which Cho 1 is situated. It comprises two small, low, C-shaped stepped walls. The structures are no more than 70-80 cm high and both have a sluice located in the central part near the base. Behind these walled structures, a small *bofedal* has formed. These two structures represent silt reservoirs or check dams, which have been described elsewhere (Lane, 2009).

Collpacocha [Co 1] Silt Dam

The lack of a management system can be most aptly appreciated at the site of Collpacocha [Co 1] silt dam (Figure 5). Here, the large 28.5 ha silt basin is slowly drying out. Although the primary function of the site is under threat, the *bofedal* created by the partial working of

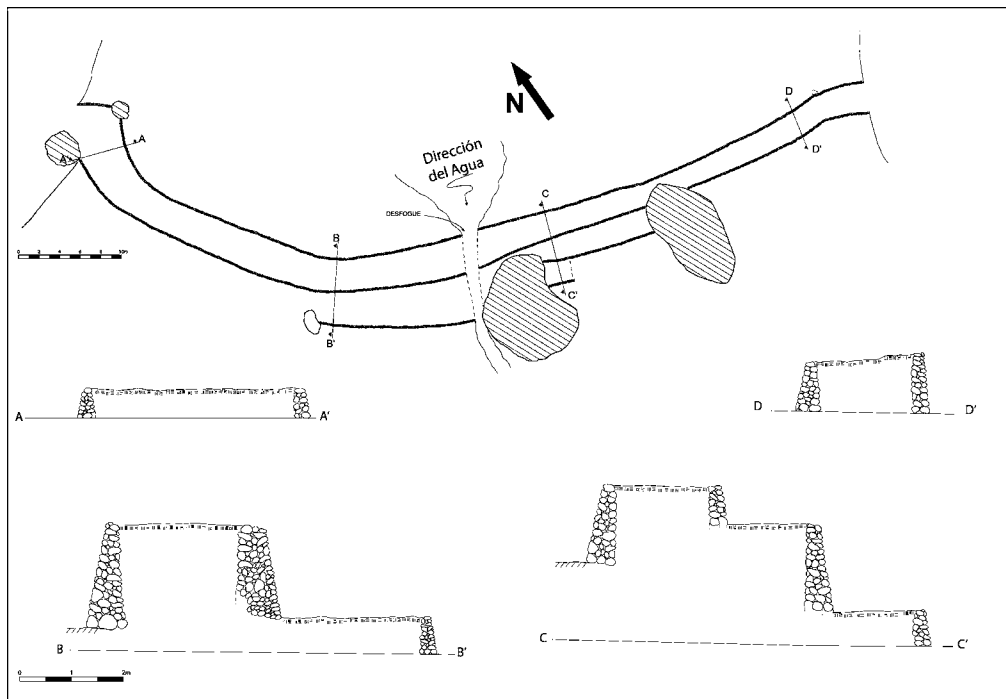


Figure 4. Plan of Cho 2 – Oleron Cochauri.

the system still represents an important source of forage for the herds of three local communities - Putaca, Cajabamba Alta and Breque (Figure 6). These three villages all have overlapping rights to the area and conflicts between them are common. The dam stretches across the whole of a large flat plain that extends from just above the confluence of the Rico and Huinchos River, where it is renamed the Chaclancayo River, to the village of Breque, located on a southern curvature of the basin and Huinchos River. The silt depth of the dam is over 6.5 m near the dam itself, slowly rising to 1.2 m at a distance of 750 m from the dam. The *bofedal* though extends almost to the village of Breque, located about 3 km distant.



Figure 5. Photograph of Co 1 – Collpacocha, Chaclancayo River. Photo: K. Lane, 2002.

This silt dam is unique not only for the immense size of its basin but also because of its close location to the important Inca settlement of Intiaurán [Co 2] (Lane and Contreras, 2007). While it is likely, as with the other structures in the study area, that the dam was built during the Late Intermediate Period (AD 1000-1480), it is also

probable that it was refurbished or expanded during the Inca Period (AD 1480-1532). Given the amount of time that this basin would have required to silt up, it is possible that for a considerable period the basin would have been partially *bofedal* and partially water.

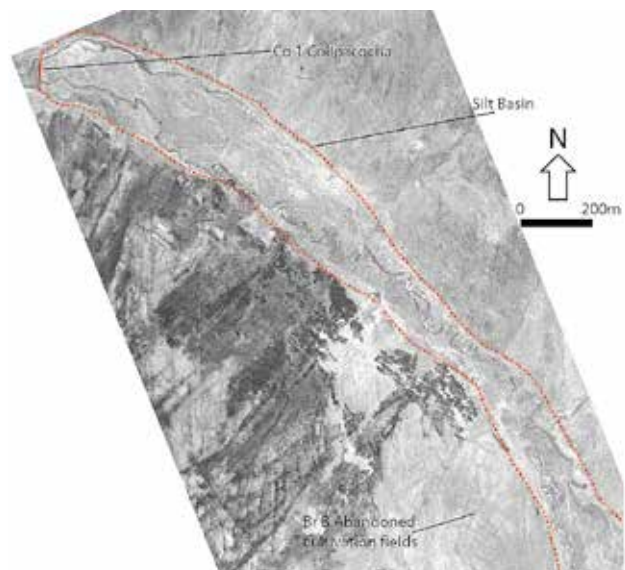


Figure 6. Aerial photograph of Co 1 - Collpacocha, showing *bofedal* behind dam wall.

Photo: Instituto Geográfico Nacional, Lima).

Collpacocha [Co 1] is 100 m in length, oriented north to south, cutting directly across the path of the Huinchos River. At its widest, it is 11 m thick and is constructed of three major stone steps, in-filled with medium and small stones compacted with silty clay (Figure 7). Parts of the structure, especially along the center and the southern end, were stripped of construction stone blocks, possibly removed by either erosion or local people. The total height

of the structure is 5.4 m. In marked difference to other silt dams, Collpacocha has three sluices, located at different heights. The first sluice, located in the north section of the dam, is set at a middle height in the dam wall just 95 cm below the top level of the dam. The sluice has a height of 60 cm and a width of 72 cm. The sluice decants onto a pond that then channels the water onto the main stream. The present outflow from the sluice is low, probably a reflection of the high degree of water flow through the river breach at the center of the structure. This outflow is orange in color, demonstrating a high level of iron content in the trapped soil behind the structure.

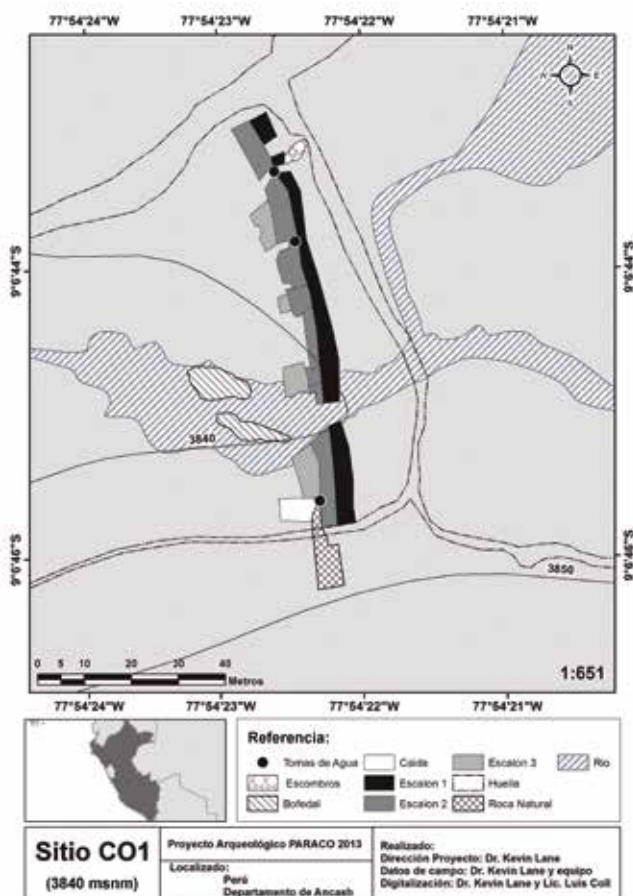


Figure 7. Plan of Co 1 – Collpacocha. Direction of water flow is from east to west (right to left).

The second sluice is also located along the northern half of the structure, although closer to the center of it. A large 60 cm by 60 cm opening still shows a modest orange water flow that joins the same channel as the first sluice. Just beyond this sluice is the main water outflow. This outflow is actually an erosion break in the dam wall. As this high-energy outflow cascades downwards, it is slowly undermining the integrity of the base of the structure. The last sluice is located at the extreme south of the structure cut into the rock outcrop to which the dam is anchored. This sluice is level with the basin and probably represented the main water outflow when the dam was in working order. The drop-pond for this outtake is cut into the natural stone to a level below the earthen channel that subsequently takes the water to the central stream. This feature would have regulated the speed of the water outflow away from

the dam, causing a substantial drop in water flow speed. This drop-pond feature is a prime component of modern dams, and serves to show the engineering knowledge of these prehispanic builders.

Sedimentation has banked all across the dam wall, while – as mentioned above – the river has cut through the center of the structure. The *bofedal* itself is rich in hard *ichu* grass and other types of forage plants, but the drying of the sides of the dam due to the present unregulated water flow means that the moor-like area is now limited to a narrow central strip along the center of the basin. Manual augering (Dutch and gauge auger) of the dam was undertaken to understand the functioning of the structure. Sixteen auger holes were drilled into the silt basin covering an area 560 m in length and 177 m in width. Although the basin continues towards the modern village of Breque, the main area of the *bofedal* was that covered by our augering survey.

Preliminary results from the boreholes show that the lowest layer is mainly composed of a dark blue-grey clay layer, probably the original water or silt basin that existed before the construction of the dam. From 4.5 m downward, the deposits were very water-logged, confirming the existence of a permanent aquifer at this depth. The residual nature of the organic remains up to a depth of 2.5 m below the surface suggests that the aquifer was previously substantially larger. Between 2.5 and 4.5 m there were layered sections of low-energy deposited organic loam interspersed with medium to high energy sand deposits. These layers probably correspond to separate stable *bofedal* periods, interspersed with high energy episodes, perhaps *huaicos*. Above these layers, between 0 and 2.5 m, there was significant geoturbation of the soil with many high-energy sand and rock deposits, most likely as a consequence of the river frequently changing course. The lack of association between layers in different boreholes implies a degree of soil matrix truncation by the river. These upper layers probably date to the abandonment and general disuse of the site and area from the 16th or 17th century onwards.

The augering of the dam at Collpacocha [Co 1] proves that the main function of the site was that of generating and sustaining a *bofedal*-type environment, while the prevalence of grey organic silts and clays in the lower layers of the first boreholes shows that a water pond existed for a period of time right against the dam wall itself. The *bofedal* at Collpacocha [Co 1] would have allowed the periodic concentration of animals, which might well have been a major consideration in the placement of the Inca administrative site of Intiaurán in close proximity.

Tsaquicocha [Pa 5] Silt Dam

Located at 4625 m and adjacent to Tsaquicocha Lake, it lies directly to the south of the Carhuacocha Dam [Pa-6], representing the southern source of Collapampa stream. The center of the wall has collapsed and the water drains through it. The dam is 13.7 m long, with a varying width of

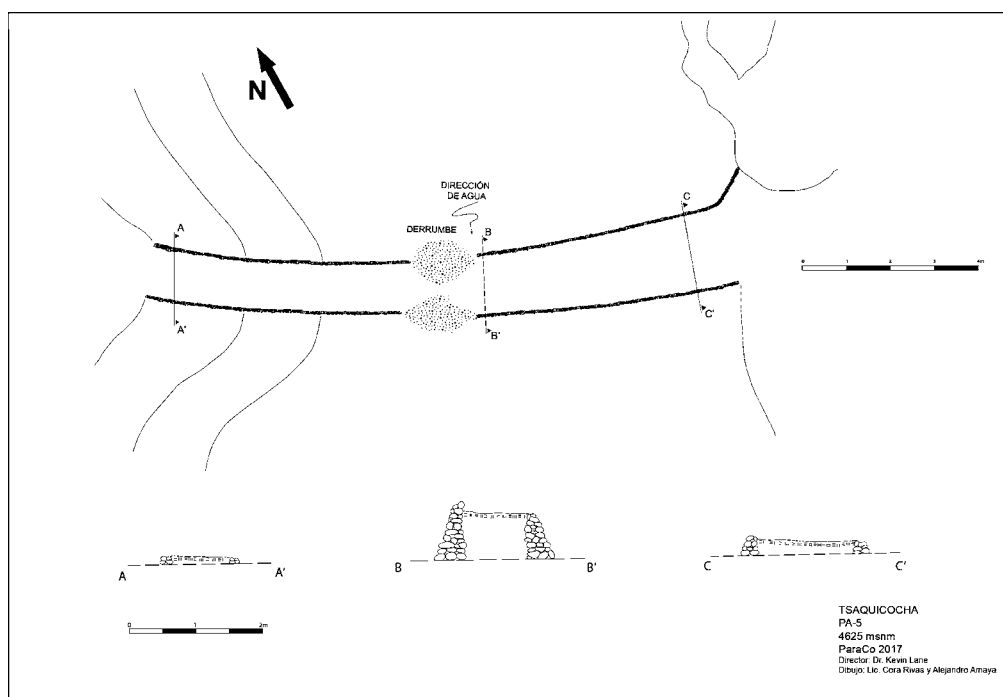


Figure 8. Plan of Pa 5 – Tsaquicocha, Collapampa River.

between 1.1 m and 1.83 m, with a maximum height 1.3 m (Figure 8). If a sluice existed, it would have been located on the central section of the structure. The dam was triple-stepped on its exterior face and the upper level is very deteriorated. The *bofedal* thus created covers 1027 m². The south-eastern end of the dam is anchored to bedrock, while the north-eastern one abuts the natural earthen slope. Given the characteristics of the site and its height, it is possible that this structure started as a water dam that then dried-up and was used as a small silt dam – the prefix *tsaqui* means “dry”, and *cocha* means “lake”, in the local Quechua language.

Huancacocha [Rac 1] Silt Dam

Located in the upper section of the Racratumanca side-valley adjacent to the town of Pamparomás, the silt dam of Huancacocha lies at 4425 m (Figure 9). The site itself is set in a natural terrace or platform – much like Cho 2 above – surrounded by steep, rocky hills. Behind the wall there is an extensive area of *bofedal* covering 17,500 m². This silt dam, double-walled and infilled with packed earth and stones, lies directly downstream from Huaytacocha (4500 m) to the northeast. The height of the structure varies between 0.3 m and 1.4 m, while its maximum width is 3 m. The wall zigzags over 50 m, making best use of the available rock outcrops (Figure 10). A single sluice 0.4 m wide by 0.6 m high drains excess water. The masonry is rough, with no evidence for repairs or reconstruction of the dam. Both extremities of the dam are anchored on bedrock.

Tsaquicocha [Uc 3] Silt Dam

Tsaquicocha is a large silt dam, located at 4300 m in the upper end of Uchpacancha Valley, directly below the large Agococha/Negrahucanan [Uc 1] water dam (4525

m). Oriented southeast-northwest, the structure is very well constructed and solid, with a double-faced wall and compacted fill stones and earth. The dam measures 75 m in length, and its width varies between 1 m – at the extremities – and 3.6 m at the center, with a maximum height of between 1 m and 4.7 m (Figure 11). The structure is anchored onto the earthen slopes of the valley. There was no sluice to the dam, with water currently filtering from beneath the wall. Behind the dam, a 16,000 m² *bofedal* is forming.



Figure 9. Photograph of Rac 1 – Huancacocha, Racratumanca Valley. Photo: K. Lane, 2002.

Conclusion

This study shows that silt dams are an intrinsic feature of the Andean hydraulic landscape, capturing water, silts and sediments, ameliorating the effects of erosion and landslides, while providing a fertile platform for animal foraging. The five examples presented here are probably just a few of the many such structures that exist across the Cordillera Negra and most likely throughout the entire

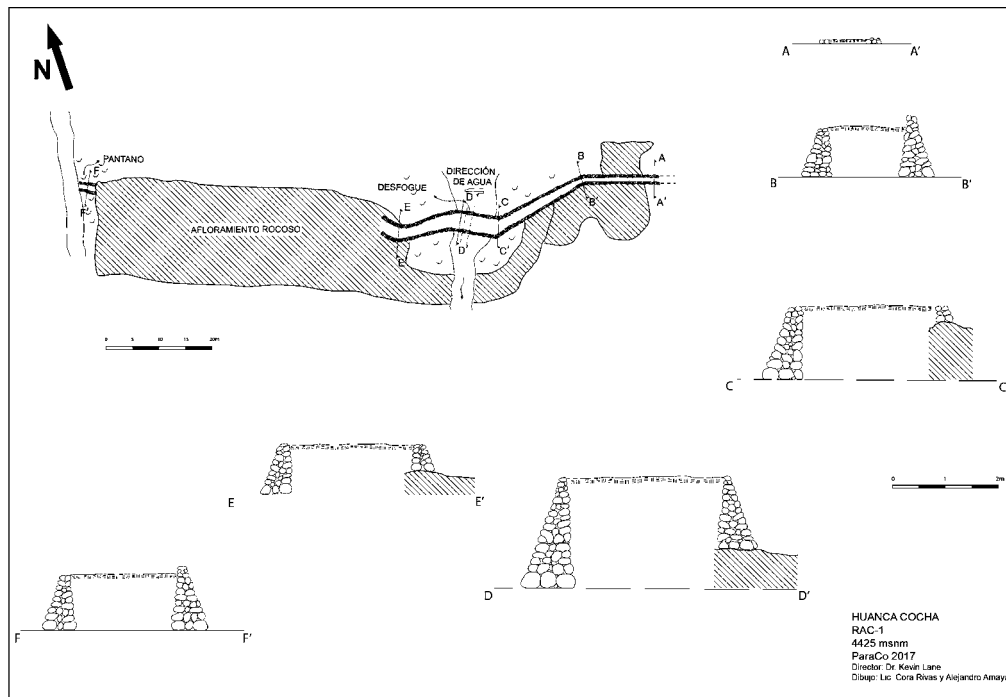


Figure 10. Plan of Rac 1 – Huancacocha.

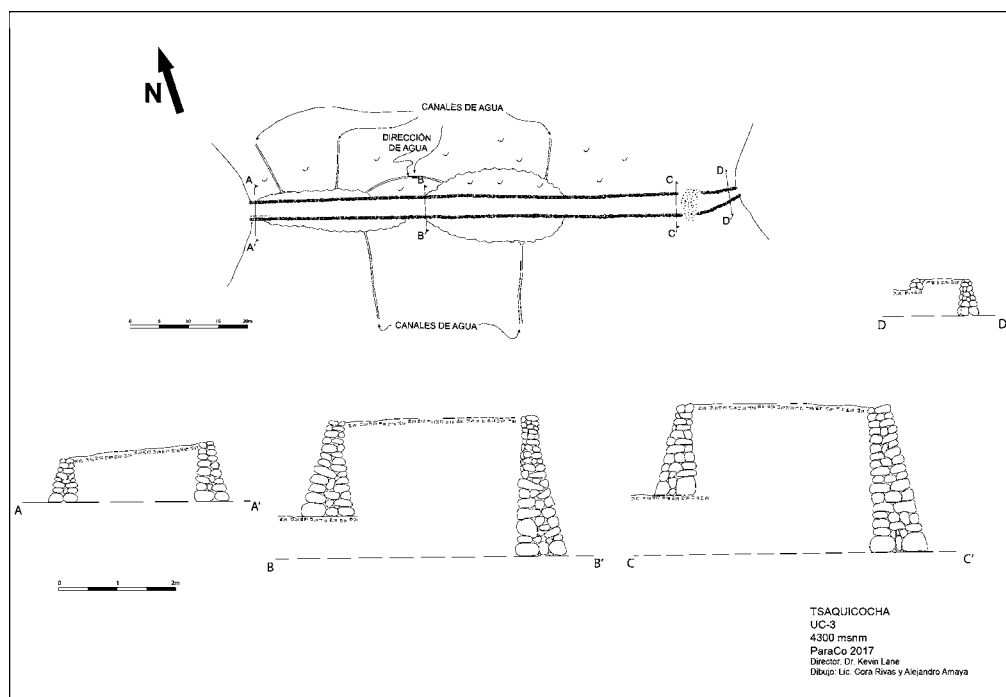


Figure 11. Plan of Uc 3 – Tsaquicocha, Uchpacancha Valley.

western *sierra*. It is this watershed that will logically have the greatest number of water and soil harvesting technology given that, unlike the glacier-capped intermontane cordillera, there is no permanent source of water aside from the seasonal rains.

Prehispanic communities developed the means to guarantee – as far as possible – continuous access to water. Yet, concomitant with this, as befitting an agropastoralist society, went a policy of controlling soil seen in the construction of these silt dams. These in turn provided the wherewithal for the creation of artificial pastures –

bofedales. At present, these features are abandoned or under threat from redevelopment as water dams. The latter should be avoided as silt dams served a set of functions which are as necessary now as they were in the past.

As this paper shows, not everything is necessarily as would seem at first sight, with the added implication that all these features need to be understood within the context of the landscape in which they are found. Only then can we have a better insight into the use, function and possible rehabilitation of these hydraulic structures, and thereby recover a small part of this lost indigenous knowledge.

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