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Reconstructing landscape at Chavín de Huántar, Perú: A GIS-based approach

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A R T I C L E I N F O

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A B S T R A C T

The landscape around the prehistoric Peruvian ceremonial center of Chavín de Huántar has undergone extensive geomorphic and anthropogenic change since the beginning of monumental construction at the site in approximately 1200 BCE. Archaeological and geomorphic stratigraphy from the site and its near periphery provide the data necessary to characterize these changes in detail. This paper reports on the use of GIS-based interpolation tools to approximate a complex prehistoric land surface using unevenly scattered point data. Such an interpolated surface serves as the basis for the reconstruction of the pre-Chavín landscape and assessment of landscape change contemporary with the site.

1. Introduction

This paper presents an experiment in using GIS-based interpolation tools to approximate a complex prehistoric land surface using unevenly scattered point data. Such a project is necessary to understand the archaeological landscape at Chavín de Huántar due to the extensive, complex, and multi-causal depositional history at the site, a first millennium BCE monumental center in the Peruvian Central Andes. The data are derived from a variety of sources, including primarily stratigraphic excavation and geomorphologic survey. Incorporation of these varied data into a GIS has allowed their synthesis into a single model, and ultimately the interpolation of a topographically realistic pre-monument surface. That surface forms the basis for reconstructed landscape to which the modern and archaeological landscapes can be compared.

Interpolation of surfaces from discontinuous data has received increasing attention in archaeology in recent years (Conolly and Lake, 2006; Hageman and Bennett, 2000; Lloyd and Atkinson, 2004; Robinson and Zubrow, 1999; Wheatley and Gillings, 2002), though it was explored significantly earlier (Zubrow and Harbaugh, 1978). Much of the focus has appropriately been methodological, stressing the advantages and limitations of various methods of interpolation as well as the theoretical underpinnings of those methods, and much of the literature has concentrated on distributions of material culture rather than physical surfaces. This article emphasizes instead the interpretive utility of such a surface at Chavín de Huántar, drawing on the combination of extant literature and the increased accessibility of software capable of carrying out computationally-intensive interpolations to consider what kind of a result may be produced, from what quantity and variety of data, and with what interpretive potential. As several studies have suggested (e.g. Forte, 2000; Katsianis, 2004; Stafford, 1995), understanding the paleolandscape can be critical to both qualitative and quantitative assessments of an archaeological site. Systematically collecting data about paleosurfaces is complicated, however, by the difficulty of identifying and accessing such surfaces as well as by the need to systematically integrate data from diverse sources. In the case of Chavín, where a dynamic geomorphic environment and prehistoric anthropogenic landscape modification have combined to significantly alter that landscape, the task is worth addressing: interpolation is an important tool for understanding archaeologically-relevant landscape change at the site.

I describe the site and its setting and summarize the evidence for landscape change there, before turning to the sources of data for this project, the means of integrating those sources, and the results of using an interpolated surface as the basis for a reconstructed landscape. Such an approach has highlighted the linked inputs of geomorphic and anthropogenic change and allowed the quantification of landscape change associated with the construction of the monumental center. The explicit description of a baseline against which the archaeological and modern landscapes can be compared is the fruit of an interpolated surface, while interpretation of the

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processes creating the observed contrasts depends on the fleshing out of a reconstructed landscape on the skeleton of the interpolated surface.

2. Background

Chavín de Huántar, in a valley bottom at 3180 m on the eastern slope of Peru's Cordillera Blanca, is a complex of stone-faced platform mounds, terraces, and sunken plazas (Fig. 1) dating to roughly 1200–500 BCE (all dates are given in calibrated radiocarbon years; the chronology remains debated (Burger, 2008; Conklin, 2008; Rick et al., 2008)). The site as visible today consists of two U-shaped groups of structures, each opening to the east. Each group surrounds a sunken plaza (Fig. 2); the whole array is the product of many distinct construction phases spread over at least five hundred years (Kembel, 2008). One of only a handful of monumental highland sites from this early period, the site has been a focus of archaeological research in the Andes since Julio C. Tello's 1919 visit, and has been key to understandings of Peruvian culture history (Burger, 1992; Conklin and Quilter, 2008; Kembel and Rick, 2004; Lumbreras, 1989; Tello, 1943, 1960). While there are some disagreements about details of Chavín's chronology and sociopolitical mechanisms underlying its rise, there is broad archaeological consensus that the site served as an important Andean ceremonial center in the first millennium BCE.

I here focus on the reconstruction of the landscape around Chavín before the beginnings of monumental construction, currently dated to approximately 1200 BCE. This date is a conservative choice; in spite of debates over Chavín's chronology (see above), no suggestion of monumental architecture predating 1200 BCE has been offered.

The site's steep setting on the eastern flank of the Andes implies a geomorphically active landscape (see Fig. 3), and a variety of pieces of evidence now suggest that the landscape associated with

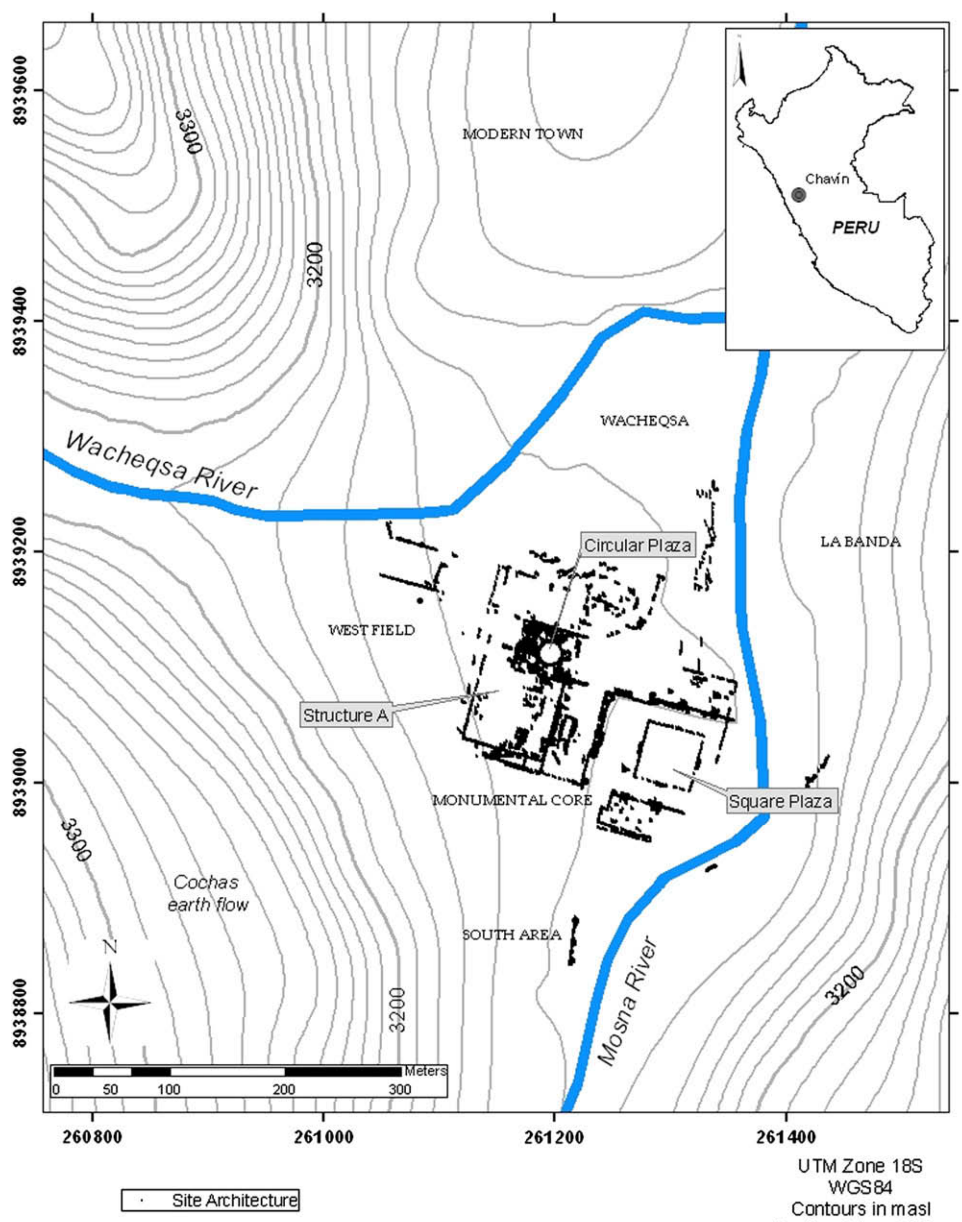

Fig. 1. Site map. Labels indicate features discussed in the text and site sectors.

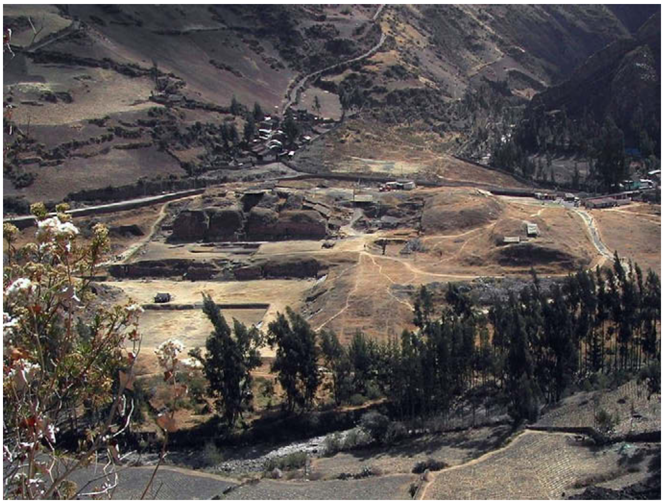

Fig. 2. View of Chavín, looking west across the Mosna River at the site's monumental core. Note the Square Plaza (at left) and the Circular Plaza (above and to the right of the Square Plaza), each surrounded by platform mounds forming U-shaped arrays.

the monumental center was distinct from that now visible. Apart from the substantial construction of the monumental complex itself, the modern landscape is different in several particulars. Depositional events that have obscured the complex as well as its setting include landslide and earth flow activity, including a historically documented major debris flow (known locally as an *aluvión*) in 1945 (Indacochea and Iberico, 1947). Moreover, movement of river channels as a result of landslide activity is a prominent feature of the local geomorphology; such channel displacement not only constitutes a substantive landscape change but is also a major cause of erosion.

In addition to these geomorphic changes, the landscape engineering that accompanied the construction of the monumental core—less immediately visible than the major structures—also had a profound effect on the monument's setting. These are discussed in detail below; the most salient examples include instances of substantial landscape engineering. The expansion of the monument apparently involved the diversion of the Mosna River and the reclamation of the riparian corridor for construction (Contreras, 2007; Rick, 2005). Remnants of walls that canalized the Mosna River are still visible today, and Tello's pre-*aluvión* photos show similar wall fragments lining the Wacheqsa River (Tello, 1960). It is also now apparent, from multiple excavations and investigations of natural exposures, that much of the near periphery of the monumental core, which does not today appear to be part of the built complex, in fact consists of series of terraces and platforms that have been obscured by colluvium.

Fig. 3. Chavín de Huántar's environmental setting, looking west. The site is visible in the foreground to the right, where the valley of the Wacheqsa River intersects the south-north trending valley of the Mosna River.

3. Evidence of landscape change

Chavín's landscape between 2000 and 200 BCE was, recent work has made clear, significantly different than that visible today (Contreras, 2007; Rick, 2005; Turner et al., 1999). The changes of the last 3–4 millennia include both geomorphic and anthropogenic elements.

3.1. Geomorphic change

Several generalized landscape processes can be distinguished as active on a human timescale around Chavín. These include landslide activity, colluvial deposition, flooding, landslide-driven river channel wander, and periodic debris flows. Evidence of such activity is spatially widespread and present across various landscape phases.

Several significant geomorphic events heavily shaped the pre-Chavín landscape. The notably flat expanse of valley floor on which the modern town is situated is the result of a substantial (covering perhaps 70 hectares) paleolake, formed when the Mosna River was dammed by a major rotational landslide on the east side of the valley (Contreras, 2007; Turner et al., 1999).

The pre-monumental landscape was also significantly affected by a substantial debris flow, the diamicton of which is visible in the cut on the south side of the Wacheqsa River. Also visible in the West Field is the evidence of a landslide that altered the level and course of the Wacheqsa River prior to the Chavín period (detailed in a forthcoming article by Contreras and Keefer).

During Chavín (approximately 1200–500 BCE) and post-Chavín (500 BCE – present) periods (dates from the Rick/Kembel chronology), both measures of overall post-Chavín deposition and evidence of specific events demonstrate the geomorphic dynamism of the landscape. Along the upper course of the Wacheqsa, the strata of colluvium immediately above the diamicton of the landslide described above contain Chavín-period ceramics (visible in Unit CdH-WF-11; see Fig. 4), demonstrating active slope processes contemporary with Chavín occupation of the West Field. (Investigation units of the Stanford project at Chavín follow a Site-Sector-Unit naming scheme (e.g. CdH-WF-10 is read as Chavín de Huántar – West Field – Unit 10); hereafter this will be abbreviated to Sector-Unit. If no sector is specified (e.g. CdH-07), units are in the monumental core.)

Subsequent to Chavín's abandonment, the most salient feature is deposition atop archaeological features. The exposure cleaned as Unit AS-06 revealed approximately 4 m of post-Chavín deposition by the Cochas earth flow, the slope southwest of the monumental core (Contreras, 2007; Turner et al., 1999). Moreover, the burial of structures in the Area Sur and the West Field, as well the accumulation of at least 5.5 m of sediment against the southwest corner of Structure A, testifies to the extent of deposition by the Cochas earth flow. Similarly, Lumbreras describes colluvial deposition in the Circular Plaza (Lumbreras, 1977, 1989), and Burger encountered earth flow deposits burying Chavín-period platform construction on the lower slopes of the Cochas earth flow in PAn-18-D1/2/3 (Burger, 1984:22). Less dramatic colluvial and alluvial deposition is also evident in the burial of archaeological features in La Banda. The

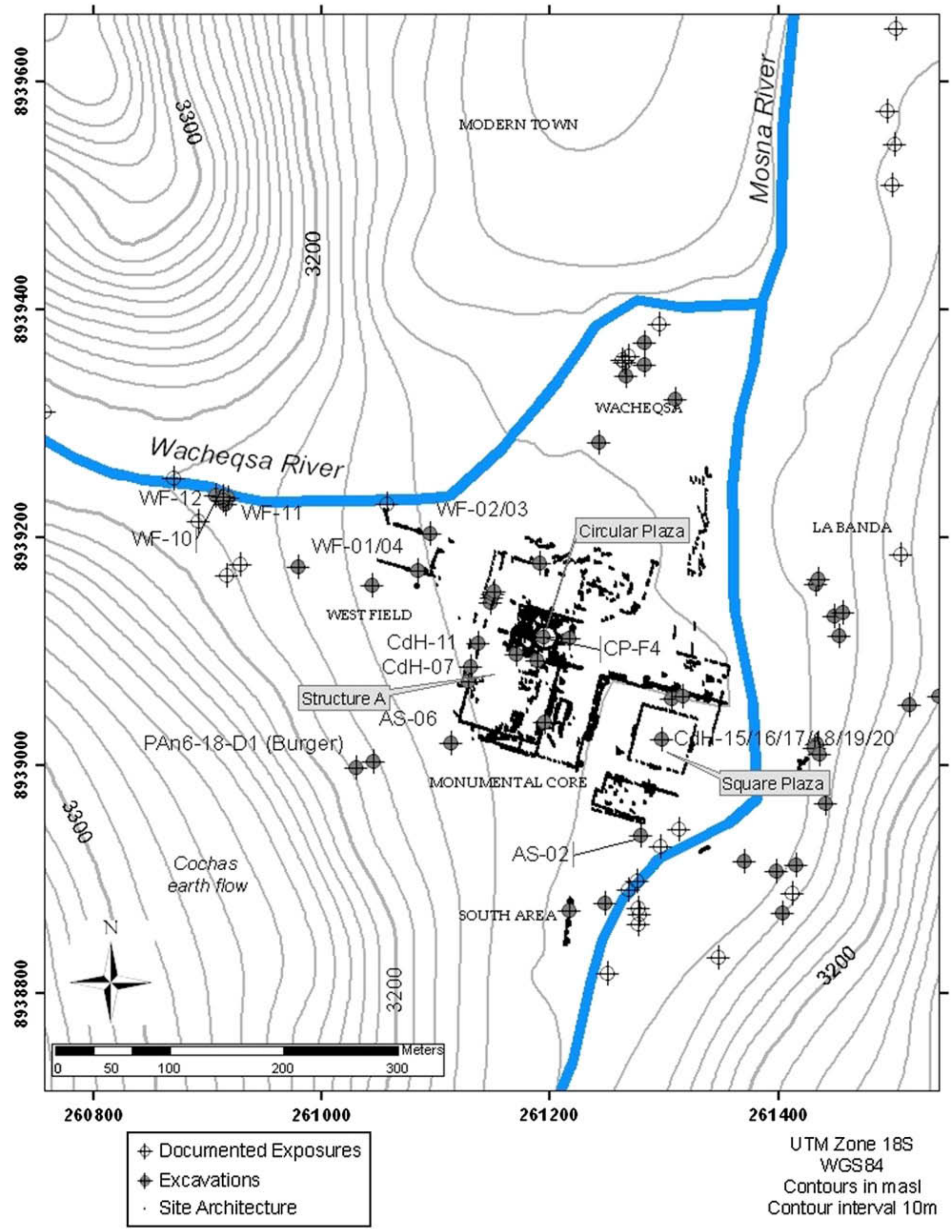

Fig. 4. Stanford Project excavations and groups of excavations at Chavín, 1998–2007. Only those mentioned in the text are labeled.

historically-attested landslide-prompted channel wander of the Mosna and Wacheqsa rivers (Contreras, 2007; Tello, 1943, 1945; Turner et al., 1999), as well as the 1945 *aluvión*, provide examples of the sorts of processes active in the area.

3.2. Anthropogenic change

A wide array of archaeological evidence demonstrates that pervasive anthropogenic alteration of the landscape formed part of the monumental project that was Chavín de Huántar. Evidence for such efforts comes from my 2004–2006 fieldwork (Contreras, 2007), from other Stanford Project research (excavations and survey between 1996 and 2006 (e.g. Kembel, 2008; Rick, 2005, 2008; Rick et al., 1998)), from the published data of other investigators (Burger, 1984; Lumbreras, 1989; and Tello, 1960 are particularly useful in this regard), and from Tello's notes and photographs archived in the Archivo Tello at Peru's Museo Nacional de Arqueología, Antropología, e Historia. Other early published material (descriptions and photographs) understandably tended to focus on the impressive structures and sculpture of the monumental core, and thus offers little information about the surrounding and underlying landscape. Information can also sometimes be gleaned from the backgrounds, however; photographs from the expeditions of Roosevelt (1935) and Kinzl and Schneider (1950) in the 1930s, in particular, are useful.

The archaeological evidence testifies to three main types of landscape modification: alteration of river channels (of both the Mosna and the Wacheqsa rivers), placement of massive fills, and construction of retaining walls. Taken as a whole, these pieces suggest that a substantial transformation of the local landscape formed part of the monumental project at Chavín.

This intentional landscape modification was accompanied, we must presume, by increasing collateral impacts on the local environment as the population and wealth of the community associated with the developing ceremonial center grew. Though such growth remains inferential, given the limited number of domestic contexts that have been excavated and the erratic sampling of the valley that they represent, the trajectory of continuous growth of the monumental center (Kembel, 2008) suggests a concomitant population increase. Burger (1984:246–250) estimated a community of 2–3000 persons spread over 42 hectares in the Janabarriu Phase, but his calculations could not take into account the implications of the previously unknown large, dense domestic area excavated by the INC and the Stanford Project in 2003 (Rick, 2005), and is probably a significant underestimate. This growth would have been accompanied by intensification and extensification of local agriculture—the landscape engineering efforts are testament to the technological capacity for terrace construction and irrigation as necessary, though no purely agricultural examples of either technology have been documented to date. It is highly likely, thus, that the catalog of instances of landscape engineering represents a substantial undercount, and like population counts should be regarded as a minimum estimate.

4. Data sources

Field data has been gathered from four sources: archaeological and geomorphologic survey, cleaning and documentation of modern stratigraphic exposures (both natural and anthropogenic), and excavation. The process has been iterative, stretching over three field seasons and tacking back and forth between archaeological and geomorphic inputs. Data gathered in the field have been augmented by the inclusion of other data from the Stanford Project (generated by fieldwork between 1995 and 2006) and other published sources (e.g. Burger, 1984; Diessl, 2004; Lumbreras, 1977, 1989). Together these comprise the basis for the sort of archaeological micro-topography that Forte (2000) describes.

4.1. Survey

Geomorphic survey in 2004, carried out with Dr. David Keefer (USGS), documented exposures within roughly a 2 km radius of Chavín. These consisted of cuts resultant from the Mosna and Wacheqsa rivers and smaller tributary drainages, road construction, and footpaths (see Fig. 4). The exposures were located with a handheld GPS, photographed, and the sediment stratigraphy described; where archaeological features or material were encountered, these were documented as well. This process also served to ground-truth the aerial photography that was used to identify local landforms. This work resulted in a geomorphic map of the local area, complementing that produced by Turner in 1999 but covering a broader area in more detail (see Turner et al., 1999 and Fig. 5).

The stratigraphy documented in this survey also provided several key data points that identified Chavín-period and pre-Chavín elevations and landforms. In addition, the geomorphic map that resulted from the 2004 fieldwork was used to plan the 2005 excavation season. Areas with high probabilities of yielding both stratigraphic sequences of recent (late Holocene) geomorphologic activity and cultural material were selected. The exposures examined in detail in 2006 were selected on a similar basis.

4.2. Excavations

The geomorphologic survey identified areas where downslope deposition in the last 2–3 millennia was likely to have interred Chavín-period surfaces; these areas were the targets for subsurface sampling in the form of moderate-sized (ranging from 4 m^2 to 16 m^2) excavation units. The excavations were intended to provide a relative chronology of earth movements; information about period and character of interred archaeological features; and a means of tying the relative chronology of geomorphic activity to both an absolutely and relatively dated cultural sequence derived from the whole corpus of Proyecto Stanford work as well as previous research at the site. The excavations were also located in areas deemed likely to provide a catalog of significant environmental perturbations—including, potentially, earthquakes, landslides, and catastrophic earth flows. Attempted landscape alteration was also a focus of investigation; the targeted locales included both areas known to have been subject to anthropogenic modification and areas in which erosion control structures would have been a logical concern. Excavations were carried out in three sectors, termed the Area Sur, the West Field, and La Banda (see Fig. 4).

Stratigraphic data from both the excavations and the cleaned exposures was recorded spatially with a total station, photographed, and thoroughly drawn and described. Cultural deposits, in both excavations and cleaned exposures, were excavated following single-context excavation procedures.

4.3. Examination of existing stratigraphic exposures

These 2005 excavations provided archaeological and geomorphologic data that was used to plan a further season of work, in 2006. The goal of the 2006 season was to clarify the stratigraphy that had been documented in 2005 by expanding the sample and adding pre-occupation strata to the database. Given the depth of anthropogenic strata established by the 2005 research (sometimes exceeding 6 m), an alternative means of accessing deeply-buried deposits was necessary for reasons of both cost and time.

Two substantial existing exposures or cuts—one along the Wacheqsa River north and west of the monument and the other apparently created by road construction southwest of the monumental core in the 1970s—were the key to this effort. Work on these exposures focused on describing the depositional histories of natural and cultural activity around the monument.

The stratigraphy thus exposed was used to amplify and improve both archaeological and geomorphologic reconstructions of the West Field and the Cochas earth flow. These operations included one exposure on the western edge of the Area Sur (AS-06) and three on the northern edge of the West Field (WF-10/10A, WF-11, and WF-12) (see Fig. 4). All were treated, in terms of spatial registration of sedimentary and archaeological stratigraphy and handling of materials, as if they were full-scale excavations. Stratigraphy was drawn, photographed, registered with total station, and described; materials were collected by stratigraphic unit and processed in the laboratory.

4.4. Other data sources

In addition to data collected in the field from 2004 to 2006, I have made use of an array of relevant information from published and unpublished sources. These primarily include other Stanford Project survey and excavations (1996–2006). In particular, I have used data from excavations carried out by John Rick in the monumental core and La Banda from 1996 to 2006, by John Wolf in La Banda in 2000, 2001, and 2003, by Christian Mesia in the Wacheqsa Sector in 2004 and 2005, and by Matt Sayre in La Banda in 2005 (some of this published in Kembel, 2008; Kembel and Rick, 2004; Rick, 2005, 2008; Rick et al., 1998). In addition, the published excavation data from Tello (1960), Lumbreras (1977, 1989, 1993), and Burger (1984), as well as Diessl's synthesis (2004) have provided useful data. Selected photographs and notes from the Tello Archive at Peru's Museo Nacional de Arqueología,

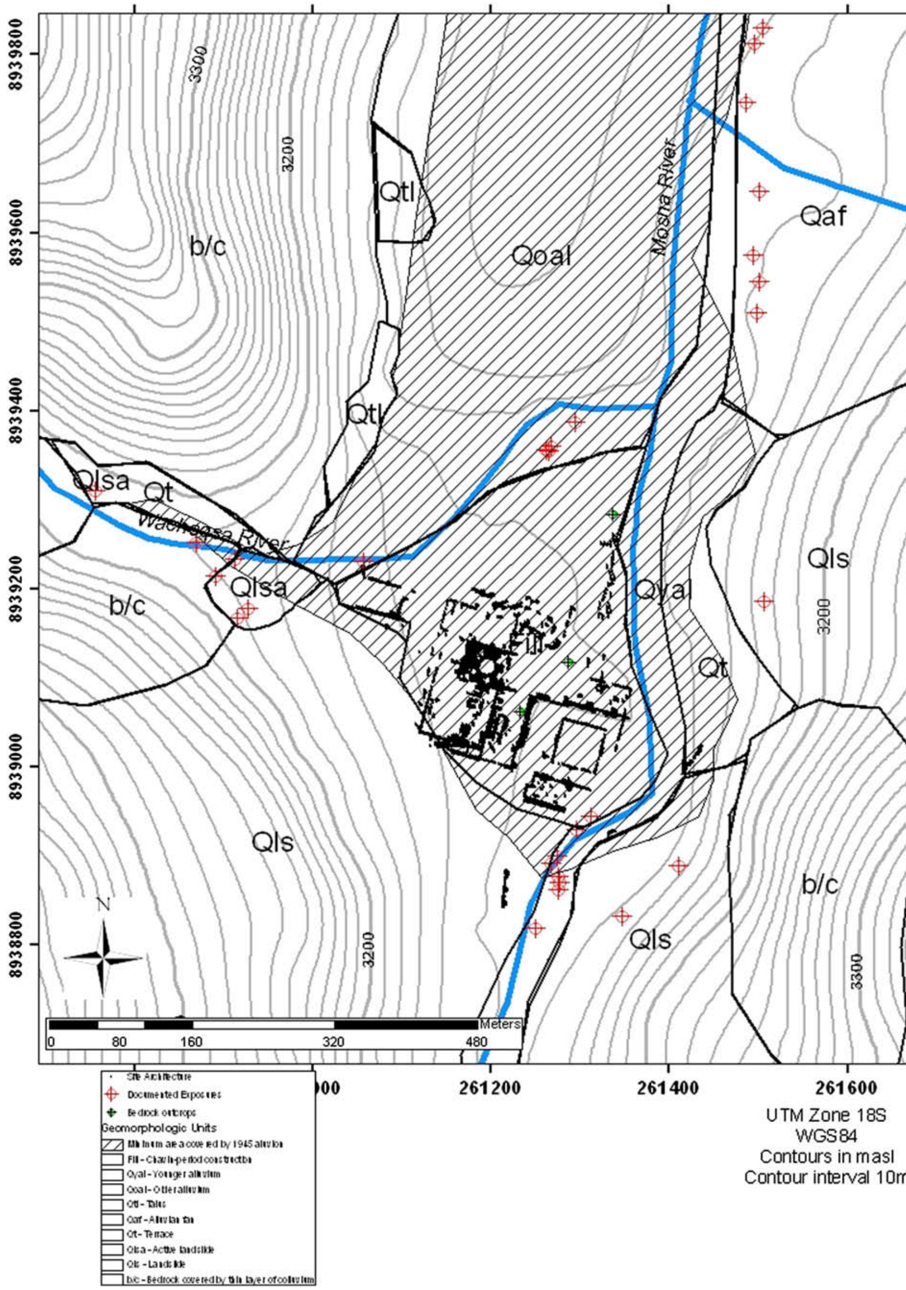

Fig. 5. Local geomorphology, derived from fieldwork by the author and David Keefer.

Antropología e Historia in Lima have also proved useful. These sources have provided both direct evidence of anthropogenic landscape change—in the case of the Tello material, much of it evidence that was subsequently destroyed by the 1945 *aluvión*—and valuable reference points for the interpolation of the pre-Chavín landscape.

5. Analysis: interpolation and landscape reconstruction

The diverse goals of the various excavations whose data I incorporate here, and the vagaries of naturally-occurring exposures, mean that data is dense in some areas and sparse in others. This both renders interpolation necessary and influences the choice of interpolation method (Conolly and Lake, 2006:Ch.6; Wheatley and Gillings, 2002:Ch.9). Conolly and Lake (2006:90) point out, "selection of an appropriate interpolation technique depends on the structure of the sample data plus the desired outcome and characteristics of the surface model," and a variety of authors have issued cautions about the variability in outcome that can result from choice of interpolation method (e.g. Hageman and Bennett, 2000; Robinson and Zubrow, 1999). This is apparent from this dataset as well, as the contrasting contours (derived from interpolated surfaces) in Fig. 6 demonstrate.

The rewards of interpolation justify these risks, however. In this case, the reward is a DEM (digital elevation model, or raster in which each cell contains an elevation value) of the pre-Chavín landscape. The available data points indicating landscape elevation pre-Chavín (see Fig. 7) are here used to generate an entire landscape surface. Such interpolation is possible as elevation data is spatially autocorrelated—that is, values are likely to vary with

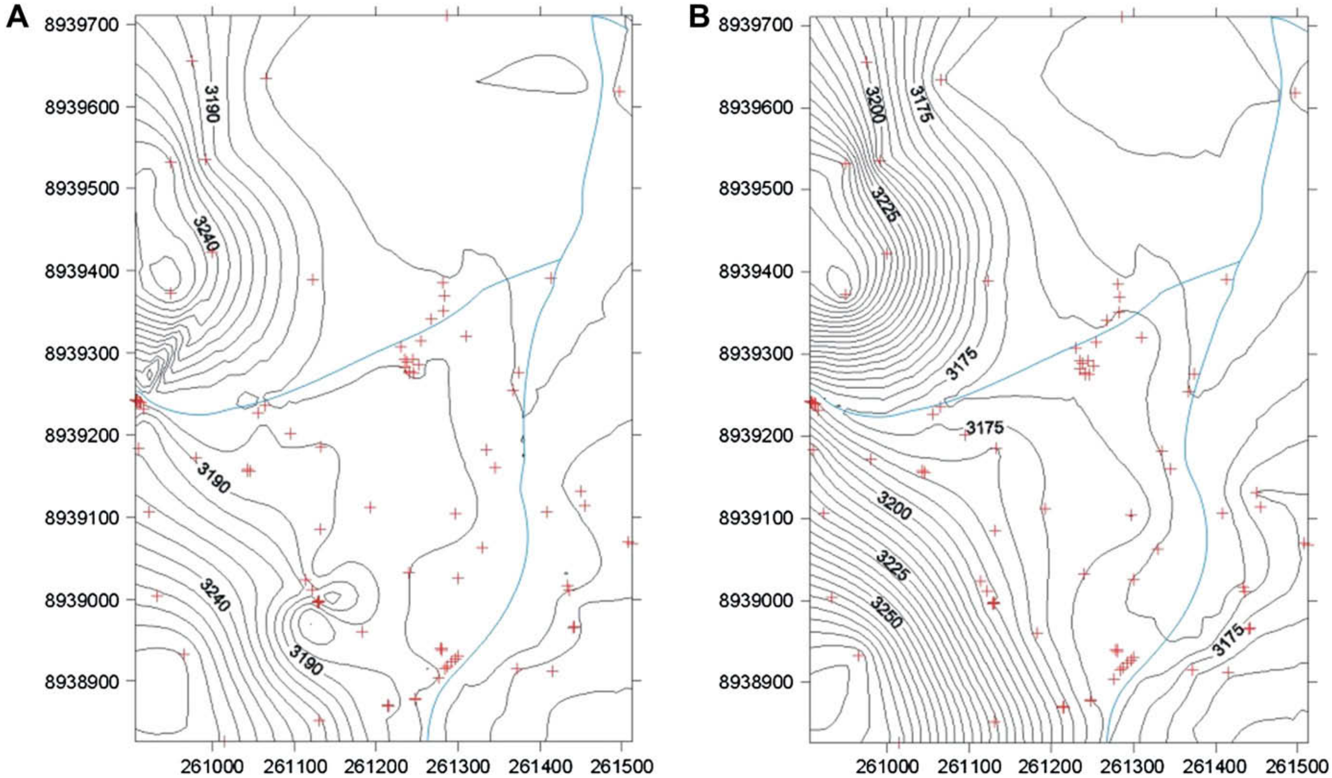

Fig. 6. Contour maps derived from contrasting interpolated surfaces in Surfer 8.0; A) radial basis function, and B) kriging.

spatial location. Simply put, any given point is likely to be similar in elevation to its neighbors (Conolly and Lake, 2006:90).

The data points employed in the interpolation are the results of excavation (either my work, other excavations carried out by the Stanford Project between 1996 and 2006, or published data from earlier excavations) and documentation of existing exposures (primarily the cuts of the Wacheqsa River and the road that bisects the monument). Stratigraphy in these locations was documented using primarily a total station, with local site coordinates matched to UTM coordinates using a differential GPS (Contreras, 2007:Ch. 5).

Where the interface of cultural material with sterile natural deposit is known, the sterile natural surface has been taken to represent a natural pre-monumental construction ground surface (in, for example, Unit WF-10; see Fig. 8). In the most common cases that surface is bedrock or alluvial material. Although treating those sub-cultural strata as indicative of the pre-Chavín surface introduces some risk of ignoring areas that might have been excavated prior to construction, in none of the cases considered here was there any apparent evidence of substantial modification of the sterile surface (excavation, cutting of bedrock, etc). The risk certainly affects the precision of the landscape reconstruction, but the value of the reconstructed model does not lie in its local precision so much as its overall relative accuracy.

In a limited number of cases (where excavations did not reach sterile soil) points known to be above the original ground surface, but significantly below modern ground surface, have been used as a proxy for the pre-Chavín surface. Although they are not exact representations of pre-construction ground surface, they serve to constrain the interpolated surface so that it more closely approximates that pre-construction landscape.

The creation of a topographically realistic digital elevation model—that is, a raster dataset with resolution adequate to capture topographic detail relevant at a human scale—from point data typically has several requirements. The method should be a) exact (pass through known points), b) continuous (without abrupt changes in slope), c) local rather than global (considering nearby values rather than all available ones), and d) constrained (results should fall within a relatively small expected range of values) (Conolly and Lake, 2006; Wheatley and Gillings, 2002). The result, of course, must be topographically plausible given the local geomorphology.

Exploratory interpolations were carried out in Surfer 8.0 and ArcGIS 9.2; the most successful results came from the Geostatistical Analyst extension in ArcGIS 9.2. The surfaces employed here were generated using the cokriging function in the Geostatistical Analyst Extension, which allows the interpolation of a surface from multiple datasets—in this case, the documented subsurface elevations, the placeholder points, and a series of points representing the estimated courses and elevations of the pre-Chavín rivers.

Although more computationally complex than other interpolation techniques, kriging is appropriate for attributes such as elevation, where value and location may be expected to covary (spatial autocorrelation). Robinson and Zubrow (1999:79) caution that kriging is "very expensive in time to calculate", but—at least with a relatively small dataset such as this one—advances in computer processor speed seem to have overcome that limitation. Moreover, in addition to providing a topographically plausible surface (without, for instance, the local extremes visible in the radial basis function interpolation (Fig. 6a)), kriging provides a means of assessing the accuracy of the modeled surface without extensive excavation (Conolly and Lake, 2006:97). By comparing the interpolated surface to a standard error surface, kriging allows assessment of how much confidence should be placed in which of the resulting areas of the surface.

The interpretive step from interpolated surface to reconstructed landscape becomes a critical one. The interpolated surface

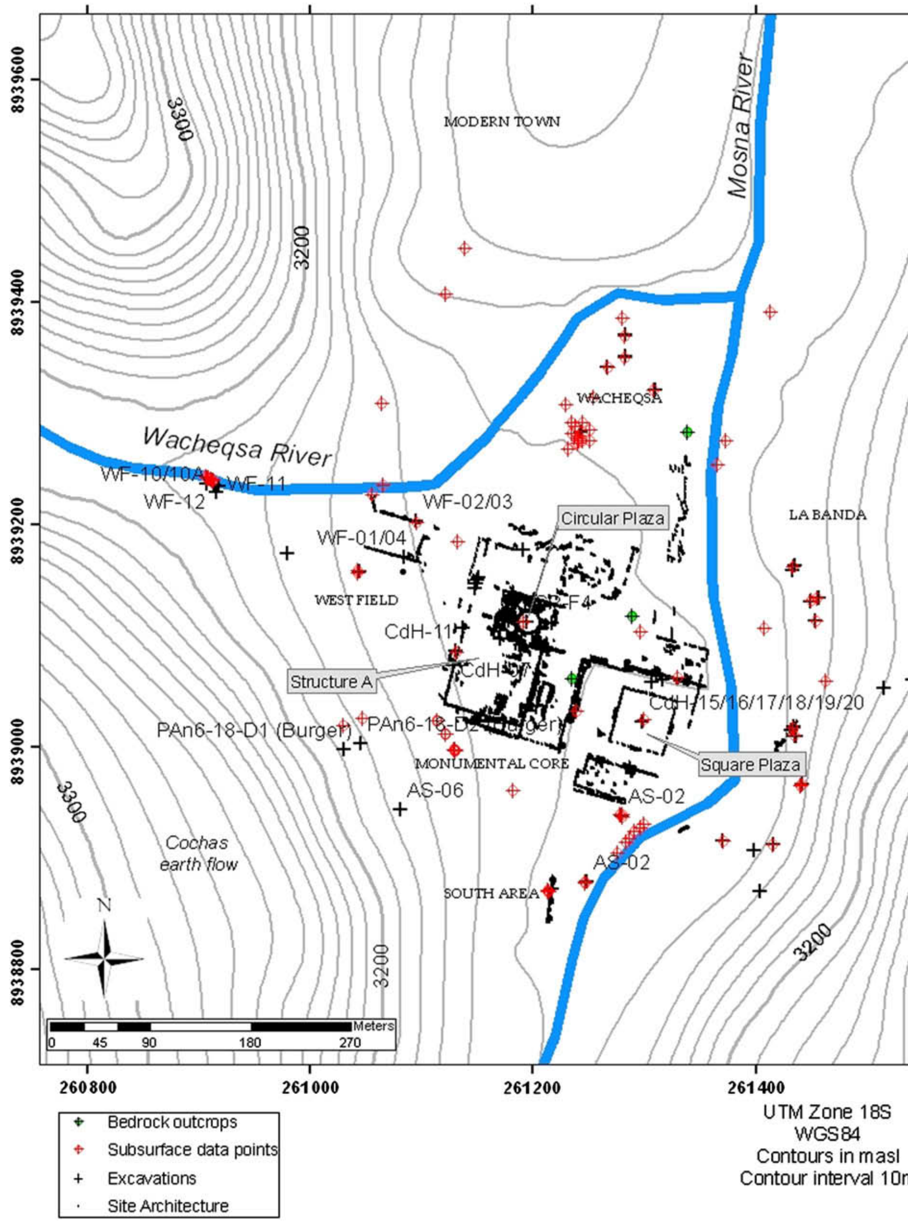

Fig. 7. Data used in the landscape reconstruction.

serves as the basis for a reconstructed landscape, in which data attributes in addition to simple elevation contribute to interpreting the model of the pre-Chavín surface. The sediment stratigraphy from the excavations in and around the monument, in combination with characterization of modern geomorphic process and the sediment stratigraphy documented in extant exposures, also provides a means of reconstructing pre-Chavín landforms. A series of key deposits give vital information about the character, as well as the elevation, of the pre-Chavín landscape. Key examples are the fluvial sediments excavated in CdH-15/16/17/18/19/20 and AS-02, and the *aluvión* and landslide deposits documented in the exposure at the north end of the West Field (WF-10/11/12) (Contreras, 2007). These data have been used to infer the surficial geomorphology of the area in the pre-Chavín period in addition to the topography (see Fig. 9; Unit Qyal includes—and likely underestimates, given the paucity of data—the pre-Chavín debris flow documented in WF-10/11/12).

6. Results

The interpolated surface and the nature of the subsurface points that were used to calculate it allow some key interpretations. Primarily, the interpolated surface allows a comparison of the pre-Chavín landscape with the modern landscape, enabling quantification of the scale of landscape change (and, in particular, of the amount of anthropogenic fill). This approximation of the pre-monument topography, in combination with the information we have about paleosurfaces, also allows some reconstruction of the local pre-Chavín geomorphology (Fig. 9). While the basic geomorphologic units are similar to the modern ones (compare with Fig. 5), the course of the Mosna River is more westerly, and the alluvium comprising the area later occupied by Chavín is not overlain with fill.

In addition, the net effect of the contrast in topography is the demonstration—dramatically visible in Fig. 10—that the pre-Chavín surface was substantially different than the modern one.

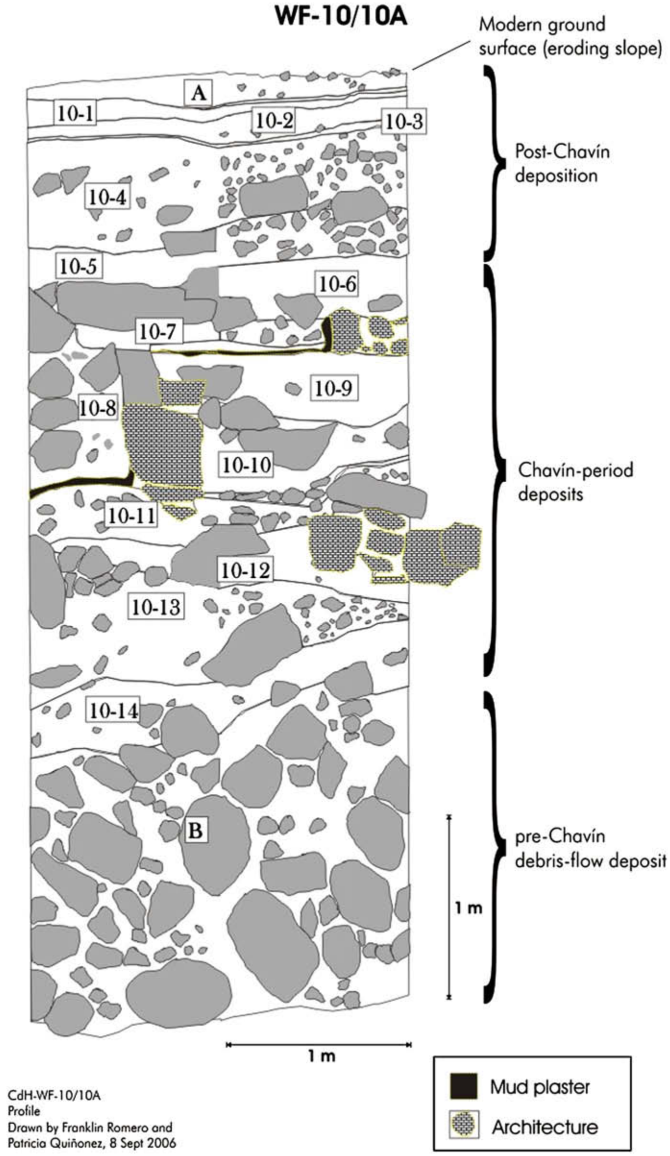

Fig. 8. Stratigraphy of Unit WF-10, where the contrast between cultural and sterile strata is apparent.

Deposition of up to 18 m has occurred throughout the area of the site and its near periphery in the last three millennia (while the specific value may result from particularities of the modeled surface, it should be regarded as reliably accurate, if not precise; larger values visible on the periphery of Fig. 10 are the result of scarcity of data and should be considered artifacts of the model rather than accurate estimates). The contrast is the result of both geomorphic and anthropogenic processes.

The majority of the available data relevant to the pre-Chavín landscape comes from Stanford excavations. In the monumental core, the chief effect of these has been to demonstrate the depth of post-monument deposition and superposed monumental construction. Amongst the earliest of these were the small but deep excavations on the west side of Structure A, designed to clarify the construction sequence of that structure (Rick et al., 1998). While even the deepest of these could not reach sterile soil (due to a rocky matrix), Units CdH-7 and CdH-11 nonetheless demonstrated that the base of Structure A is minimally 5.5 m below current ground surface. Similarly, Unit CP-F4, in the Circular Plaza, demonstrated that superposed fills extend to a depth of approximately 1.4 m below the plaza surface. Data of this sort comprise a series of points within the monumental core area that serve to suggest a substantially lower pre-Chavín surface, constrained by outcropping bedrock visible on the modern surface in two locations and inside the subsurface Rocas Gallery (see Rick, 2008 and Fig. 7).

A further series of Stanford excavations, located in the near periphery of the monument, have served to demonstrate that much of this area, not generally conceived of as part of the monumental construction project, in fact forms part of the built environment. Unit WF-09 in the West Field, for instance, reached a depth of 6 m below modern ground surface without penetrating through cultural fills to a sterile surface. Similarly, Unit WF-1/4, set against the face of the lower terrace in the West Field, demonstrated the wall height to be minimally 2 m, rather than the <1 m visible on the surface, while against the face of the upper terrace WF-2/3 demonstrated a wall height of approximately 4 m. Comparable results from the Area Sur and La Banda demonstrate the pervasiveness of cultural fills and landscape-altering walls in the monument's near periphery. These excavations, even where they have not reached a sterile surface, have served to provide a minimal depth for that surface.

Raster calculations (see Conolly and Lake, 2006:Ch.9; Kvamme, 1999) using the interpolated pre-Chavín surface suggest that the combination of architecture and built landscape required an estimated net fill of approximately 59 000 m^3 within the roughly 20 hectare area of the monumental core and its near periphery. This figure is more than double that estimated for architectural fill only (25 000 m^3), suggesting concomitantly greater labor investment and need for planning and management. In addition to postulating laborers levering quartzite blocks into position and carrying bags of rubble fill to build the monumental architecture of the ceremonial center proper, that is, we should also be considering engineering efforts at river re-channeling, terrace construction, and slope management.

7. Conclusions

The array of known points and resultant interpolation provides the skeleton of the archaeological landscape, which may then be fleshed out into a reconstructed landscape using the available stratigraphic information and the geomorphology and archaeology of the valley. I have focused here on prehistoric landforms rather than changes in land cover due to the scarcity of local data about the latter. Regional patterns suggest, however, that land cover in the first millennium BCE was generally similar to that visible today. The changes wrought on the landscape by the introduction of agriculture are clearly critical—probably including anthropogenic burns, changes in forest cover, and the adoption of plant and animal domesticates—but remain poorly documented (Contreras, 2007:Ch. 3).

The contrast between the landforms of the pre-Chavín landscape and the modern one—mapped extensively and intensively since 1995 by the Stanford project—is dramatic, and encompasses substantially more than the simple addition of the architecture of the monumental core to a landscape otherwise similar to the modern one (see Figs. 10 and 11). It is a relatively straightforward task to imagine Chavín without structures; that is, to imagine Chavín as it appears today, but without the visible construction. However, a variety of processes combine to render this a wholly inadequate means of conceiving of either the landscape that Chavín's builders encountered when they began construction or the landscape they left behind perhaps 700 years later. Rather, the surface interpolated from the archaeological data demonstrates that the majority of the valley surrounding the monumental center has experienced deposition of up to 18 m.

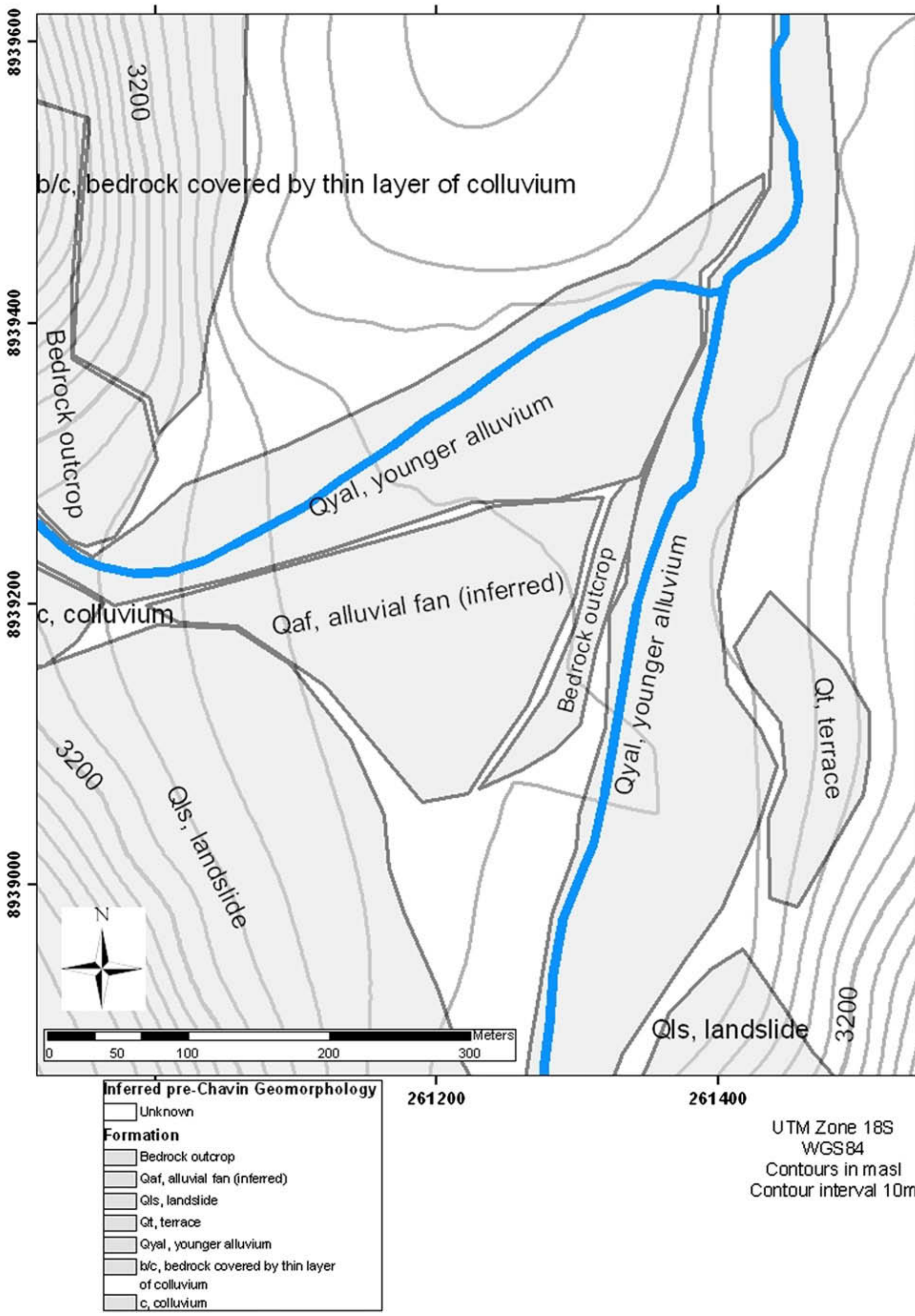

Fig. 9. Inferred pre-Chavín geomorphology. Note that the Qyal deposit flanking the Wacheqsa River includes the diamicton of the pre-Chavín debris flow documented in WF-10/11/12. Note also the more westerly course of the Mosna River.

Two lessons thus stand out from this GIS-based landscape reconstruction: 1) the dynamism of the physical environment, and 2) the ubiquity and scale of anthropogenic landscape modification. As emphasized above, that deposition (and other changes) reflects the activity of a variety of processes, both geomorphic and anthropogenic. Moreover, there is a likely—if not always demonstrable—interplay between those two types of processes. That is, anthropogenic activity often affected local geomorphic processes, and geomorphic activity affected human activity. In addition to the probable but as yet undocumented effects of agricultural activity on slope stability, it is clear that Chavín's builders altered the channels of both local rivers and both undercut and stabilized surrounding slopes. Conversely, they likely experienced both landslides and floods in their dynamic setting. The contrast between that modern landscape and the pre-Chavín one (see Fig. 11) reflects inputs of both processes.

In sum, these pieces of evidence serve to emphasize that the dynamism of the Chavín landscape was eminently relevant to human occupants of the area. That is, Chavín's landscape is not one that was formed in deep time, that human occupants encountered as a static arena for their activity, but rather one that continued (and continues) to evolve around its human occupants, in response to their activity in some ways and independently of it in others.

In broader terms, the project of understanding the archaeological landscape is an attempt to rise to the challenge posed by archaeological and environmental reconstruction in an environment that has been heavily modified over a significant period of time. This challenge

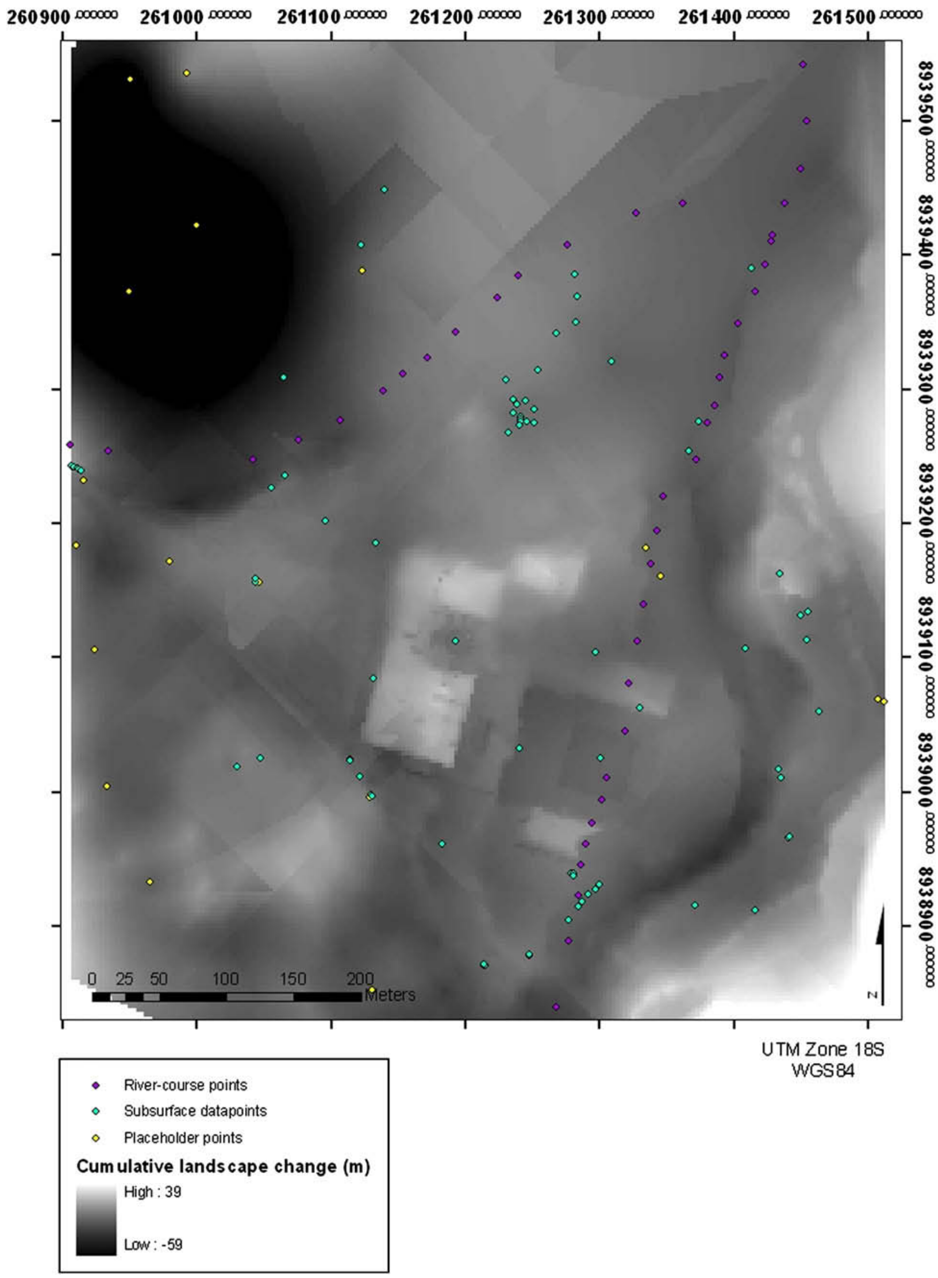

Fig. 10. Raster representation of cumulative landscape change since approximately 1200 BCE. Lighter areas represent addition of fill (white area at upper left is an artifact of the reconstruction). The figure is derived by comparing the interpolated pre-Chavín surface to the modern landscape (mapped in detail by the Stanford Project). Areas of most extreme change are generally artifacts of the model, but the general trends are reliable.

has often been noted by archaeologists working in the Andes (e.g. Kaulicke, 1998; Moseley, 1983; Rick, 1988; Silverman, 2004) but has remained difficult to address (but see Dillehay and Kolata, 2004; Huckleberry and Billman, 2003). Interpolating a prehistoric surface and interpreting the associated landscape offers a baseline against which landscape change—whether geomorphic or anthropogenic, and at a temporal scale relevant to archaeology—may be assessed. Such a baseline can obviously be further refined as more data becomes available, and can serve meanwhile as a tool for planning excavation strategy, whether the goal is to investigate areas of substantial fill, quickly access sterile strata, or add data in underexplored areas. While the limits of an interpolated surface must be recognized, the existence of a concrete basis for comparison opens various interpretive avenues, ranging from the analysis of labor inputs to the evaluation of a constructed symbolic landscape.

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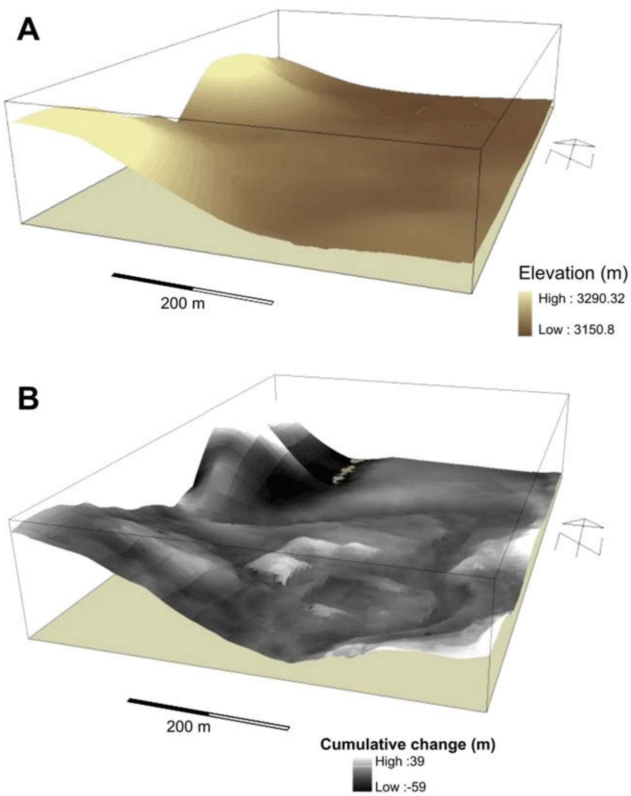

Fig. 11. Perspective view of landscape change. A) Reconstructed pre-Chavín surface; B) Cumulative subsequent landscape change. As in Fig. 10, light areas represent deposition of material.

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