Ancient agriculture and domestic activities: a contextual approach studying silica phytoliths and other microfossils in soils

M. Alejandra Korstanje and Patricia Cuenya

Based on microfossil and soil data, we discuss a different methodological approach to agricultural and domestic archaeological studies, taking two Formative sites in the north-west Argentinian high valleys (province of Catamarca) as case studies, independently of traditional datasets and historical analogies. As a result of our investigations we not only recognised the vegetal species cultivated in ancient fields (dated to *c.* AD 800) but also distinguished some of the agricultural practices, such as crop rotation and alternation, use of animal fertilisers and irrigation resources, as well as the abandonment of the site. From this perspective, corral episodes could also be distinguished. In residential enclosures, we obtained results concerning activity areas, the definition of floors and the identification of reoccupations.

Keywords: archaeology, silica phytoliths, microfossils, ancient soil use, ancient agriculture, activity areas

Introduction

Most agricultural approaches in north-western Argentina focused on macro-remains obtained from architectural facilities, including hearths, pits and shelters. Generalisations were made taking into account current environmental conditions and ethnographic sources. Only in the last decade has phytolith analysis provided the tools with which to approach directly open-air producer sites, where macro-remains are not preserved.

One of the principal manuals (Piperno 1988) indicated some of the roles of phytoliths for archaeological reconstruction, as

> *an independent avenue of data and interpretation for four major areas of archaeobotanical studies: (1) the origins and dispersals of domesticated plants and development of agricultural systems; (2) the availability, economic usage, and non-economic roles of wild plants; (3) the nature of environments and environmental modification associated with past human occupation of sites; and (4) the relationship between technology, economy and social organization. (Piperno 1988, 168)*

Any archaeologist interested in economics and food production should feel excited enough with these sets of possibilities and still more can be added, such as site formation processes and taphonomy, which can also be approached from this point of view. Following this logic, we started our research on agricultural systems, but once we realised the limitations of phytolith analysis for our area (Korstanje 2009), much of the enthusiasm passed away and showed us that we needed extra tools to answer our questions. Since then, we have re-focused the research on the possibilities of whole microfossil assemblages as a tool for studying ancient agricultural sites (Korstanje 2009; Coil *et al.* 2003).

We define 'microfossils' as those biogenic particles invisible to the naked eye, and deposited in any type of soil or sediment context (Coil *et al.* 2003, 991). In this sense, the study includes ancient silica phytoliths, diatoms, faunal spherulites, starch granules, calcium oxalates, cellulose rings, chrysophites and micro-charcoal. The methodology presented in this paper is a step further than 'multiple microfossil research', improved by combining such information with soil physical and chemical characteristics, for a better understanding of ancient soil use, and the compo-

---

M. Alejandra Korstanje (corresponding author), Instituto de Arqueología y Museo (IAM), Fac. de Cs. Naturales e IML. Universidad Nacional de Tucumán – Instituto Superior de Estudios Sociales (ISES), CONICET-UNT, Argentina; e-mail: alek@webmail.unt.edu.ar; Patricia Cuenya, Instituto de Arqueología y Museo (IAM), Cátedra de Pedología, Fac. de Cs, Naturales e IML, Argentina

Published by Maney on behalf of the Institute
Received February 2009; accepted June 2009
DOI 10.1179/146141010X12640787648739

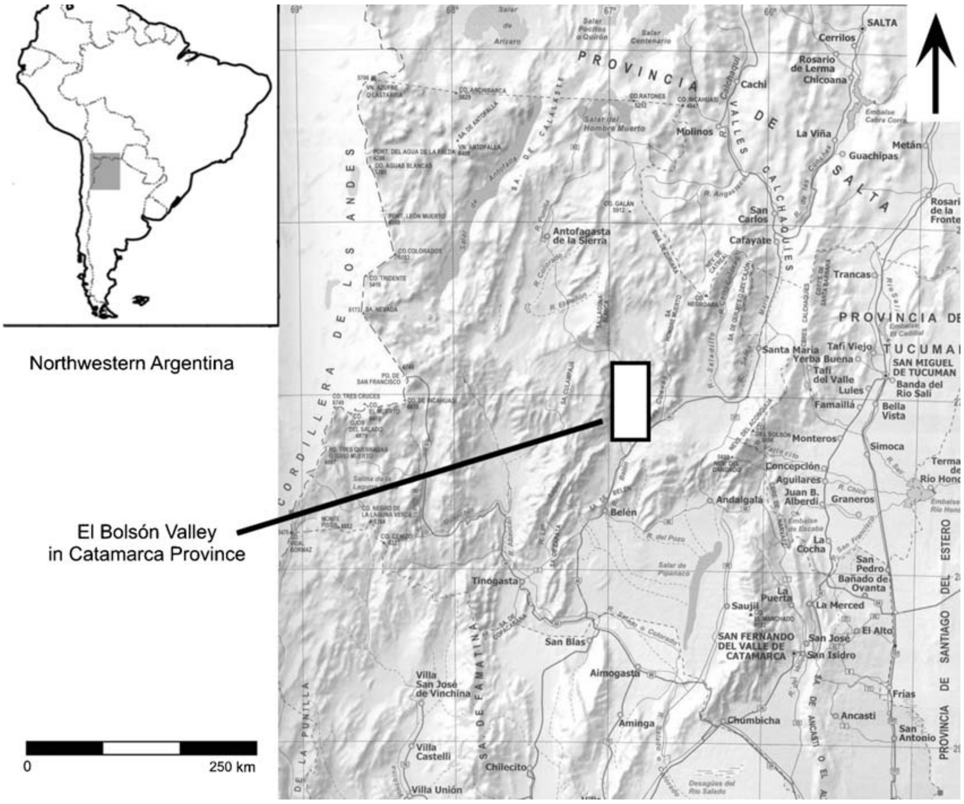


Figure 1 **The Valley of El Bolsón in north-western Argentina** 5

nents that survive to the present. We explain this methodology through a comparison of two sites (Morro Relincho and El Alto El Bolsón), to show the complex functionality of structures — formerly assumed from architectural features only — ranging from residential areas, agricultural fields, corrals or a combination of these.

Environmental and archaeological characterisation

The Valley of El Bolsón is located in north-western Argentina (Province of Catamarca), between 26°52′ and 27°00′ South and 66°41′ to 66°49′ West (Fig. 1). Four micro-environments may be defined, corresponding to different phytogeographic regions: Altoandina, Puna, Prepuna and Monte (Cabrera and Willnik 1980):

1. *Altoandina* (above 3400 m.asl) is defined by the prevalence of xerophytic Poaceae (such as *Festuca* spp., *Poa* spp. and *Stipa* spp.) and non-columnar Cactaceae;
2. The *Puna* occupies only a short segment of the landscape, at the northern end of the valley, characterised by the predominance of bushy steppe (with endemic species such as *Parastrephia phyllicaeformis*, *Fabiana densa* and *Baccharis polifolia*);
3. The *Prepuna* (in the range 2500–3400 m.asl) is defined by the prevalence of columnar Cactaceae (such as *Trichocereus* spp.), xerophytic Asteraceae and the 'cortaderal' (*Cortaderia* spp.); *Cortaderia selloana* is, however, especially predominant at the bottom of the valley;
4. The *Monte* is defined by a wider diversity of taxa: Zigofilaceae (*Larrea divaricata*, other species of *Larrea* and *Bulnesia retama*), Fabaceae (*Prosopis alba* and P. *nigra*, *Cercidium cupine*, *Acacia caven* and *Geoffroea decorticans*); it includes different altitudinal slopes at around 1000 to 2500 m.asl.

El Bolsón, classified as a high valley (2900–2500 m.asl), constitutes an ecotone between the Puna and the rest of the sub-area known as Valles y Quebradas (Aschero and Korstanje 1996). Geologically, this is part of the Sierras Pampeanas province, represented by diverse lithological formations: granitic outcrops, neogenetic ignimbrites, quaternary sediment (fine sand, pelite and tuff interleaved into conglomerates) and fluvial deposits (Navarro García 1984). Soils are, in general, scarcely 1 developed and correspond to the regional rock weathering and a lesser contribution of aeolian sediments, matching Aridisol and Entisol Soil Orders, with profiles of the type A/C and/or A/Cr/R (USDA 2006) (Cuenya 2004).

Figure 2 **Landscape and structures at the archaeological site, Morro Relincho**

Arid to semi-arid climate characterises the region. It is defined by the strong contrast of temperature and precipitation between the summer and winter, with an annual mean temperature of 18°C. The mean annual precipitation is estimated to be between 200 and 450 mm (Irurzun 1978).

The sites

a) *Morro Relincho* is located between 3100 and 3280 m.asl, on the main slope sector of the mountain (+20%), characterised by Altoandina vegetation. The structures are located at the edge of a sharp back slope of the Bolsón River which, at first sight, does not seem to be favourable for human occupation (Fig. 2). The total area is 1·3 ha. The architectural features consist of 16 stone circles, whose dimensions vary between 22 and 3·70 m diameter. Some of the large circles communicate with smaller ones through a clear space. Small circles are constructed of simple walls, with sharp flat stones, while large circles are also of simple walls but built with large round stones as foundations (Fig. 3).

b) *El Alto El Bolsón*, larger than the former, is located in an alluvial fan, developed by the cyclic deposition and transport of detritus fluxes discharged from nearby hills. Holocenic epigenesis dissected the principal fluvial courses, which today surround the area (Fig. 4). The site contains a total of 327 stone structures of different periods. In part, the occupations overlap in time, but the apical zone of the fan has only Formative period structures (*c*. 1000 BC–AD 1000) (Fig. 5), on which we focused. The stone structures show different forms and disposition: those considered to be agricultural fields may be round enclosures (isolated or aggregated), open alignments transversal to the slope and open or closed terraces. The residential architecture, spread within the agricultural fields, shows two types of construction: medium circular enclosures attached to a larger area or '*patio*', and isolated circular enclosures. Both types also show slightly different construction techniques.

Brief considerations on ancient Andean agriculture

There follows below an overview of some of the agricultural practices we try to identify in the past.

From an ethnographic perspective on Andean agricultural systems, one important subject is the technological problem of unirrigated agriculture. There are current examples, as in the Colca Valley (Arequipa, Peru), where the annual average precipitation is lower than 400 mm, but there is extensive agriculture without irrigation (Treacy 1994). The explanation for this may be technical (introduction of cultivars resistant to drought, water control) or climatic (more humid periods than at present). In any case, this example suggests that unirrigated agriculture might have been possible in our area.

According to the present record and perspective, the plants that resist drought and frost best, are quínoa (*Chenopodium quinoa*) and kañiwa (*Chenopodium pallidicaule*), but other crops may also survive unirrigated agriculture, especially micro-thermal tubers such as añus (*Tropaeolum tuberosum*), ullucos (*Ullucus tuberosus*) and ocas (*Oxalis tuberosa*) which, additionally, grow in high altitude environments. To some extent, potatoes (*Solanum tuberosum*) also resist cold temperatures, and can be seeded in high altitudes, but need more water and fertilisers than the rest of the tuber range.

Regarding the soil use and production techniques involved in these systems, Valero Gutiérrez (1992), in

Figure 3 Map of the site, Morro Relincho

his study on Peruvian peasant communities, defines as '*muyuys*' or 'turns' those special unirrigated places where there is a patchy fallow system (parcels are cultivated for a given time and then rested for three to five years), where the characteristic cultivar is the potato. The *muyus* are placed in the higher agricultural zone (between 3400 and 4350 m.asl, at the junction between agricultural frontier and highland vegetation) and, while they are in the resting period, cattle are kept there to feed on crop remains and herbs. In this way, they are 'naturally' fertilised with manure during the uncultivated period. This practice, as a simple mechanism to fertilise soils and feed cattle, has also been observed in north-western Argentina at Laguna Blanca, Antofagasta de la Sierra and Cotagua (Korstanje 2005). Concerning crop rotation and alternation, we observed at Titicaca basin (Bolivia) and Argentina that maize and potatoes may alternate if manure is added to soils before seeding the tubers (Korstanje 2005).

Brief consideration of the microfossil record

Here we need to introduce some basic considerations concerning soil characteristics in agronomic systems and also some characteristics of Andean peasant agriculture, to further understand what is expected

Figure 4 Landscape and structures at the archaeological site, El Alto El Bolsón

from an ancient soil use perspective. Its is important to stress that, as this methodology can be used to study other agricultural systems besides the Andes, scholars should make their own base line for research, as some of the initial conditions may be different.

The chemical characteristics of a soil under agricultural use co-vary depending on whether the plant contributes or extracts different substances or elements. For example, a general decrease of nutrient elements such as phosphorus (P) and nitrogen (N) is expected, as these elements are absorbed by the plant, and subsequently exported out of the system once the plant is harvested. However, there might also be an increase of some humic substances if people carry out conservative practices such as fallowing, mulching and manuring or zero ploughing. In these systems, the 'economic' part of the plant is extracted (fruits, ears, tubers, etc.), taking away some of the nutrients, but the elements that are incorporated into the rest of the plant (stems, leaves, etc.) are retained for the next cycle, in the form of organic matter. This is the reason why the ratio between organic matter and phosphorus varies depending on different processes, for instance, whether the plant was extracted complete or not, whether fertilisers were incorporated or not, or whether there was intensive use or not.

The parameters we use in this article (principally organic matter and phosphorus) are not the only ones used to understand the use of soil, since there are other chemical elements that may be added and removed (such as nitrogen, calcium, iron, etc.), but these two are the most stable for studying ancient soils (Porta Casanellas *et al.* 1994; Labrador Moreno 1996; Fitzpatrick 1996; Gallegos del Trejo 1997). This is because, even if soils are not closed systems, nor encapsulated and isolated in time, some stable features are preserved in time and become indicators of the prehistoric uses of soils (for example, P).

Regarding taphonomic problems, it was assumed that phytoliths are highly stable in soils and with little mobility (Rovner 1983), but are constrained by the same taphonomic processes as any other particle included in the silt fraction (Juan-Tresserras 1997). In soil science, it is considered that, at a textural level, there is stability of the particles in the silt fraction (Porta Casanellas *et al.* 1994), but this does not mean that there are no micro-movements of the individual particles. In a soil under agricultural use, periodic ploughing implies an extra dynamism to soil weathering and leaching. However, we do not consider this a definitive limit for the study of ancient soils, since we can avoid this bias by making comparisons among samples from similar types of environment and soils. In other words, soils from similar environments can be compared (for example, arid to arid) but, unless one carries out a comprehensive taphonomic analysis for each situation, we recommend against a comparison of soil use between two very different environments (for example, arid to humid).

In our case, both sites are in similar and close environments and, as Table 1 shows, textural proper-

Figure 5 Map of the site, El Alto El Bolsón

ties are quite similar in all the cases studied. Therefore, the same major natural taphonomic processes have organised both soils. If there were differences in chemical properties (organic matter and phosphorus) and microfossils assemblages, these should be cultural rather than natural.

Even if there were some early suggestions of possible intromission of phytoliths from the soil fraction transported by wind, one of the main strengths of phytoliths as archaeological remains is that, under normal conditions, they are deposited in the soil directly *in situ* after the plant decays (Piperno 1988). This condition is quite important when studying open-air producer sites. In our case, we have an additional advantage, as the sites are located on high mountain slopes, where neither water nor wind can carry them from other places (see soil granulometry in Table 1). However, in this case, we have the opposite effect: a great Aeolian and hydric erosion turns into a high loss of the soil's silt fraction. In this sense, we consider that a proportion of the original microfossil assemblage has been deposited in the lower areas and lagoons of the valley (where we are conducting interdisciplinary research with pollen specialists).

The following is a brief explanation, for non-specialists, regarding the potential of the microfossil record relative to agriculture and domestic activities, for our case studies (Korstanje 2005). Taxonomic determinations are done using broader microfossil assemblages, taking silica phytoliths and starch granules for the determination of Andean crops (Korstanje and Babot 2007). Scholars interested in using this methodology should check the expectations for their own study area and plant record.

The reported cultivars in the Andes are not equally recognisable in the archaeological record, if the soil has been tilled in the past. Since maize, as a Poaceae, is a major producer of silica phytoliths, in vegetative as well as reproductive structures, we can expect to find diagnostic maize phytoliths when maize was cultivated; the problems associated with maize phytolith identification (see Pearsall *et al.* 2004) are not relevant here, as no other grasses in the area yield cross shaped phytoliths similar or identical to those of maize. On the other hand, since potatoes are Solanaceae (a family that do not produce diagnostic phytoliths), we cannot expect to find them, but instead can anticipate diagnostic starch granules.

Cellulose rings also have very limited diagnostic possibilities, but they are very common in fibrous taxa
(such as the Bromeliaceae family; Flórez and Lozano 2
1999), so we quantify them in a presence/absence way only, as possible indicators of plants used for handicrafts.

Even though micro-algae, such as diatoms, may have taxonomic importance, and may give information about their immediate environment in ancient times (Stoermer and Smol 1999), we currently use them only as an irrigation indicator, based on their frequency of appearance. Crisophycean are lesser known (golden brown) algae, but they have been reported as nitrogen indicators (Binford *et al.* 1996). In the same way we use micro-charcoal frequencies to identify fires, but not for taxonomic purposes.

Calcium oxalates have very restricted diagnostic potential and, since they are quite fragile, are not [3] often found in most contexts (Juan Tresserras 1997) but, given that they always occur in modern samples of camelid faeces (*guano*), we use them not as indicators but as a supporting evidence for the presence of guano, when spherulites are also present.

Finally, we have concluded from our own research that spherulites can differentiate Andean camelidae from European cattle (Canti 1998), but that they cannot be used to distinguish different camelid species. So we use them, on a presence/absence basis, to indicate dung (Korstanje 2004).

Methodology

Based on this type of information, our goal is to advance microfossil research, by including the analysis of all possible microfossils (faunal, algal and vegetal) and their relationship with soil matrix characteristics. These assemblages explain some of the trends in site formation processes and, more importantly, are positive evidence of cultural practices in ancient soil use. In our case, the identification of vegetal taxa from the fields is crucial for demonstrating what people directly cultivated as opposed to what they consumed or exchanged. Little research has been done on the microfossils of the fields themselves (Pearsall 1993; Fujiwara 1993; Rosen and Weiner 1994; Lentfer 2002). To achieve such a challenging goal, we analysed soil characteristics, as this matrix is the natural and cultural context in which we can make sense of microfossils.

We followed, to some extent, the spirit of previous research, which considered only two types of microremains together (Cummings 1992; Piperno 1993; Kealhofer *et al.* 1999; Campos *et al.* 2001; Verdin *et al.* 2001; Balme and Beck 2002), and where the major advantage was to enhance the potential of one microfossil over the other. For example, the pollen

Table 1 Soil characterisation

Level (cm)		SAND	SILT	CLAY	Texture	pH	%C	% MO	Pt (ppm)
Control	0–20	–	–	–	–	6·96	0·06	0·1	447
	20–46	80·8	3	16·2	Sandy loam	7·03	0·22	0·38	462·3
Morro Relincho		SAND	SILT	CLAY	TEXTURE	pH	%C	% MO	
XII	0–20	81·8	3	15·2	Sandy loam	6·22	0·2	0·34	–
	20–50	82·8	2	15·2	Sandy loam	6·93	0·24	0·41	–
	50–70	84·8	2	13·2	Loamy sand	7·49	0·16	0·27	–
XVI	20–25	–	–	–	–	6·39	0·26	0·44	–
	30–35	84·4	4	11·6	Loamy sand	6·77	0·28	0·48	–
	40–45	–	–	–	–	7·22	0·14	0·24	–
	50–55	82·4	4	11·6	Sandy loam	7·88	0·32	0·55	–
	60–65	74·4	10	15·6	Sandy loam	7·48	0·36	0·62	–
El Alto El Bolsón		SAND	SILT	CLAY	TEXTURE	pH	%C	% MO	Pt (ppm)
79	60–70	62	18	20	Sandy clay loam	0·48	0·82	6·84	–
	50–60	66	16	18	Sandy loam	0·44	0·75	6·78	430·9
	40–50	68	16	16	Sandy loam	0·81	1·41	6·53	435·5
	30–40	68	18	14	Sandy loam	0·64	1·1	6·36	478·6
	20–30	74	14	12	Sandy loam	0·6	1·03	6·31	–
	10–20	72	16	12	Sandy loam	0·87	1·51	6·11	–
	0–10	74	15·6	10·4	Sandy loam	1·27	2·2	6·3	–
82 d	65–70	53·2	21·4	25·4	Sandy clay loam	0·54	0·93	7·26	499·4
	60–65	70	16	14	Sandy loam	0·63	1·1	7	532·4
	55–60	57·2	19·6	23·2	Sandy clay loam	0·95	1·65	7·41	563·2
	50–55	59·2	17·6	23·2	Sandy clay loam	0·66	1·13	7·13	489·5
	45–50	70	18	12	Sandy loam	0·56	0·96	6·8	548·6
	35–45	58·8	19·6	21·6	Sandy clay loam	0·68	1·17	6·95	–
	30–35	62·8	17·2	20	Sandy loam	1·09	1·89	6·93	–
104	30–45	79·2	13·2	7·6	Loamy sand	0·42	0·72	6·67	399·2
	15–30	79·2	14·2	6·6	Loamy sand	0·81	1·41	6·57	414
	5–15	79·2	15·22	5·6	Loamy sand	0·81	1·41	6·46	–

record is most useful for Asteraceae (difficult to identify from phytoliths) and phytoliths for Poaeceae (difficult to identify from pollen), as well as other possible combinations within silicious algae and phytoliths. Apart from the limitations relating to the set of plants growing in our area, and their representation through phytolith production, other problems were that most of the investigations of the agricultural problem derive from samples in domestic contexts (Pearsall 1978; 1993; Rosen 1992; Rosen and Weiner 1994; Rosen 2001; Mbida Mindzie *et al.* 2001) or from lagoon systems (Kealhofer and Piperno 1994). This difference in the origin of the samples is important; since agricultural sites are open-air sites which do not have the stability of lagoons, as they have been ploughed and worked at various times. The literature referencing this is very scarce (Archer and Bartoy 2000) and, in most cases, is analysed from perspectives other than microfossils and phytoliths (Miller and Gleason 1994).

Materials

At agricultural sites, soil samples were collected from test pits following observable pedogenic levels in the field. To describe the soil we use the 'Norms of Soil Recognition' (Echevehere 1976). At the residential sites, archaeological stratigraphy was followed (in this case, every 5 cm, since the sediment column did not show observable cultural levels). We took around 500 g. of sediment for each sample. This quantity is much more than needed since, for microfossils, we use 10 g. (depending on the granulometry of the soil) and, for soil analysis, we use around 100 g. The extra was taken because these samples are non-replicable, and repeated analyses, or other analysis, may be needed, including perhaps at another laboratory. The samples were further separated in the laboratory for microfossil analysis and pedological determinations.

For soils, we made the following determinations: texture (Bouyoucos 1936); pH (soil-water 1 : 2·5); organic matter (O.M.) percentage (Walkley and Black 1934) and, in some cases, total phosphorus (P) (Bray and Kurtz 1945). These results are summarised in Table 1 and presented in all graphs of the case studies below.

For microfossils, we used the 'multiple extraction' method (Coil *et al.* 2003), consisting of a controlled low chemical protocol that allows the extraction of multiple different microfossils on the same slide. Silica phytolith descriptions and classifications were basically made using Bertoldi de Pomar's (1971) taxonomy, because this classification has been the most used in South America for the last three decades. For new specimens, we introduced a description according the International Code for Phytoliths Nomenclature, ICPN (Madella *et al.* 2005).

For quantification, we followed the aliquot method, calculating frequencies and densities by counting all the phytoliths (diagnostic and unknown) and other microfossils in 20 microscope fields, at 200 × magnification. For special identifications, 400 × and 1000 × magnifications were used. For starch, cellulose rings, calcium oxalates and spherulites (all observable in dark field), the whole slide was scanned, and then results were standardised as densities. Table 2 shows figures for microfossil densities, showing the different patterns extracted from these numbers. No statistical analysis has yet been conducted. The counting methodology was as follows:

a. During the extraction and soil fraction separation stages, all the powder obtained was weighed on a precision scale.
b. Once the microfossil assemblage had been separated by flotation from the general silt fraction, one drop of it was placed on the slide (this is called the aliquot method, since each drop is supposed to have the same volume). This was weighed on a precision scale.
c. Once covered, the area occupied by the drop was measured and calculated for each slide.
d. The area of the fields observed under the microscope were also calculated (this was done only once for each magnification, e.g. 200 ×).
e. Once the amount of each type of microfossil was known for the entire microfossil scan (e.g. the number of silica phytoliths per field area) this was extrapoled to the whole slide area (slide area × amount of silica phytoliths/field).
f. As the mounted sample was weighed on the slide, with this figure it was possible to determinate the amount per unit weight (number of microfossils/g. floated silt) by multiplying the number of microfossils on the slide by 1000 (to convert from milligrams to grams) and dividing by the weight of the sample.

The figures are therefore high, because they were calculated for the whole sample and not only for the fields observed.

A *control sample* was made from an area without archaeological structures to represent soil and microfossil 'natural' features.

The positive results of this method, combined with soil analysis, have proved to be an excellent approach for archaeological problems, when considering one of

Table 2 Microfossil densities (number of microfossils/g. floated silt)

Level (cm)		**Siliceous microfossil density**			**Non-Siliceous microfossil density**						
	Control	**Silicaphytoliths**	**Diatoms**	**Chrysophites**	**MicCharcoal**	**Pollen**	**Spores**	**Starch**	**Cellulose**	**Spherulites**	**C· Oxalates**
	0–20	2·393·877·551	1·427·405·248	29·737·609	14·868·805	208·163·265	29·737·609	0	0	0	0
	20–46	1·419·394·841	20·620·748	30·931·122	44·678·288	6·873·583	13·747·166	182·149·943	0	0	0
Morro Relincho		Siliceous microfossil density			Non-Siliceous microfossil density						
		Silicaphytoliths	Diatoms	Chrysophites	MicCharcoal	Pollen	Spores	Starch	Cellulose	Spherulites	C· Oxalates
XII	0–20	5·914·285·714	62·585·034	234·693·878	125·170·068	15·646·259	516·326·531	31·292·517	0	0	0
	20–50	5·722·534·014	235·374·150	250·085·034	0	29·421·769	132·397·959	0	0	0	0
	50–70	130·634·428	3·647·715·173	90·439·219	0	90·439·219	0	0	0	0	130·634·428
XVI	20–25	4·283·163·265	167·602·041	111·734·694	55·867·347	204·846·939	186·224·490	0	0	0	0
	30–35	3·086·580·087	42·671·614	263·141·620	64·007·421	35·559·678	192·022·263	0	0	0	0
	40–45	23·968·923·933	316·326·531	532·003·711	0	28·756·957	0	43·135·436	71·892·393	0	0
	50–55	6·661·176·658	157·557·398	297·608·418	315·114·796	122·544·643	245·089·286	26·259·566	0	0	0
	60–65	4·910·131·195	48·615·160	97·230·321	182·306·851	97·230·321	72·922·741	0	0	0	0
El Alto El Bolsón		Siliceous microfossil density			Non-Siliceous microfossil density						
		Silicaphtoliths	Diatoms	Chrysophites	MicCharcoal	Pollen	Spores	Starch	Cellulose	Spherulites	C· Oxalates
79	60–70	4·623·661·290	157·983·871	305·435·484	473·951·613	31·596·774	52·661·290	0	0	0	0
	50–60	52·274·125·000	676·375·000	2·222·375·000	3·768·375·000	0	483·125·000	386·500·000	0	96·625·000	0
	40–50	8·825·142·857	185·142·857	23·1428·571	663·428·571	30·857·143	200·571·429	0	0	169·714·286	0
82 d	65–70	21·960·000·000	256·200·000	329·400·000	1·281·000·000	0	292·800·000	0	0	0	0
	60–65	5·465·793·103	137·793·103	137·793·103	688·965·517	80·379·310	195·206·897	0	0	0	0
	55–60	25·072·666·667	413·111·111	476·666·667	1·366·444·444	127·111·111	413·111·111	0	0	508·444·444	31·777·778
	45–50	6·696·344·828	117·068·966	105·362·069	362·913·793	23·413·793	35·120·690	23·413·793	0	0	0
	30–35	7·837·967·742	174·435·484	69·774·194	523·306·452	23·258·065	81·403·226	11·629·032	0	0	0
104	30–45	4·289·431·034	119·482·759	436·112·069	1·421·844·828	11·948·276	17·922·414	0	0	0	0
	15–30	10·442·793·103	298·706·897	418·189·655	609·362·069	11·948·276	83·637·931	0	0	23·896·552	0
	5–15	22·140·000·000	670·909·091	279·545·455	1·621·363·636	195·681·818	475·227·273	475·227·273	363·409·091	0	0

the golden rules of archaeology: to explain assemblages in context. For this reason, even if, in the laboratory, all samples were analysed blind, all the contextual information that architecture, artefacts and environment can bring to the problem are used in the interpretation of results.

Expected associations between microfossil assemblages, soil physical and chemical characteristics, and human activities

To follow this reasoning, it is important to remember that, even if microfossils represent independent evidence for the study of agriculture in the epistemological sense, they should be explained in relation to contextual data, including archaeological architecture and artefact analysis. We cannot consider them without taking into account the fact that, as with any other archaeological ecofacts (for example, macroscopic remains); similar combinations may lead us to infer different circumstances or activities depending on the recovery context.

Based on the criteria described above, it is possible to find a correspondence within every set of microfossil combination and soil characteristics, and what is expected from the perspective of ancient soil use. We have arranged some expectations (or hypotheses), presented in the following synthesised way: if there are ***a*** and ***b*** in ***x*** proportions, we can assume an ***f*** use of land. For example, if we find high values of organic matter (O.M.) and an average abundance of silica phytoliths, we can infer that the soils have not been used for agriculture. It is important to repeat that these are comparative, not absolute, values, and so 'high' does not mean any particular number but a value that is higher than that of the *control sample*. However, this interpretation should be considered in relation to certain local, contextual or environmental factors, which are explained in secondary bullet points (e.g. 1·1). These are suggestions for scholars working in other environments.

Expected associations in agricultural fields

1. High values of organic matter (O.M.) and average abundance of silica phytoliths: *soils not used.*
   1.1 It is important to check whether phytoliths correspond or not to current flora types.
2. Low O.M. and an abundance of silica phytoliths: *soil used for agriculture.*
   1.1 It is necessary to distinguish silica phytoliths corresponding to well-known crop types.
3. O.M. variable according to the moment of abandonment, an abundance of silica phytoliths and the presence of spherulites: *soil used for agriculture and fertilised with dung.*
   1.1 If O.M. is high, the soil was fertilised and little used; if it is low, the soil was fertilised and exhausted.
   2.1 It is necessary to distinguish silica phytoliths corresponding to well-known crop types. Normally the soil is fertilised before tuber culture, by which time the inferior levels would show free starch presence and low quantities of silica phytoliths (tubers do not produce abundant or diagnostic silica phytoliths http://www.worldlingo.com/wl/msoffice11?service=WorldLingo_ES-EN&lcidFrom=3082&lcidTo=1033&lcidUI=3082-_ftn1#_ftn1) When we refer to 'tubers' we consider the whole range of Andean tubers. Potatoes (Solanum sp.) have no silica phytoliths at all.
4. Low O.M., an abundance of silica phytoliths and an abundance of micro-charcoal: *soil used for agriculture with chaff burning after harvest.*
   1.1 It is necessary to distinguish silica phytoliths corresponding to well-known crop types. Normally this situation is expected at the end of the maize cycle, when chaff is left *in situ.*
5. Phosphorus (P) diminishes to the lowest value in the agricultural field: *agricultural use.*
6. Presence of abundant silica algae (especially diatoms): *irrigation.*
7. Presence of abundant chrysophites: *soils with elevated nitrogen values.*
8. Presence of siliceous skeletons in high evaporation-sweating environments: *irrigation.*

Expected associations in corrals (pens)

The corrals can easily be confused with the agricultural fields, since many of the microfossils present in camelidae manure (*guano*) can also occur in agricultural features. The best method of distinguishing them is by counting and characterising microfossil associations in well preserved ancient pellets and comparing these with ancient soil samples. As this is not always possible, it is essential to use other independent lines of evidence, for example the values of O.M. or P.

Modern camelid dung presents the following assemblage of microfossils (Korstanje 2004):

1. *Silica phytoliths* of the fodder that individuals have consumed — generally grasses of the

nearby area, but also *chaff* from cultivars (for example maize) or remains of food for human consumption, mainly when there are small animals kept near the houses.

2. *Spherulites* are a distinctive element characteristic of large herbivorous excrement. The presence of spherulites indicates guano, but its absence does not indicate guano absence, since they are very fragile and the quantity produced by excrement is very low.
3. *Calcium oxalates*, unstable and often poorly preserved, with a composition is similar to spherulites, survive in similar micro-environments. In camelidae pellets they are usually large (c. 20 microns).
4. *Cellulose rings* are present very frequently in guano. We do not know by which processes they are preserved, but perhaps they are an element that the animal cannot digest completely.
5. Silica algae are present in the guano from water drunk by the animal.
6. *Starches* of the fodder that individuals have consumed from cultivars (for example, maize) or remains of food for human consumption, mainly when there are small animals kept near the houses.
7. If the concentrations of P and O.M. are high compared to the lowest value, it is interpreted as the result of a *shepherd's activity*. Presence of spherulites indicates the space was used as a corral.
8. One does not expect to find *micro-charcoal* in guano (but it might be incorporated during feeding, for example if the animals feed in a field that was previously burnt).

As we see, except for micro-charcoal, all the microfossils can be found in guano, the spherulites being the only material that defines it exclusively. On the other hand, from the soil perspective, corrals are clearly indicated only by the high P and O.M. concentrations. Nevertheless, if the corrals were reused as agricultural fields as ethnography frequently shows (Korstanje 2005), the parameters O.M. and of P should be less.

Expected associations in domestic structures

In residential areas, the microfossil combination can be arranged in many ways according to the activities studied in archaeological and ethnographic cases (Barba 1990; Manzanilla 1997; Korstanje 2005). For this reason, microfossil evidence should not be considered independently from the structural and artefactual archaeological information.

1. Combination of high frequencies of silica phytoliths, starches, pollen, micro-charcoal and high values of O.M.: *kitchen and food preparation area.*
   1.1 Silica phytoliths should be of any of the known crops of the region. In our case it is possible to differentiate parts from maize, Fabaceae (beans) and Cucurbitaceaehttp://www.worldlingo.com/wl/msoffice11?service=WorldLingo_ES-EN&lcidFrom=3082&lcidTo=1033&lcidUI=3082 - _ftn1#_ftn1. These three crops were most frequently cultivated in north-west Argentinian valleys (for a complete characterisation of Andean useful plant silica phytoliths and starch granules, see Korstanje and Babot 2007).
   1.2 The taxonomic identification of pollen is very important if the regional pollen rain is controlled.
   1.3 If the foods processed were mainly tubers, the abundance of silica phytoliths might decrease steeply, but starches should increase.
   1.4 Food preparation processes such as heating and grinding may be observed from starch granule alterations (Babot 2003).
2. Combination of cellulose rings, silica phytoliths, pollen and low O.M.: *fibre processing.*
3. Micro-charcoal and spherulites: *use of guano for combustion.*
   1.1 The spherulites appear agglutinated due to heat action (Korstanje 2004). If spherulites are present, the rest of the microfossil set associated with guano should also be present (see above).
4. Presence of abundant silica algae: *use of water in some activity* (which might include the cleaning and consolidation of the patio floors with water).
5. If the concentrations of P are high compared to the lowest value, *a domestic use is considered.* This may or may not be associated with higher O.M. If the presence of spherulites is not stated, a residential domestic locus is assumed.

Results: control sample

The control sample was taken from an area where the soil was thought not to have been used for agricultural activities, since it was away from the

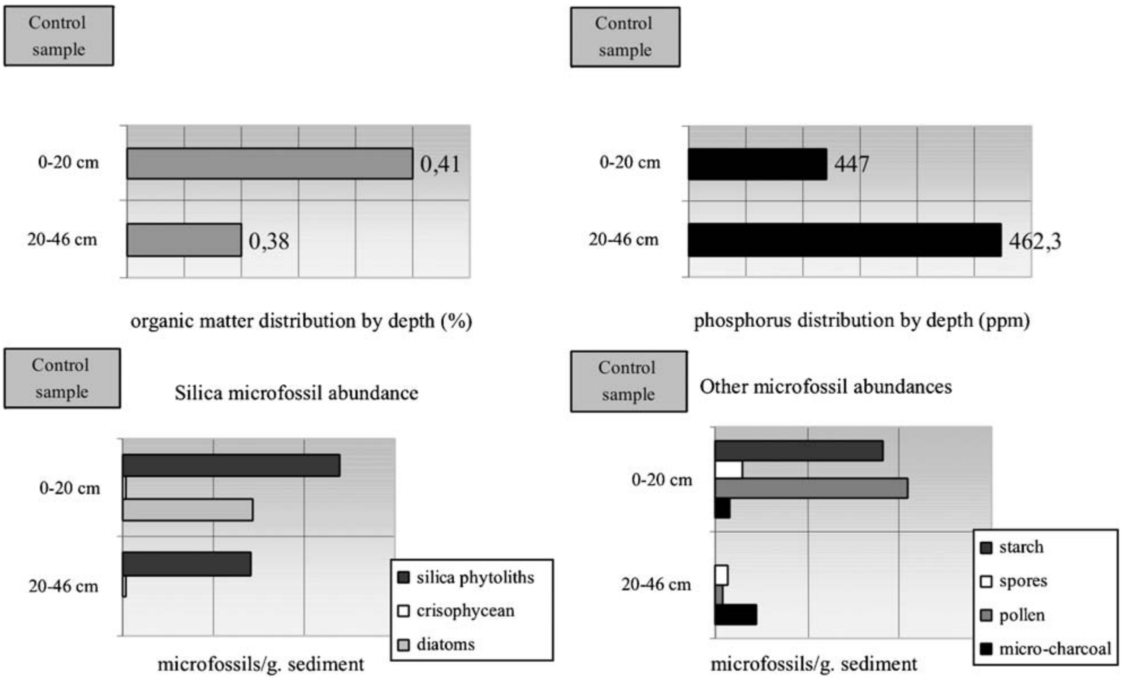


Figure 6 Control sample graphs

sites and there were no structures around it or related to it. All the graphs in this section are based on the results presented in Tables 1 and 2.

Microfossil description (Fig. 6)

The upper level (0–20 cm) showed a high presence of Pooids, followed by Arundinoids and what we have called '*cf.* Arecaceae' (globular equinates). These silica phytoliths are very similar to those from the leaves of palms, but they are smaller and the prickles are smoother (Korstanje and Cuenya 2008, table 3). We cannot think of a possible ancient environment for the growth of palms in the area, nor can they be explained by wind transportation from nearby areas. Other vegetal taxa were explored, but the identity of these phytolith types remains unclear (Cummings and Yost 2008). Panicoids were present as a very low proportion. Regarding morphotypes, estrobiololites were predominant, followed by micro-prismatolites, globulolites and halteriolites in almost the same ratios. In contrast, in the following level (20–46 cm), the almost absolute predominance of Pooids is remarkable, and was associated with the high occurrence of estrobiololites and micro-prismatolites.

Other microfossils showed variable patterns. For example, diatoms were abundant in the superficial level, together with Poaceae pollen and some Poaceae starch granules.

Interpretation

The greater abundance of microfossils in the superficial level, and their decline with depth, corresponds with the parameters expected for a non-anthropogenic sample. The presence of panicoids and maize (*Zea mays*) starches in the upper level of this sector of open field is significant. A probable reason for the presence of Panicoid silica phytoliths is that today goats and cows graze here and in crop fields; thus, they might accumulate these sets in their dung pellets. The high abundance of diatoms in the superficial level is consistent with this idea.

Results: archaeological samples

All the graphs in this section are based on the results presented in Tables 1 and 2.

Morro Relincho

1. Example of soil use at a large isolated stone circle (Fig. 7a): STRUCTURE XVI: Test 2 × 0·50 m in the middle of the structure. Samples: 20–25 cm, 30–35 cm, 40–45 cm, 50–55 cm and 60–65 cm

Microfossil description (Fig. 8): The level at 20–25 cm depth showed a high proportion of Pooids, followed by Arundinoids and '*cf.* Arecaceae' in association with a small number of silica phytoliths. Predominant morphologies were estrobiololites followed by micro-prismatolites. Panicoids occurred in low concentrations. The level below this was very similar but showed a slight increase in the total number of silica phytoliths and the presence of probable 'fly eye shaped' starch, characteristic of Chenopodeaceae. At the level 40–45 cm, the same composition of forms and tribes was maintained but the total number of specimens increased dramatically.

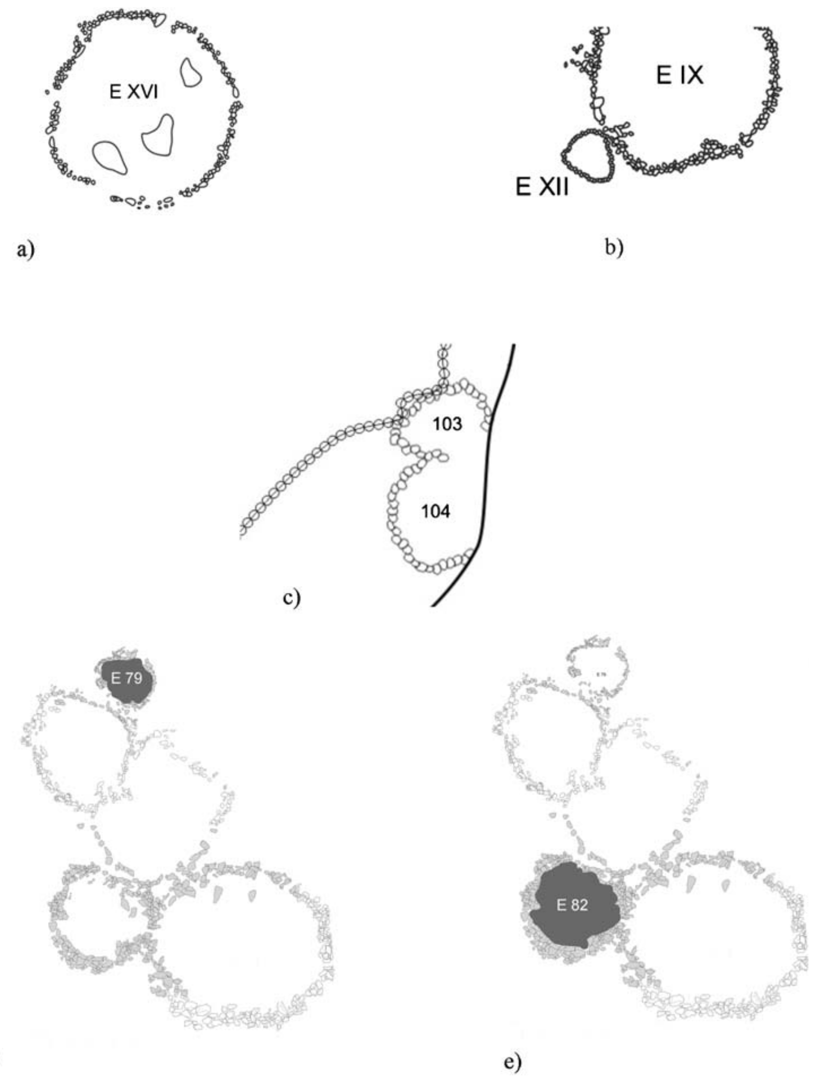


Figure 7 **Architectural plan of the studied structures at each site. a. Morro Relincho, structure XVI; b. Morro Relincho, structure XII; c. El Alto El Bolsón, structure 104; d. El Alto El Bolsón, structure 79; e. El Alto El Bolsón, structure 83**

Panicoids also increased at this interval. In subsequent levels the total values decreased again, and forms and tribes varied down to practically only estrobiololites and Pooids.

Regarding the rest of the microfossils, the sample was varied and interesting. The level at 40–45 cm, which is the one with more silica phytoliths, contained cellulose rings and starch granules. The next two levels had abundant micro-charcoal. Pollen was abundant in every level. Diatoms were absent in the bottom two levels that were damp during excavation (but with no evidence of rain or irrigation) (Fig. 9).

Interpretation: At 40–45 and 50–55 cm depths, maize remains indicate increasing land-use as shown by the high concentration of Panicoids, and perhaps quinoa. Silica phytoliths of ulluco (*Ullucus tuberosum*) may be present but more detailed analysis is needed to verify this. Cellulose rings might be part of this or another process that we still cannot explain. These data agree with the strong loss of organic matter in these levels.

2. Example of soil use at a small stone circle associated with a larger circle (Fig. 7b): STRUCTURE XII: Archaeological excavations (2 × 2 m squares). We describe here only the sector A2C profile: Samples: 0–20 cm, 20–50 cm and 50–70 cm

Microfossil description (Fig. 10): The first two levels show a similar presence of silica phytoliths, which is different to other samples previously analysed, where they decreased from the second level down. The distribution of associated forms and tribes is also similar within the sample and to those

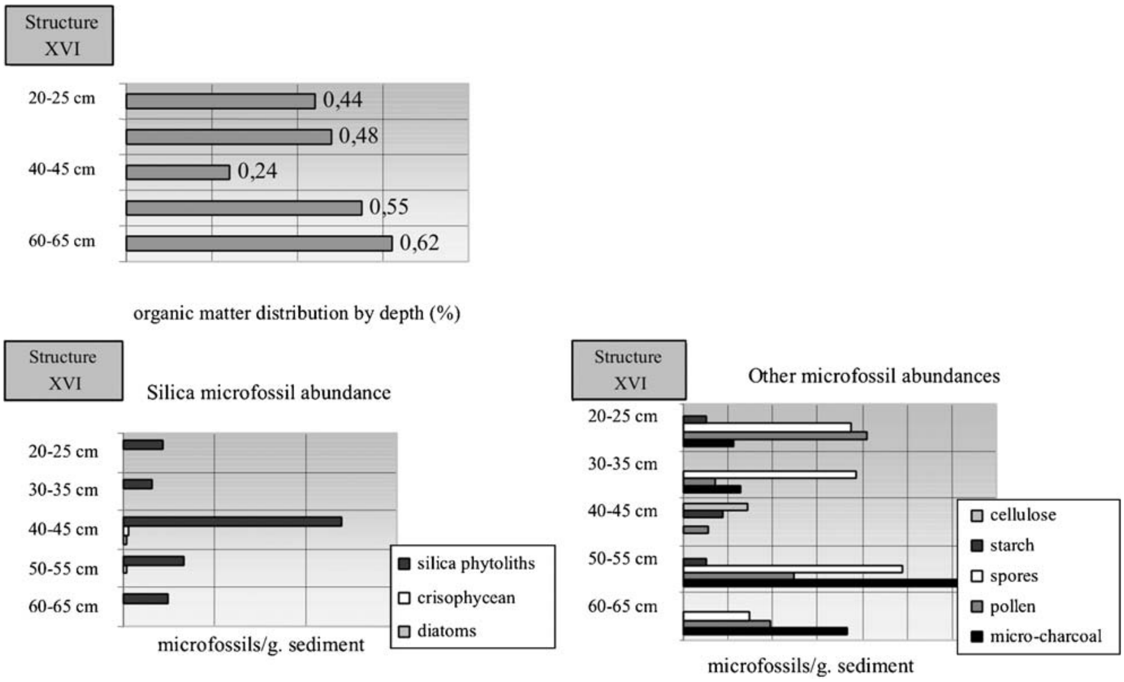
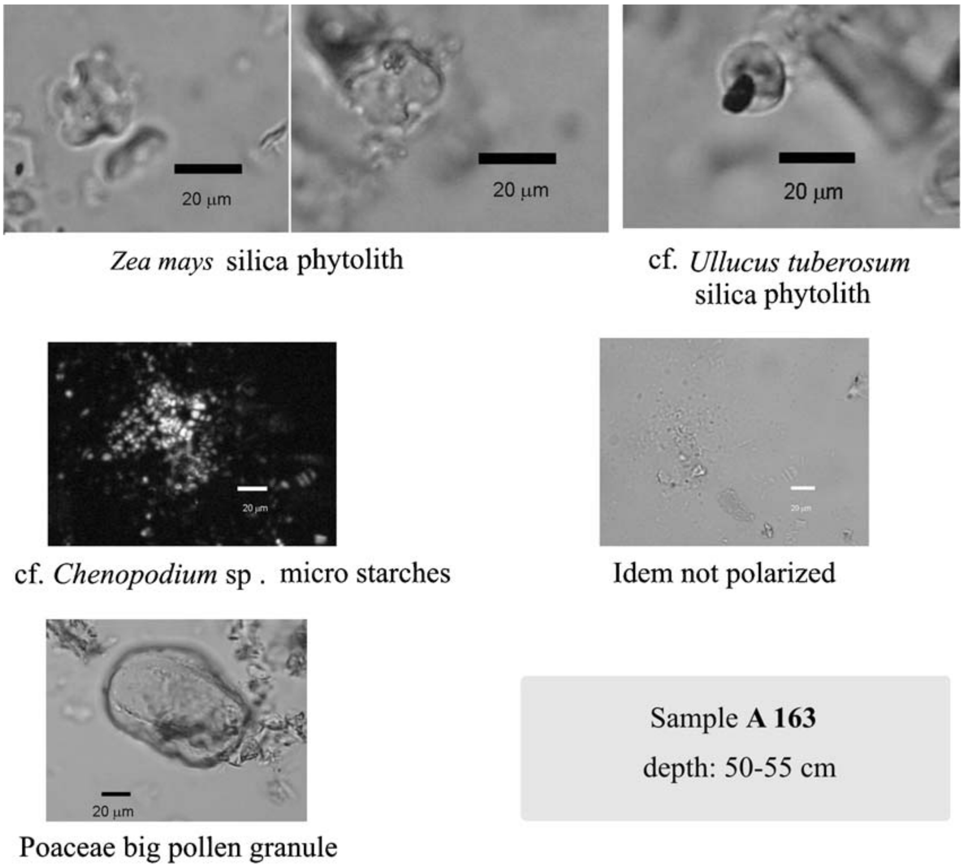


Figure 8 Morro Relincho's Structure XVI graphs

already described. In both levels Panicoids are scarce but increase slightly in the second level. The scarcity of silica phytoliths at the deeper level (50–70 cm) is understandable since Panicoids increase. By contrast, diatoms and calcium oxalates are highly abundant.



Zea mays silica phytolith

cf. *Ullucus tuberosum* silica phytolith

cf. *Chenopodium* sp . micro starches

Idem not polarized

Poaceae big pollen granule

Sample **A 163**
depth: 50-55 cm

Figure 9 Microfossil assemblage at Structure XVI

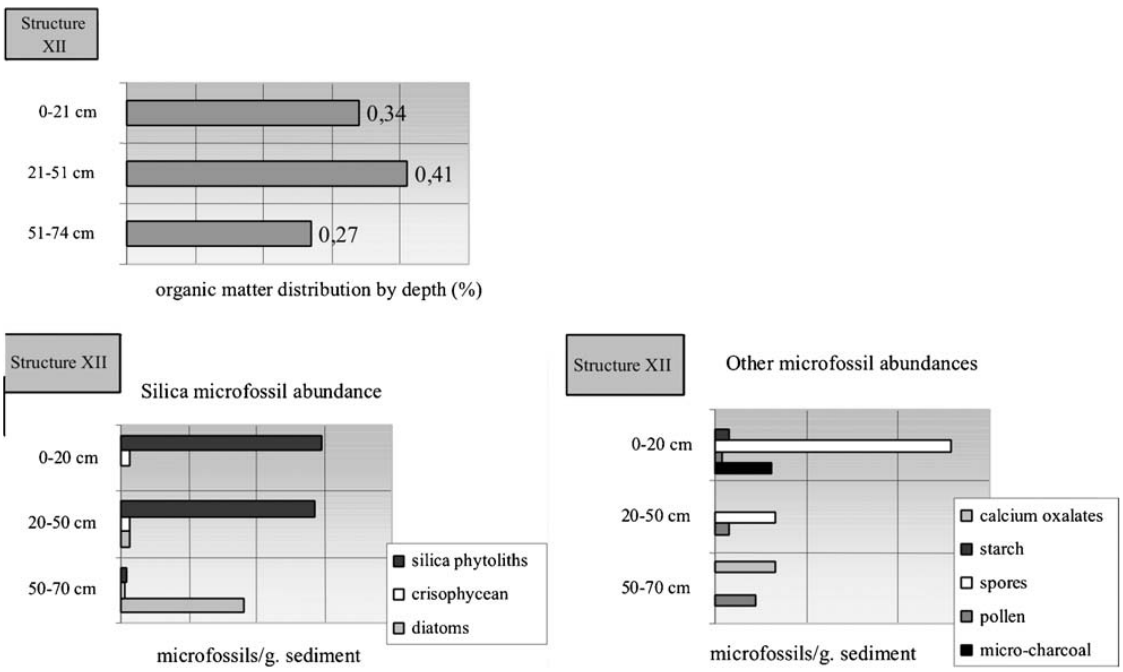


Figure 10 Morro Relincho's Structure XII graphs

Interpretation: From an architectural point of view, this small structure is not suitable for agriculture, nor do the values of organic matter and microfossils indicate a production horizon. On the other hand, a stone 'sickle' was found in the level at 20–50 cm, which is interpreted as an activity area due to the greater presence and variety of microfossils. The high abundance of spores in these two levels is abnormal compared to the other samples, and may indicate decomposition of organic matter. Then again, based on the archaeological findings, the almost total absence of silica phytoliths and large quantity of diatoms associated with calcium oxalates at this level deserves greater attention. We think this indicates an activity that we do not yet understand, and we are conducting experiments to interpret this assemblage.

El Alto El Bolson

For this site, studied after Morro Relincho, the analysis included total phosphorus (P) in the general methodology for soil study. P is a good geo-indicator of human occupation and activities because it is a stable element when fixed in soils.

3. Example of soil use at a large double circle ('canchones') (Fig. 7c). STRUCTURE 104: Test pit 50 × 50 cm. Samples: 5–15 cm, 15–30 cm and 30–45 cm

Microfossil description (Fig. 11): The samples had abundant silica phytoliths. The second level (15–30 cm), contained a considerable number. Panicoids were also present and we could already see a clear maize context while scanning during the microscope blind test. We noted an isolated case of chain phytoliths similar to *Canna* sp. types ('*achira*').

The range of morphotribes indicates the predominance of estrobiolites, followed by micro-prismatolites, globulolites and halteriolites. Starch granules, cellulose rings, grass pollen and micro-charcoal were present in the most superficial level. A diverse group of silica algae was also recorded. In the second level, by contrast, spherulites appeared and the other microfossils disappeared except for micro-charcoal. In the third level we found only abundant micro-charcoal and spores. A maize context is indicated by the silica phytolith types and the abundance and variability of silica algae, assumed to be the result of irrigation. Poaceae pollen also occurred. High organic matter content was recorded in both superior levels and decreased at the deepest level (Fig. 12).

Interpretation: The absolute abundance of silica phytoliths in this structure is greater than in the rest of the samples except for the residential areas, discussed later. We interpret the highest level as refuse activity or a patio for diverse activities but, being a superficial level, we think it is subject to current soil dynamics.

At the second level, a high concentration of Panicoids and spherulites indicate maize cultivation. Spherulites are associated with a soil fertilised with guano. A possible alternative explanation is a

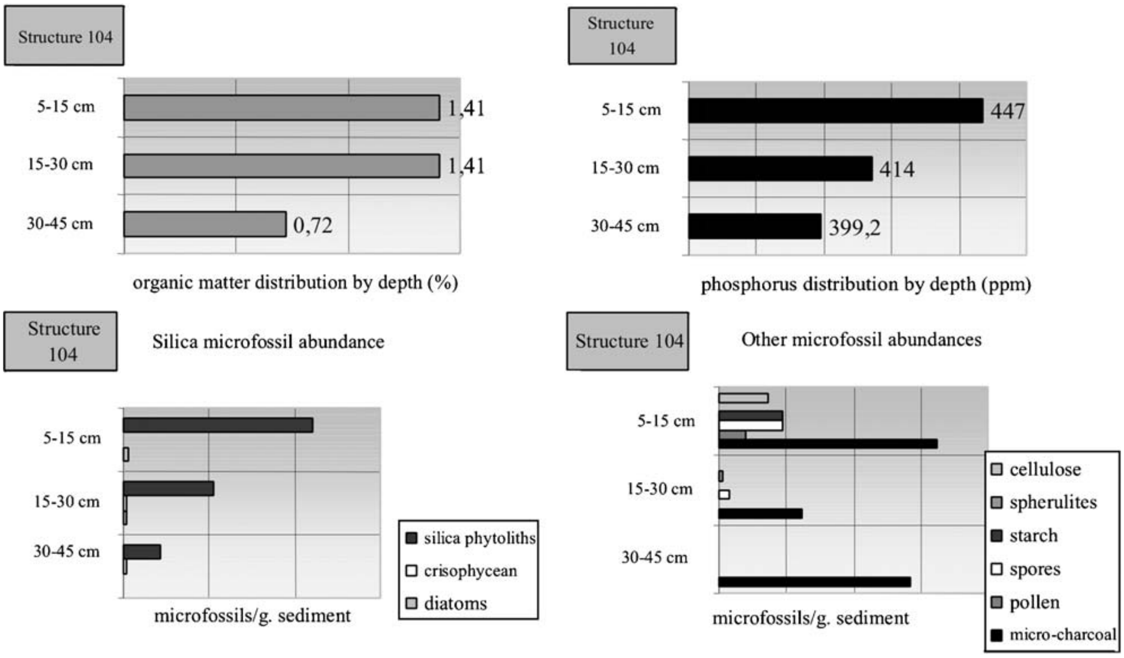


Figure 11 **El Alto El Bolsón's Structure 104 graphs**

corral rather than an agricultural field, if Panicoids are interpreted as indicators of animal feeding rather than cultivation. However, the latter does not seem appropriate due to the abundance of both items and the low values of phosphorus in the corral.

The lower level corresponds to an exhausted soil cultivated with maize and then burned. The organic matter and phosphorus content of the second and third levels is consistent with the microfossil data. In cultivated areas, the values of O.M. and P decrease whereas, in a cultivated but fertilised soil, they remain at acceptable levels.

4. Examples of soil use at associated stone circles (Fig. 7d). STRUCTURE 79: Test pit 0·50 × 0·50 cm. As for other structures considered domestic from the architecture, the test pit samples were taken from artificial levels separated by 10 cm. For microfossil analysis we only considered here the lower samples at 40–50 cm, 50–60 cm and 60–70 cm

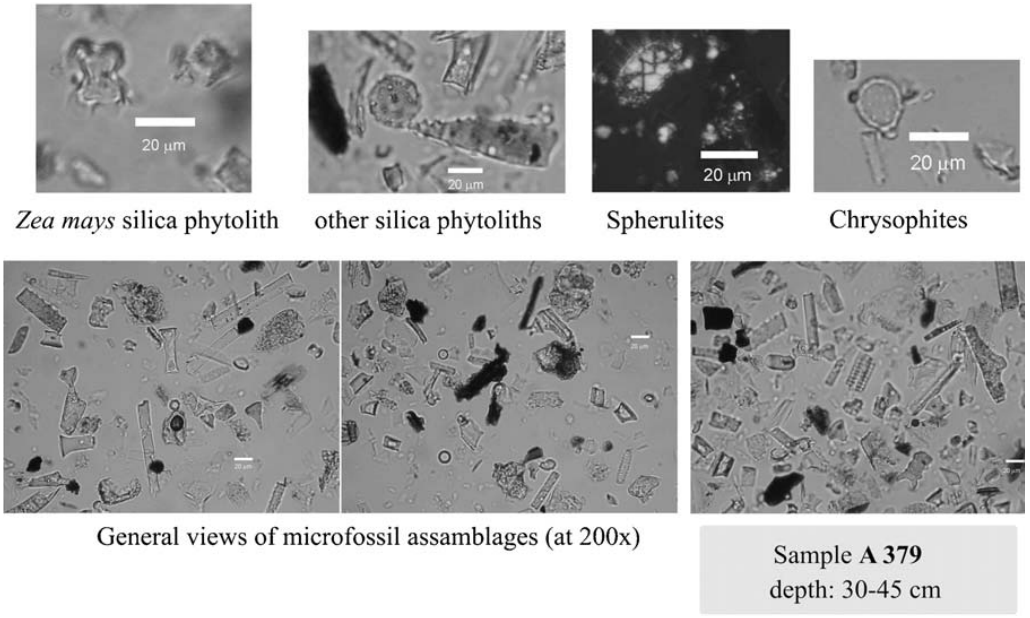


Figure 12 **Microfossil assemblage at Structure 104, El Alto El Bolsón**

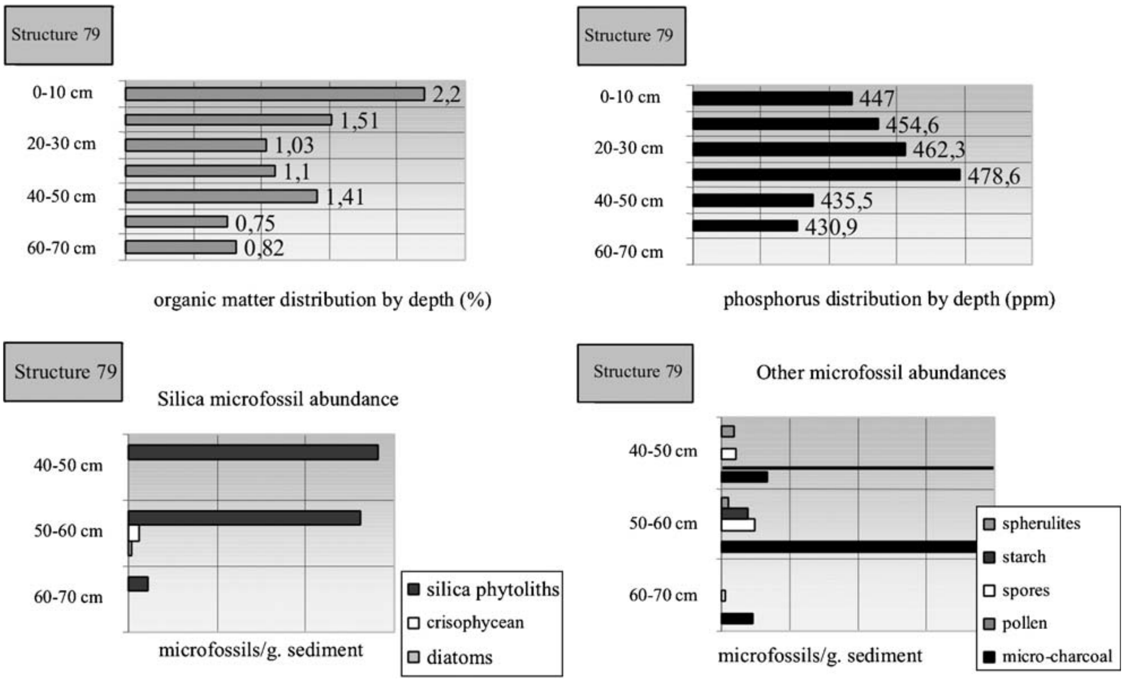


Figure 13 El Alto El Bolsón's Structure 79 graphs

Microfossil description (Fig. 13): As regards the silica phytoliths, the three samples were practically identical. There was a predominance of Pooids, followed by Arundinoids. The Panicoid presence was low, but they were present in all three levels. Regarding the morphotypes, there was a predominance of estrobiololites, followed by micro-prismatolites and then globulolites and halteriolites. The sample at 60–70 cm had fewer silica phytoliths than the other levels, but the values were high compared with the cultivation areas already analysed. In the level at 40–50 cm there were spherulites and 'fly eyes' starch grains corresponding to the Cheno-Ams association (*Chenopodium quinoa*, 'Quinoa', *Amaranthus caudatus*, 'Amaranth', and wild species). The level at 50–60 cm was the same, except that micro-charcoal was also incorporated. The pollen corresponded to Poaceae.

Interpretation: The occurrence of spherulites indicates guano but the architectonic morphology does not match an agricultural structure (where fertilisation with guano might have been practiced), and so we consider it to be a corral for herding small animals, leaning against the house area. Increasing organic matter at a level of 40–50 cm is consistent with this explanation. A high P concentration in the level at 30–40 cm also suggests a corral episode. The test pit excavated did not reach the floor at the lower levels (as in structures 82 and 83). We believe the surface exposed in this test pit corresponds to a later occupation; thus we cannot infer the activities conducted in the earlier occupation.

5. Examples of soil use at associated stone circles (Fig. 7e). STRUCTURE 82: Based on its architecture, this structure is assumed to be a domestic site. It was sampled at 5 cm intervals. The sample at 50–55 cm was lost during sample processing. SECTOR D4B. Samples: 30–35 cm, 45–50 cm, 55–60 cm, 60–65 cm (identified as a part of a 'floor') and 65–70 cm (also identified as a 'floor')

Microfossil description (Fig. 14): The five samples analysed were identical with each other and with the structure described above. There was a predominance of Pooids with far fewer Arundinoids (there was a slight increase of these in the level at 58–63 cm). Panicoid concentration was low but constant in the three lower levels (they increased slightly in the level at 58–63 cm).

Regarding morphotypes there as a predominance of estrobiololites, followed by micro-prismatolites with much lower quantities of globulolites and halteriolites.

Interpretation: Two segments of 'the floor' can be differentiated: on the one hand, the superficial cover, or the 'floor exposed at the time of abandonment', and, on the other hand, the floor formed by the frequent treading, compaction and accumulation of artefacts that we call the 'built floor'. Based on their pedologic and microfossil characteristics, the two are different.

Floor exposed at the time of abandonment: in the level at 58–63 cm, there was a large quantity of

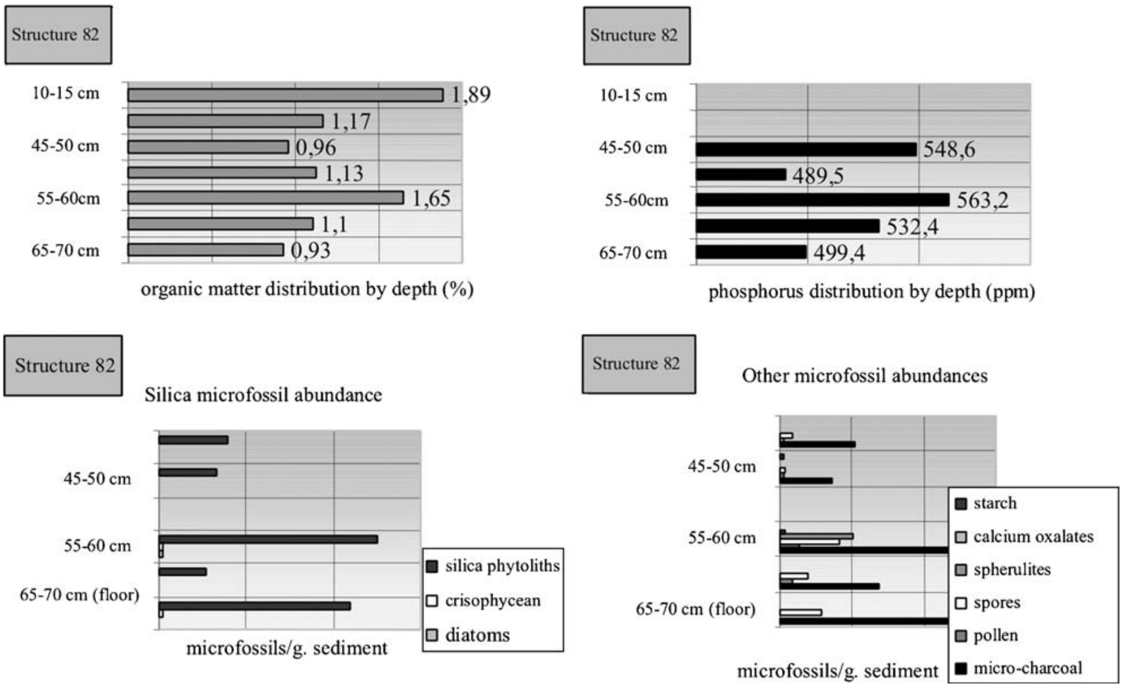


Figure 14 El Alto El Bolsón's Structure 82 graphs

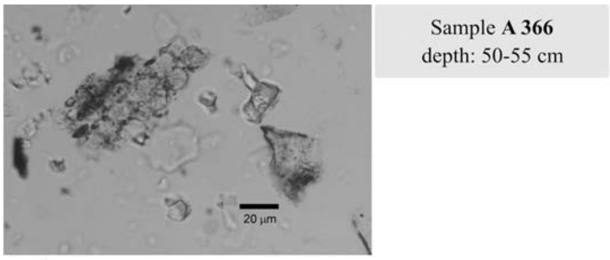
spherulites, some calcium oxalates, and micro-charcoal. Charcoal is the only element present in the following level of compacted floor. In addition, there is a considerable increase in silica phytoliths, phosphorus and organic matter. This is thought to be 'trash' produced by several activities and not removed by sweeping or compacted by treading.

Built floor: This corresponds to levels at 63–68 and 68–70 cm, both defined during the excavation by the horizontal position of the artefacts. Silica phytoliths decrease in the level at 63–68 cm and increase again in the next level where silica phytoliths correspond to Cucurbitaceae. Pollen of Poaceae is present, except in the floor level at 63-68 cm, where Chenopodeaceae pollen is more abundant (Fig. 15).

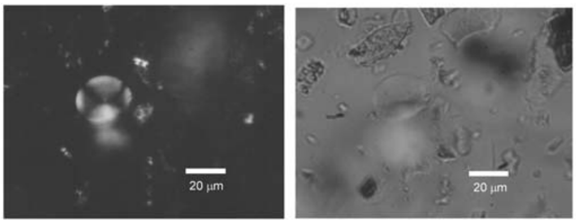
Sector D is located in a repaired area of the structure and we found starch with evidence of thermal alteration. We interpret it as a kitchen area where guano was used as fuel; the great abundance of micro-charcoal indicates fire events, and the diversity of food (maize, Cucurbitaceae and the Cheno-Ams association) is related to food preparation. This is the only structure that shows an increase of fine and argillaceous textures in the floor levels. This occupation has been dated to level 11 (90 cm) at 1210 ± 40 calibrated years BP (UGA# 9065, dated on bone).

Discussion

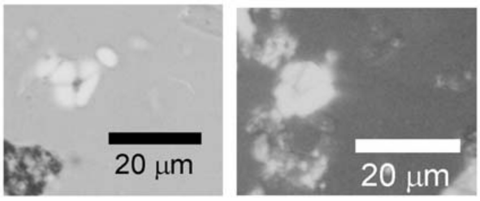
The case studies were chosen as examples of different possible combinations of soils — structure and chemistry — on the one hand, and microfossil assemblages on the other. It is important to stress that, based on only one of these components or sets of data, the inferences on ancient use and activities might be quite different.



cf. Canna edulis silica phytoliths



Solanum sp. starch granule under and without polarized light



Fabaceae starch granules   Tuber starch granule

Figure 15 Microfossil assemblage at Structure 82, El Alto El Bolsón

We defined the types of assemblage that could be expected and from different contexts and activities in order to make sense of a wide variety of data. For example, the association between low O.M. and high phytolith frequencies has been shown to be powerful enough to identify a layer of cultivated soil. Then, if some of the microfossils some are taxonomically identifiable (for example, maize phytoliths and starch, or tuber starch granules), we can enhance that interpretation by adding information on what was cultivated in that layer. In addition, if these cultivars were found in different but not widely separated layers we can suggest that there was crop alternation (one type of plant cropped, followed by a fallow period and then a different cultivar). Alternatively, if they occur in adjacent levels, we can infer crop rotation (two different cultivars in successive years). If spherulites appear, then we know they have been fertilising the fields (and, depending on O.M. proportions, know when the soil was abandoned). This was clearly the case in Structure XVI of Morro Relincho which, at a depth of at 40–45 cm, showed a strong decrease in O.M. and a considerable increase in silica phytoliths. Since this last change is reinforced by the presence of Panicoids, and the absence of diatoms, we can claim, at least, maize cultivation without irrigation.

In agricultural fields, therefore, we have found that the interpretation of microfossil assemblages and soil characteristics is relatively straightforward. Even if there are different ways of using the soil, the expected activities relating to cultivation are always demonstrated by the characteristics we considered. Therefore, the expectations set out in the introduction work very well.

Regarding household activities in residential areas, the problem becomes more complex, because the combinations of soil features and microfossils are broader (as the activities themselves might be broader). This makes our research more challenging since it tests the way we are able to explain microfossil evidence, even where we have no accurate taxonomic determinations. We think this can be improved conducting more experimentation on the residues expected from domestic activities, and we are currently working on this. Also, other strategies may be added when possible (such as micro-morphology and other chemical signatures). For example, in what we called the ‘floor exposed at the time of abandonment’ (Structure 82, sector D4B), what kind of activity can generate a combination of spherulites, calcium oxalates and micro-charcoal? Calcium oxalates have been reported in other research areas as residues of processing ‘tortillas’ (Barba and Ortiz 1992), for example, but we do not think that activity generates spherulites and micro-charcoal as well.

Finally, corrals are neatly defined by high concentrations of P, O.M. and the presence of spherulites, as shown in the 40–50 cm layer of Structure 79. For this feature, even if spherulites were absent (due to preservation problems), the final indication that the place was used for animal penning is the presence of an architectural enclosure, or other remains depending on the study area and habitats of the shepherd.

It is important to emphasise again that we do not arrive at these conclusions simply by mechanically ‘adding up’ the set of data. It is not a black box with inputs that result in unique outputs. It is a contextual matter. The same assemblage may not always imply the same activity. Other additional features can make a difference to our interpretation. For example, spherulites may indicate manure, fertiliser or fuel for cooking (which we determine depending on whether they are found in a residential area, a field, or an artefactual context). Similarly, maize phytoliths may imply cultivation or food processing, and are an occasional component of faeces.

Conclusions

There are some cases where, using this methodology, the dataset leads us to concrete explanations, as for example those concerning corrals and agricultural areas. Following this methodology, we have identified, in an earlier paper (Korstanje and Cuenya 2008), activities such as crop rotation and fertilisation, which were not previously reported in the literature on the basis of the archaeological micro-dataset. Also, we claim it is important that these data come from the field record itself rather than from inferences based on macro-remains in residential areas or ethnographic records and analogies. Therefore, the combined studies of soil and microfossil assemblages offer new possibilities for recognising and explaining activities in archaeology, directly from the sites.

This methodology is perfectly applicable in other environments or parts of the world but, of course, as with any scientific method, knowledge of all the factors and particularities of the soils, plants and people of these other places should be taken into account by the researchers. For agricultural questions, once the method is well established and calibrated for the environment and taphonomic processes involved, the combination of P and O.M. values with microfossil assemblages proved to be useful. The study of ancient soil use practices, such as fertilisation, crop rotation, irrigation, burning after harvest, and the type of cultivars, will be improved by the methods discussed in this paper.

Understanding and differentiating the signatures of fertilised fields from those of corrals or other structures will be essential for reconstructing human activities; therefore, the proper identification of microfossils and determination of soil markers (such as phosphorus concentration) will be crucial in future studies. Domestic records include a combination of microfossils and soil markers that reflect the multiple activities conducted inside the house. We propose to continue this type of research, especially using experimental archaeology to identify patterns of microfossil distribution, and hence activities.

References

Aschero, C. A. and Korstanje, M. A. 1996. Sobre figuraciones humanas, producción y símbolos. aspectos del arte rupestre del noroeste Argentino [About human figures, production and symbols. Aspects of north-western Argentinian rock art], pp.13–31 in *Aniversario del Museo Arqueológico 'Dr. Eduardo Casanova' 25*. Tilcara: Instituto Interdisciplinario Tilcara, Universidad de Buenos Aires.

Archer, S. and Bartoy, K. 2000. Plants in the plowzone? Archaeology and paleoethnobotany at Carter's Grove site 10, Williamsburg Virginia. Unpublished paper presented at the 65th SAA Annual Meeting, Philadelphia.

Babot, M. del P. 2003. Starch grain damage as an indicator of food processing, pp. 69–82 in Hart, D. and Wallis, L. (eds.), *Phytolith and starch research in the Australian-Pacific-Asian regions*. Canberra: Pandanus Books.

Balme, J. and Beck, W. 2002. Starch and charcoal: useful measures of activity areas in archaeological rock shelters. *Journal of Archaeological Science* **29**, 157–66.

Barba, L. 1990. *Radiografía de un Sitio Arqueológico* [Radiography of an Archaeological Site]. México, DF: Universidad Nacional Autónoma de México.

Barba, L. and Ortiz, A. 1992. Análisis químico de pisos de ocupación: un caso etnográfico en Tlaxcala, México [Chemical analysis of the occupation floors: an ethnographic case study in Tlaxcala, México]. Latin American Antiquity **3**, 63–82.

Bertoldi de Pomar, H. 1971. Ensayo de clasificación morfológica de los silicofitolitos [Essay on a phytolith morphological classification]. *Ameghiniana* **8**, 317–28.

Binford, M., Brenner, M. and Leyden, B. 1996. Paleoecology and Tiwanaku agroecosystems, pp. 89–108 in Kolata, A. (ed.), *Tiwanaku and its Hinterland. Archaeology and Paleoecology of an Andean Civilization*. Washington, DC: Smithsonian Institution Press.

Bouyoucos, G. J. 1936. Direction for making mechanical analysis of soils by the hydrometer method. *Soil Science* **42**, 225–30.

Bray, R. H. and Kurtz, L. T. 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science* **59**, 39–45.

Cabrera, A. and Willink, A.1980. *Biogeografía de América Latina* (Serie Biología Monografía 13). Washington, DC: Secretaría General de la Organización de los Estados Americanos.

Campos, S., del Puerto, L. and Inda, H. 2001. Opal phytolith analysis: its applications to the archaeobotanical record in the East of Uruguay, pp. 129–42 in Meunier, J. D. and Colin, F. (eds.), *Phytoliths: Applications in Earth Sciences and Human History*. Lisse: A. A. Balkema.

Canti, M. C. 1998. The micromorphological identification of faecal spherulites from archaeological and modern materials. *Journal of Archeological Science* **25**, 435–44.

Coil, J., Korstanje, M. A., Archer, S. and Hastorf, C. 2003. Laboratory goals and considerations for multiple microfossil extraction in archaeology. *Journal of Archaeological Science* **30**, 991–1008.

Cuenya, P. 2004. Determinaciones analíticas de sedimentos y suelos de El Bolsón [Soil and sediments analytical determinations]. Unpublished report for the Universidad Nacional de Tucumán, Argentina.

Cummings, L. S. 1992. Pollen and phytolith analysis at the Hutton-Pinkham site, eastern Colorado: a feasibility study. *Southwestern Lore* **58**, 19–25.

Cummings, L. S. and Yost, C. 2008. Regional distribution of globular echinates in North America: a call for collaboration, p. 13 in Osterrieth, M. (ed.), *Proceedings of the 7th International Meeting on Phytoliths Research and the 4th South American Meeting on Phytolith Research*. Mar del Plata: Universidad Nacional de Mar del Plata.

Echevehere, P. H. 1976. *Normas de Reconocimiento de Suelos* [Normative for Soil Recognition] (2nd edn., publication 152). Castelar: Secretaría de Agricultura y Ganadería, Instituto Nacional de Tecnología Agropecuaria, Departamento Suelos.

Fitzpatrick, E. A. 1996. *Introducción a la Ciencia de los Suelos* [Introduction to Soil Science]. México, DF: Trillas.

Flores, M. T. and Lozano, G. 1999. *Silicofosiles Altoandinos* [High Andean Silica Fossils]. Medellín: Colciencias-Banco Interamericano de Desarrollo, Universidad Nacional de Colombia, Medellín; Comité de Investigaciones Universidad de Antioquía, Universidad de Ponta Grossa.

Fujiwara, H. 1993. Research into the history of rice cultivation using plant opal analysis, pp. 147–60 in Pearsall, D. and Piperno, D. (eds.), *Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology* (MASCA Research Papers in Science and Archaeology 10). Philadelphia: University of Pennsylvania.

Gallegos del Trejo, A. 1997. *La Aptitud Agrícola de los Suelos* [Agricultural Aptitude of Soils]. México, DF: Trillas.

Irurzun, J. 1978. Contribución al conocimiento del clima de la Provincia de Catamarca [Contribution to climate understanding in the Province of Catamarca], pp. 43–81 in *Geografía de Catamarca. Sociedad Argentina de Estudios Geográficos* (Serie Especial 5). Buenos Aires: GAEA.

Juan-Treserras, J. 1997. *Procesado y Preparación de Alimentos Vegetales para Consumo Humano. Aportaciones del Estudio de Fitolitos, Almidones y Lípidos en Yacimientos Arqueológicos Prehistóricos y Protohistóricos del Cuadrante E.N. de la Península Ibérica* [Vegetal Food Processing and Preparation for Human Consumption. Contributions of Phytoliths, Starches and Lipids studies in Prehistoric and Protohistoric Archaeological Deposits of the Eastern Quadrant of the Iberian Peninsula]. Unpublished PhD thesis for the Universidad de Barcelona.

Kealhofer, L. and Piperno, D. 1994. Early agriculture in southeast Asia: phytolith evidence from the Bang Pakon Valley, Thailand. *Antiquity* **68**, 564–72.

Kealhofer, L., Torrence, R. and Fullagar, R. 1999. Integrating phytoliths within use-wear/residues studies of stone tools. *Journal of Archaeological Science* **26**, 527–46.

Korstanje, M. A. 2001. Andean phytolith reference collection. Unpublished report for the University of California at Berkeley.

Korstanje, M. A. 2004. Microfossils in camelid dung: taphonomical considerations for the archaeological study of agriculture and pastoralism, pp. 70–78 in O'Connor, T. (ed.), *Biosphere to Lithosphere: New Studies in Vertebrate Taphonomy*. Oxford: Oxbow Books.

Korstanje, M. A. 2005. La Organización del Trabajo en Torno a la Producción de Alimentos, en Sociedades Agropastoriles Formativas (Pcia. de Catamarca, Rep. Argentina) [The Organization of Labour towards Food Production, in Farming Societies of the Formative Period. (Province of Catamarca, Argentina)]. Unpublished PhD thesis for the Universidad Nacional de Tucumán, Argentina.

Korstanje, M. A. 2009. Microfósiles y agricultura prehispánica: primeros resultados de un análisis múltiple en el N.O.A. [Microfossils and pre-Hispanic agriculture: first results of multiple analysis in north-western Argentina], pp. 249–63 in Zucol, A. F., Osterrieth, M. and Brea, M. (eds.), *Fitolitos: Estado Actual de su Conocimiento en América del Sur* [Phytoliths: Current State of Knowledge in South America]. Mar del Plata: Universidad de Mar del Plata, Argentina.

Korstanje, M. A. and Babot, M. del P. 2007. Andean crop sphere: vegetal and faunal microfossil characterization, pp. 41–72 in Madella, M. and Zurro, D. (eds.), *Plants, People and Places: Recent Studies in Phytolithic Analysis* (Proceedings of the 4th International Meeting on Phytolith Research). Oxford: Oxbow Books.

Korstanje, M. A. and Cuenja, P. 2008. Arqueología de la agricultura: suelos y microfósiles en campos de cultivo del Valle del Bolsón, Catamarca, Argentina [Archaeology of agriculture: soils and microfossils in agricultural fields at the Valley of El Bolsón, Catamarca, Argentina], pp. 133–47 in Korstanje, M. A. and Babot, M. del P. (eds.), *Matices Interdisciplinarios en Estudios Fitolíticos y de otros Microfósiles* [Interdisciplinary Nuances in Phytoliths and other Microfossil Studies] (BAR International Series 1870). Oxford: British Archaeological Reports.

Labrador Moreno, J. 1996. *La Materia Orgánica en los Agrosistemas* [Organic Matter in Agro-systems]. Madrid: Publicaciones del Ministerio de Agricultura, Pesca y Alimentación.

Lentfer, C. 2002. Phytolith analysis of sediments from the Kundil's Sections at Kuk, Papua New Guinea, and evidence of early holocene banana cultivation. Unpublished paper presented at the 67th SAA Annual meeting. Denver, Colorado.

Madella, M, Alexandre, A. and Ball, T. 2005. International code for phytolith nomenclature 1·0. *Annals of Botany* **96**, 253–60.

Manzanilla, L. 1997. Indicadores arqueológicos de desastres: Mesoamérica, los Andes y otros casos [Archaeological indicators of disasters: Mesoamerica, the Andes and other cases], pp. 20–43 in García Acosta, V. (ed.), *Historia y Desastres en América Latina* 2 [History of Disasters in Latin America 2]. México, DF: Red de Estudios Sociales en la Prevención de Desastres en América Latina.

Mbida Mindzie, C., Doutrelepont, H., Vrydaghs, L., Sweennen, R., Sweenen, R., Beeckman, H., de Langhe, D. and de Maret, Y. P. 2001. First archaeological evidence of banana cultivation in central Africa during the third millennium before present. *Vegetation History and Archaeobotany* **10**, 1–6.

Miller, N. and Gleason, K. 1994. Fertilizer in the identification and analysis of cultivated soil, pp. 25–43 in Miller, N. and Gleason, K. (eds.), *The Archaeology of Garden and Field*. Pennsylvania: University of Pennsylvania Press.

Pearsall, D. 1978. Phytolith analysis of archaeological soils: evidence for maize cultivation in formative Ecuador. *Science* **199**, 177–78.

Pearsall, D. 1993. Contributions of phytolith analysis for reconstructing subsistence: examples from research in Ecuador, pp. 109–22 in Pearsall, D. and Piperno, D. (eds.), *Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology* (MASCA Research Papers in Science and Archaeology 10). Philadelphia: University of Pennsylvania.

Pearsall, D., Chandler-Ezell, K and Chandler-Ezell, A. 2004. Maize can still be identified using phytoliths: response to Rovner. *Journal of Archaeological Science* **31**, 1029–38.

Piperno, D. R. 1988. *Phytolith Analysis: An Archaeological and Geological Perspective*. San Diego: Academic Press.

Piperno, D. R. 1993. Phytolith and charcoal records from deep lake cores in the American tropics. pp. 59–71 in Pearsall, D. and Piperno, D. (eds.), *Current Research in Phytolith Analysis: Applications in Archaeology and Paleoecology* (MASCA Research Papers in Science and Archaeology 10). Philadelphia: University of Pennsylvania.

Porta Casanellas, J., López Acevedo Reguerín, M. and Roquero de Laburu, C. 1994. *Edafología para la Agricultura y el Medio Ambiente* [Edaphology for Agriculture and Environment]. Madrid: Mundi-Prensa.

Rosen, A. M. 1992. Phytoliths as indicators of ancient irrigation farming, pp. 281–87 in Anderson, P. (ed.), *Préhistoire de l'Agriculture: Nouvelles Approaches Expérimetales et Ethnographiques* (Monographie du CRA 6). Paris: Editions du CNRS.

Rosen, A. M. 2001. Phytolith evidence for agro-pastoral economies in the Scythin period of southern Kazakhstan, pp.183–98 in Meunier, J. D. and Colin, F. (eds.), *Phytoliths: Applications in Earth Sciences and Human History*. Lisse: A. A. Balkema.

Rosen, A. M. and Weiner, S. 1994. Identifying ancient irrigation: a new method using opaline phytoliths from emmer wheat. *Journal of Archaeological Science* **21**, 125–32.

Rovner, I. 1983. Plant opal phytolith analysis: major advances in archaeobotanical research. *Advances in Archaeological Method and Theory* **6**, 255–88.

Stoermer, E. and Smol, J. 1999. *The Diatoms. Applications for the Environmental and Earth Sciences*. Cambridge: Cambridge University Press.

Treacy, J. M. 1994. *Las Chacras de Coporaque. Andenería y Riego en el Valle del Colca* [Agricultural Fields in Coporaque. Andenes and Irrigation at the Colca Valley]. Lima: Instituto de Estudios Peruanos.

Valero Gutierrez, G.1992. *Intensificación Agrícola en Tierras de Secano*. [Agricultural Intensification in Non-irrigated Lands] (Trabajos del Colegio Andino 7). Cusco: Centro de Estudios Regionales Andinos 'Bartolomé de las Casas'.

Verdin, P, Berger, J.-F. and López Saez, J. 2001. Contribution of phytolith analysis to the understanding of historical agrosystems in the Rhône mid-valley (southern France), pp. 155–72 in Meunier, J. D. and Colin, F. (eds.), *Phytoliths: Applications in Earth Sciences and Human History*. Lisse: A. A. Balkema.

Walkley, A. and Black, I. A., 1934. An examination of the Degjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**, 29–38.

Authors Queries

Journal: **Environmental Archaeology**
Paper: **15104**
Title: **Ancient agriculture and domestic activities: a contextual approach studying silica phytoliths and other microfossils in soils**

Dear Author
During the preparation of your manuscript for publication, the questions listed below have arisen. Please attend to these matters and return this form with your proof. Many thanks for your assistance

Query Reference	Query	Remarks
1	Author: Navarro Garcia not in bibliography	
2	Author: Flores in biblio	
3	Author: Juan-Treserras in biblio	
4	Author: g. or g?	
5	Figures 1, 3, 5, 7, 9 and 12 are low quality, please supply a higher resolution version if possible.	