ARTICLES

Abstracts from the 6th International Meeting on Phytolith Research

Phytolith Analysis of *Chusquea ramosissima* Lindm. (Poaceae: Bambusoideae) and Associated Soils

Montti Lía, Fernández Honaine, Mariana; Osterrieth Margarita and Graciano Ribeiro, Dalva

In the subtropical forests of northeastern Argentina, the woody bamboo *Chusquea ramosissima* Lindm. constitutes an important component of the forest understory. This species is an aggresive colonizer that can inhibit the natural regeneration especially in open natural areas and gaps created by timber extraction. The area is characterized by deep red soils (Kandiudults). Phytolith study of the area will allow us to understand the dynamics of this species within forest for which the study of the phytolith production–deposition processes is necessary. The aim of this work is to analyze the phytolith assemblage produced by *Ch. ramosissima* and deposited on superficial soil horizons. Phytoliths from leaves, culm and roots of several individuals were extracted following a calcination technique. Cuts and anatomical observations of the organs were made by means of routine techniques. In order to identify the silica deposits, stain with aqueous colorant blue of methylene and borax were used. The first five cm of soil were sampled from places with different bamboo abundances. Phytolith assemblage of leaves is characterized by silicification of epidermic cells (bulliforms and long cells) and short shank, concave/rect ends dumbbells. In less proportion we observed stomatal complexes, microhairs bases, subepidermic elements and rectangular crenate phytoliths. In culms, the phytolith assemblage is characterized by rectangular smooth phytoliths, rectangular crenate phytoliths and rectangular phytoliths articulated with short cells. Other morphotypes observed are hooks and roundells. Rectangular phytoliths, possibly xylem elements, are the main morphologies in root. The results will be compared with the phytolith assemblage of the superficial horizons of the dominant soils of the area.

Silicification of Conifers in Relation to the Environment

Allan G. Sangster and Martin J. Hodson

Biomineralisation in the cell walls of the root, stem and leaf tissues of conifers was measured by gravimetric analysis or by energy dispersive x-ray microanalysis. Silicon predominates, but calcium and aluminium also are present. Quantitative comparisons indicate that silica deposition lacks homogeneity, varying widely between taxa and between individual root and leaf tissues. Silicon accumulation increase with leaf age and may reach maximum values in the tip region. While internal factors, especially cell type and tissue maturation, may be limiting to Si deposition, external factors including site (soil) characteristics also moderate deposition patterns within taxa.

At the individual plant level, abiotic criteria (e.g. pH), by influencing the release of adsorbed Si into the soil solution, can determine the quantity of soluble Si available for uptake, transport and ultimately tissue biomineralisation. Abiotic factors operating at the atmospheric interface with the aboveground biomass including temperature, light, humidity, wind velocity and others, affect Si transport by modification of the rate of transpiration. However, more experimental evidence of the impact of these environmental stresses on phytolith formation *per se* is required.

At the ecosystem level, conifer forest communities can be severely reduced or even eliminated by climatic impacts, representing the most severe limitation to phytolith formation. Reduction of Si deposition may result from defoliation caused by abiotic stresses including hurricanes, ice storms, fire, drought and others and also from biotic stresses such as competition, herbivory and insect/pathogen outbreaks. Often, these impacts are localised; whereas, widespread atmospheric trends such as El Niño/Southern Oscillation variations and global warming may affect the silica biocycle, including phytolith formation, over entire biomes.

Differenciating Banana Phytoliths. First Outlooks

T. Ball, L. Vrydaghs, I. Van Den Hauwe, J. Manwaring and E. De Langhe

Recent reports indicate that phytoliths may provide direct archaeological evidence of banana cultivation and domestication. However, archaeologists may, in many places, recover phytoliths generated by banana plants with quite different historical backgrounds.

The Eumusa and Australimusa sections of the genus *Musa* were involved in banana domestication. The Australimusa domesticates are confined to an area stretching from extreme eastern Indonesia to the Pacific. The first Eumusa domesticates stemmed from *Musa acuminata* subsp. *banksii* in or around Papua New Guinea, leading to the generation of the first "edible" AA banana. Later, a combination of intra- and interspecific hybridization, polyploidisation and somatic mutations generated a wide range of cultivars. This diversity is composed by genome-groups commonly marked as edible AA, AAA, AAB, ABB, and BBB, with "A" reflecting the "*acuminata*" genome and "B" the "*balbisiana*" genome. This complex situation calls for a systematic morphotypic and morphometric analysis of phytoliths from the different genome-groups. To this end, the following sequential research strategy has been adopted:

(1) to detect any possible difference between phytoliths of the species *Musa acuminata* and *M. balbisiana*;

(2) to assess the effect on phytoliths of domestication;

(3) to appraise the effect on phytoliths of polyploidisation and hybridization;

(4) to detect any difference between phytoliths of the Eumusa versus the Australimusa section.

The current results suggest that:

(1) *Musa acuminata* and *M. balbisiana* phytoliths can only be differentiated on morphometric grounds;

(2) the domestication of the wild ancestors does not influence the phytolith's morphology and size;

(3) morphotypic analysis distinguishes the Eumusa diploids from the triploids ones;

(4) phytoliths deriving from the intra- and interspecific hybrids cannot be differentiated;

(5) the Australimusa phytoliths can be distinguish from those of the of the Eumusa diploid, but not systematically from the triploids as a whole.

Further Investigation into Phytoliths as Indicators of Irrigation: an Outline of on-going Crop Growing Experiments and their Implications for Phytolith Research

Emma Jenkins

Growing experiments involving local land races of wheat, barley and sorghum were set up at three agricultural research stations in Jordan in November 2005. Each crop was grown under four irrigation regimes: no irrigation, sub-optimal irrigation, optimal irrigation and super-optimal irrigation, and the levels of silica, nitrogen, phosphorous and potassium present in the soil were recorded. The aim of these experiments was to expand upon Rosen's existing research on phytoliths as indicators of irrigation and to gain an understanding of how other variables, such as soil type, can affect silica uptake and phytolith formation. The ultimate aim is to use this technique on phytolith assemblages from archaeological sites in Jordan in order to increase our knowledge of the development of irrigation and agriculture in this area.

Statistical Significance of Phytolith Assemblages

D. Zurro and M. Madella

This paper presents an analysis of phytolith assemblages from the point of view of their statistical significance. In an ideal world, whenever we study a population, we should collect the research data from the entire population. However, this is very often an impossible task and therefore what is normally selected is a proportion of the total population. In phytolith studies, a phytolith assemblage is a sub-population of phytoliths that contains–or at

least it is assumed it contains–information about the original population (phytolith input). It is quite obvious, from browsing the phytolith literature, that the "dimension" of a *significant* phytolith assemblage varies substantially, with authors counting 200, 250, 300, 500 or more phytoliths to determine a significant assemblage.

The aim of this study is to clearly determine when it is possible to consider the sampled phytolith assemblage as a significant representation of the phytolith population of a sample. In this light, a very heterogeneous group of sediment samples have been selected from vastly different contexts and includes both archaeological and non-archaeological deposits. This selection would like to represent the variety of deposits that could normally be the subject of phytolith investigation.

For each sample, a "species curve" has been calculated (but in the case of phytolith it would be better to call it a "typologies curve") along with basic statistic parameters to understand the significance of numerically different phytolith assemblages. Results are then discussed to understand the possibility of harmonizing the study of phytoliths from different depositional realities.

Is DNA Present in Siliceous Phytoliths?

Rivka Elbaum, Cathy Melamed-Bessudo, Noreen Tuross, Avraham A. Levy and Steve Weiner

DNA extracted from fossil plants could contribute to our understanding of the plants used at an archaeological site and help resolve open questions concerning the domestication and evolution of crops. The main obstacle for using ancient plant DNA widely is its lack of preservation in charred material, and usually poor preservation in plant materials. Here we tried to overcome this barrier by finding a niche where plant DNA is relatively protected. We hypothesized that DNA is trapped within phytoliths during their formation.

In order to address this question, we developed a method to dissolve phytoliths under conditions that do not degrade naked DNA, and showed that only a minimal amount of DNA was lost during the procedure. A hyper-sensitive PCR assay did not however detect any DNA in extracts of phytoliths from an unburned phytoliths-rich layer in Iron-Age sediments from Tel Dor, Israel. Measurements of the d13C composition of modern wheat and rice phytoliths suggested the presence of relatively large amounts of sugars or proteins in the water soluble fraction and lipids in the insoluble fraction. A different dissolution procedure was used to show that modern wheat phytoliths contain large quantities of glyco-conjugated proteins in a degraded state. These results indicate that DNA is absent or not abundant in a random assembly of fossil siliceous phytoliths. As the potential of this approach to investigating archaeobotanical issues is so great, we suggest that other modern and fossil samples of phytoliths be examined for preserved DNA.

Crops and Livestock in the Chalcolithic Site of Grar, Northern Negev, Israel

(4500-4300 BCE)

Ofir Katz, Ruth Shachack-Gross, Isaac Gilead and Pua Bar (Kutiel)

The Chalcolithic site of Grar is one of the oldest (4500-4300 BC) agricultural sites in southern Israel and among the largest sites of the period. This study is a report of the initial results obtained through examination of the minerals and microscopic remains, focusing on phytolith evidence for cereal crops and livestock exploitation. The study was carried out on one exposed section from the excavation that took place during the 1980s. The section was cleaned and bulk samples were collected as well as a few blocks for micromorphological examination. Control sediments (i.e., sediments that do not include archaeological artefacts) were collected around the site. Minerals were identified using Fourier Transform Infrared Spectroscopy, phytoliths were studied quantitatively and micromorphology was done following conventional procedures. Sediments from the site are significantly different from the control sediments. The latter are loessial sediments composed of quartz, clay and calcite, while sediments from the site also include the minerals opal, gypsum and dahllite, and evidence for burned clay. In addition, the absolute numbers of phytoliths in the site's sediments are more than 2 orders of magnitude higher than in the control sediments. Black thin lenses at the site stand out from other sediments in their high phytolith concentrations, presence of dung spherulites and wood charcoal and wood ash. These are

interpreted as burned livestock dung and suggest that dung was used as fuel. A systematic examination of the phytoliths from the site sediments showed that most phytoliths were from herbaceous plants, mainly grasses. Wheat and barley were probably more common than others. In addition, a preliminary study of silica-skeleton sizes indicates the possibility that wheat and barley had more available water than present natural conditions. This analysis is still ongoing in order to determine whether wheat and barley fields were managed by the Chalcolithic population at Grar.

Plant Food Production and Transformation in Mediterranean France during the Neolithic Period. The Phytolith Records on Grindstones.

Pascal Verdin

During the Neolithic period, many changes happened in human societies. One of them is the relation to plants, especially domestication, but also changes in diet and plant food choices were very important. In two neighboring sites from France dating from the Neolithic period, situated in the French Catalogne, grindstones were found and their phytolith residues analysed in seven samples. In the first site located in Trouillas and dating from the beginning of the Vth millennium BC of the Peri-Cardial culture (Old Neolithic), two grindstones revealed phytolith assemblages related to the probable treatment of a wide range of wild plants. The ratio Dicots/ Grasses phytoliths showed high values as well as the ratio leaves–straw/glumes–short cells phytoliths among the Poaceae. This probably shows that there was no developed cereal or domesticated crop production. In the second site, situated in Montesquieu (8 km from Trouillas) and dating from the beginning of the IVth millennium BC of the Montbolo culture (Mid Neolithic), five grindstones revealed completely different assemblages. These assemblages are dominated by Poaceae and their short cells phytolith fraction, and thus show a specialized production of cereals or wild cultivated Poaceae, and Leguminoseae. These results form another argument, along with the archaeological ones, to consider that the end of the Vth millennium BC in the Mediterranean region is the crucial period of the development of agriculture based on cereals, or at least at the beginning, based on wild cultivated Poaceae.

Multi-proxy Archaeobotanical Analysis of Neolithic Dung from La Grande Rivoire (Isère, French Alps)

Claire Delhon, Lucie Martin, and Stéphanie Thiébault

The Rock shelter of *La Grande Rivoire* is located in the southern French Alps, in the Vercors massif, at 580 m a.s.l. Its excavation, directed by P-Y. Nicod (Department of Anthropology, University of Geneva, Switzerland) and R. Picavet (CNRS-UMR 6636, Grenoble, France), has allowed the description of thick layers of fossil dung accumulated during the middle to final Neolithic.

The analysis of phytoliths and plant macro-remains (charcoal, seeds, fruits …) from these layers gives information not only on the composition of the surrounding vegetation cover, but also on husbandry practices.

As it is obvious that plants do not only reflect the surrounding vegetation, the multi-proxy approach is a way to understand whether each taxon has been spontaneously browsed by livestock, or if it has been voluntarily brought into the shelter by shepherds as bedding, fodder or alimentary supplement for the animals.

Peculiar botanical spectra show that the gathering of plants was an important activity for the neolithic shepherds of *La Grande Rivoire*. According to the high proportions of dicotyledon phytoliths, it seems that livestock mainly fed on tree branches and leaves, at least when kept in the shelter. Ash (*Fraxinus excelsior*) probably dominated the diet as is shown by unusual high frequencies of this species in the anthracological diagram from the Neolithic. Further, the presence of macro-remains from other taxa, such as fir (*Abies alba*) or mistletoe (*Viscum album*), suggests their use for special cares.

Plough Land, Garden and Grassland: The Phytolith Analysis of the Brussels' Early Medieval Soils

Vrydaghs, L.; Devos, Y. and Degraeve, A.

Historians established that during the early medieval period Northwestern temperate European agriculture was marked by a strengthening of its practices (Duby 1977;

Mazoyer & Roudart 2002). According to their views, it involved technological innovations such as deep ploughing, manure, crop rotation and animal husbandry. Based on the historical sources, the dates of this 'agricultural revolution' vary with the geographical region under consideration. For the 'Duchy of Brabant' (Belgium), these changes seem to occur during the second half of the 11th century till the end of the 13th century (Mazoyer & Roudart 2002). Unfortunately, almost no archaeological evidences are available to support these views.

In connection with the issue of building permits, the Direction of Monuments and Sites of the Brussels Capital Region conducts a systematic archaeological follow-up. One of the major features of these rescue excavations is the systematic occurrence of homogenous dark horizons. Palaeoenvironmental research, including archaeopedology and archaeobotany, led to their identification as former fields, gardens and grassland (Devos *et al.* accepted).

Phytolith analyses are part of the archaeobotanical approach. They have been conducted for bulk samples and soil thin sections (Vrydaghs *et al.* in press). The phytoliths of the identified fields display generally the same range of evidences: comparable crop spectra (*Triticum* sp. and/or *Hordeum* sp. and *Avena* sp.) and phytolith distribution in the soil ('random').

Although the pH conditions favour the preservation of the phytoliths, the surface of the phytoliths associated to the crop spectra is characterised by the occurrence of 'moon-craters.' These evidences coincide with the archaeopedological identification of plough land and the use of manure. However, the present contribution intends to discuss these phytolith characteristics in the light of those noted for garden and grassland, in order to establish if they might be viewed as direct markers of former intense agricultural practices.

The Identification of Domestic Activities and their Spatial Distribution in Ain Abu Nekheileh (Wadi Rum, Southern Jordan) through the Study of Phytoliths and Spherulites

R. M. Albert, D. O. Henry and M. Portillo

The Pre-Pottery Neolithic B site of Ayn Ab_ Nukhayla (Wadi Rum, Jordan) contains large structural installations defined by rock walls (loci) that are interconnected and differ in design and construction. One of the questions that arose from their study was how to identify possible herding and agricultural activities. The combined study of phytoliths and spherulites identified from different loci are presented here.

The results of a detailed study which involves quantitative, morphologic and morphometric analyses of phytoliths identified in different structural installations of the site- loci are discussed here. Cereal processing is evidenced by the concentration of the inflorescent parts of festucoid grass phytoliths associated with the presence of handstones and querns in specific areas of the site. These loci appear to have been specific areas in which domestic activities have been undertaken, including the grinding of cereals and the preparation of other plant resources. In contrast, other areas such as Locus 20, seem to have been used as a pen for herding animals (ship/goat).

The results obtained though this study provide new insights on plant uses and the emergence of food production in Early Neolithic communities in the Levant.

Archaeobotanical Remains from the Bronze Age Facies of El Mirador Cave, Sierra de Atapuerca, Spain

Cabanes, D.; Burjachs, F.; Allue, E.; Expósito, I.; Rodríguez, A.; Euba, I.; Vergès, J. M.

El Mirador site (Sierra de Atapuerca) presents a Holocene sequence formed by burnt animal dung product of pastoral activities during the Bronze Age and the Neolithic period. Due to the high sediment variation in the profile, *facies* descriptions have been used to guide archaeologists in their work. We propose here a combined study of phytoliths, pollen, charcoal and seeds to describe these *facies* and, in this way, to improve our knowledge on the genesis and diagenesis of the *facies* level corresponding to the Bronze Age period.

The results show that 70% of the phytoliths identified in the Bronze Age level correspond to grasses, mainly festucoids. The phytolith morphological study indicates that leaves and stems were the major source of these plants.

Around 10% of the total phytoliths identified come from the wood and bark, whereas dicot leaves are really scarce. Dentritic morphologies, probably from cultivated cereals, are more abundant in the archaeological samples than in the control samples. The palinological results indicate that the arboreal cover is low, with *Pinus* sp. as the most abundant taxa. Deciduous *Quercus*, *Quercus-ilex-coccifera* type and cf. *Juniperus* are present as well. Riverside trees are identified too, as well as some shrubby vegetation dominated by *Cistaceae*, *Erica* and *Buxus*. The rest of the pollen record is dominated by Poaceae and Asteraceae, with an anthropic artifact of Cerealia.

The most abundant taxon identified by the carpology analysis is the *Triticum asestivum/durum*, followed by *T. dicoccum* and *Hordeum vulgare nudum*. Leguminosae and other fruits such as blackberries and blackthorn were also noted. Charcoal analysis has identified mainly deciduous and evergreen *Quercus*, but there are also other taxa like Pomoideae, *Sambucus*, *Fraxinus*, *Corylus avellana* and *Pinus*.

The archaeobotanical residues from El Mirador Cave indicate an anthropic origin related to human activities both, inside and outside the cave. The human activities carried out outside the cave are related to cropping and livestock, which are the basic exploited resources. The landscape during this period might be a mosaic of different biota (riverside, mountain, etc). The activities inside the cave are related mainly to animal enclosure, combustion structures and plant processing.

Phytolith Study of an Archaeological Site: Gascón 1, Provincia de Buenos Aires,

República Argentina

Margarita Osterrieth, Fernando Oliva and Lumila Menéndez

The purpose of this study is to analyze phytoliths derived from human dental tartar of individuals belonging from the archaeological site, Gascón 1, which is located in the Ecotonal Pampean Area (EPA). In this sense, the primary goal of this study is to provide information about the vegetable diet of past populations in the area.

The phytoliths from human dental tartar will be compared to those of soil samples from pottery, as well as both the areas of the tombs corresponding to the abdomen and the periphery of the skeletons.

Gascon 1 is situated on the Middle-West Buenos Aires Province, on the margin of unnamed Lagoon, 37° 29' 30" (South latitude and 63° 13' 30" West longitude), located in the homonymous locality that belongs to the Partido of Adolfo Alsina. During the excavation, five burials have been recovered accompanied by mortuary goods such as metal objects and *Ovis aries* remains. This association allowed us to assign the site after the contact between Indigenous and Hispanic peoples (*ca.* S XVIII).

These first results are encouraging, given the sample fertility. Therefore, if done properly, the analysis of these plant remains can furnish reliable information about the paleoenvironment and mobility patterns and will be helpful in reconstructing dietary aspects of past human populations.

Pedostratigraphic Sequences of the Late Pleistocene and Holocene of the South of Sierra de San Luis. Phytoliths and Palaeonvironmental Inferences

Edgardo Strasser, Jorge Chiesa, Margarita Osterrieth and Ernesto Perino

The thorough study of the sedimentologic characteristics (biophysical-chemical and textural) and the characterization of quality and quantity of the silicophytoliths allowed the discrimination of the different pedologic horizons of the outcropping sediments in the south end of Sierra de San Luis. They are attributed to the Late Pleistocene and Holocene on the basis of radiocarbon datings and the presence of remains belonging to extinguished South American mammals characteristic of the Lujanense Mammalian Age, such as *Megatherium americanum*, Equus (*Ameripphus*) neogeous and *Scelidotherium Leptocephalum*, exhumed in the cross sections of this area of study. At a zonal scale, these deposits present variable thickness, generally between 6 and 12 meters, and they have loessial character with the intercalation of loessial strata, cineritious beds, palaeosoils, alluvial levels and the soil itself (Haplustol Entic and typical and Ustortentes). The high level of textural and structural homogeneity, color and scarce content of organic matter makes it difficult to deduce

stages of more palaeopedogenetic activity. Records carried out in the area and based on the textural analysis (detail of the succession including the horizon A), geobiochemicals (involving the relative contents in Ni, Cu, Pb and Zn) and content of phytoliths allows the identification of four levels, two of them characterized by developing in edaphic-climatic conditions of ustic humidity régime similar to present-day ones and linked to the Holocene; and two levels of aridic régime related to the Late Pleistocene. Preliminary results based on the phytolithic study indicate tenors that fluctuate in the 2% for the Aeolian sedimentary levels, where *Prismatolitas, Flabelolitas* and *Aculeolitas* predominate inside the so-called macrosilicophytoliths with varied states of preservation. In the fraction of thin to medium slime (less than 40 µm) the *estrobilolitas* and *doliolitas* predominate followed by *halteriolitas* in a smaller proportion, with a good state of preservation in general. In the palaeo-edaphic levels the quantity of silicophytoliths exceeds the 5% in relation to the total mineralogy. The macrosilicophytoliths present morpho-kinds similar in type and quantity to those in sedimentary levels although with a greater diversity within each morpgo-kind. Articulated forms are common as a conspicuous evidence of the environmental stability that accompanied the development of these palaeosoils. Within the microsilicophyliths there is an increment of *halteriolitas* in similar proportions to the *Estrobilolitas* and the *Doliolitas* that are in scarce proportion. On the basis of such results, the silicophyliths constitute themselves into a good indicator of the environmental conditions of the Late Pleistocene–Holocene that dominated in the southern area of Sierras Pampeanas and depressions around the highlands. Geomorphologically speaking, there are deposits that correspond to "high pampas" being peripheric to the mountain cordon; the former present varied shapes and sizes whereas the piedmont deposits have an important side continuity but with marked textural variations from facies of alluvial ranges to stratum of loess with palaeosoils. The records of the high pampas are produced in a climatic régime with greater availability of hydric resources; one of the evidences available in that sense is the greater thickness and evolution of the palaeosoils and alternated levels with diatomeas.

Ancient Agriculture and Domestic Activities in Northwestern Argentina: a Contextual Approach Studying Phytoliths and other Microfossil in Soils

Alejandra Korstanje & Patricia Cuenya

The agricultural studies in northwestern Argentina have been scarce since macro-vegetal remains are rarely preserved. Most of these studies have been about agricultural architectural facilities and localization, taking into account environmental and ethnographic sources. More recently, phytoliths' analysis have provided the tools to approach open air productive sites where macro remains are not conserved. Since then, one of us has been researching on the possibilities of the whole microfossils assemblages (phytoliths, diatoms, faunal spherulites, starch granules, etc.) as a tool for ancient agricultural sites and residential activities areas (Korstanje & Babot 2002). The "multiple extraction" method, consists of a laboratory and taphonomical controlled, low chemical protocol that permits the extraction of multiple different microfossils in the same slide (Coil et al. 2003, Korstanje 2003, 2004). The positive results of this methodology combined with soil analysis have proved to be an excellent approach for both problems, when considering one of the golden rules of archaeology: good context assemblages. Therefore, we take into account all the contextual information that architecture, artifacts and environment can bring to this problem.

As a result of our investigations, we have found for the first time in archaeological studies not only the vegetal species that were cultivated in ancient fields (dated in *ca.* 800 A.C.), but we were also able to distinguish some of the agricultural practices such as crop rotation and alternation, use of animal fertilizers, irrigation resources, and abandonment of the site (Korstanje & Cuenya 2005). From the point of view of residential activities areas, we have some interesting results but with some question marks or cautionary tales about the Phosphorus/Organic Matter ratios in relation to microfossil and artefactual record, that might be a subject of debate.

Food Residue, Phytoliths and Starches

Linda Scott Cummings

Examining food residue from fired clay cooking balls, ceramic sherds, and steatite sherds has yielded a variety of phytoliths and starches representing the various foods cooked. Sedentary Archaic people living at the Poverty Point site, approximately 3000 years ago, did not practice agriculture but had a rich and varied diet. Recovery of starches from Poverty Point Objects (PPOs) represents cooking lotus (*Nelumbo*) root. Earlier cooking clays from southern Texas exhibits a similar population of starches, also representing cooking lotus root. Examination of residue from a variety of ceramic sherds and steatite sherds from Archaic through Woodland occupations has yielded a variety of phytoliths and starches representing use of maize, as well as native plants.

Phytolith Evidence for Grass-dominated Vegetation in the Early Miocene of the Eastern Mediterranean

Strömberg, Caroline A. E. and Werdelin, Lars

Data from mammalian faunas suggest that grass-dominated vegetation spread across the Eastern Mediterranean region during the Late Miocene (<11 Ma). However, floral evidence for this ecological change is wanting. Grass macrofossils and pollen are extremely rare until the Pliocene. Furthermore, available palaeobotanical information can seldom be closely correlated with mammal fossils, making it difficult to rigorously test hypotheses about palaeoecological change.

To remedy this situation, we extracted and analyzed phytoliths from a large number of sediment samples collected at Eocene-Miocene faunal localities in Turkey, Greece, and Iran. Although biosilica recovery in these samples is often extremely poor and spotty, the material yielded phytolith assemblages and other biosilica from 25 localities ranging in age from late Early Miocene to Late Miocene (~20-7 Ma). An Eocene locality also produced a rich phytolith assemblage which served as a baseline comparison. Phytolith analysis demonstrated that the Eocene phytolith assemblage contains a mixture of grass phytoliths (silica short cells) interpreted as deriving from bambusoid grasses and phytoliths typically produced by woody and herbaceous dicotyledons and palms. In contrast, all Miocene phytolith assemblages are dominated by a diverse set of primarily pooid silica short cells; PACCAD morphotypes, such as chloridoid forms, contribute in varying, but minor abundances. Phytoliths from dicotyledons and palms are also present, but have become rare by the Late Miocene (9-7 Ma). These data indicate that open-habitat, C3 grasses formed a vital part of ecosystems in Turkey >7 Myr before ungulates with typical grazing morphologies occupied the region.

Comparative Study of Modern Phytolith Data from Africa: a Synthesis to Interpret Pliocene Samples from the Ethiopian Rift

Doris Barboni, Laurent Bremond and Raymonde Bonnefille

Reconstructing past vegetation especially past tree cover density at early hominid sites in Africa is an important focus of paleoenvironmental studies because theories imply the influence of environment on human evolution. At paleo-hominid sites where pollen grains are poorly preserved, phytolith assemblages may be used to reconstruct some aspects of the vegetation. Because of redundancy and multiplicity in the production of phytoliths, and because of selective dissolution of phytoliths with large specific surface area, it is important to assess the potentials and limitations for phytolith assemblages to characterize vegetation. In this study, we considered phytolith assemblages restricted to 12 types, found most common in modern soils. We aimed 1) to test how well limited phytolith assemblages characterise African phytogeographical zones, 2) to measure how well phytolith assemblages correlate to the openness/closeness of various vegetation types in Africa, and 3) to propose an interpretation of Pliocene phytolith data from the Middle Awash Valley, Ethiopia.

To do so, we compiled (and analysed as a whole) modern phytolith data obtained from the analysis of 149 surface soil samples distributed within 10 various phytogeographical zones in East and West Africa. We carried a principal component analysis on the whole African dataset using both modern and fossil phytoliths assemblages, and compared the abundance of certain phytolith types (such as the globular types associated with woody plants) with values of the percent tree cover generated from 500-meter resolution MODIS satellite data.

Results on the modern African dataset show that 1) the relative abundances of 11 (out 12) phytoliths allow discriminating of all vegetation zones except the Somalia-Masaï, which exhibits at elevation <600 m high proportion of rondels and trapeziforms, like the Afromontane zones; 2) the co-occurrence of rondels and polylobates characterizes zones above 1900 m asl; 3) the relative abundance of globular phytoliths (granulate, smooth, and echinate) is well correlated to 500m-resolution satellite estimates of the tree cover (r= +0.77 for n=149). The tree cover, however, is largely underestimated in the Afromontane zones, where globular phytoliths do not trace high-elevation forests. The fossil phytolith dataset will be interpreted taking into account these biases in the modern phytolith signal.

Reconstruction of the Vegetation of the Eastern Palaeolake Margin of Olduvai Gorge, Tanzania, during Lowermost Bed II Times.

Rosa Maria Albert, Marion K. Bamford and Dan Cabanes

Well known for the occurrence of *Paranthropus boisei* (formerly *Zinjanthropus boisei*) and *Homo habilis*, Olduvai Gorge in northern Tanzania has been studied by researchers using different approaches in order to determine the environment in which these early hominins lived and evolved .Our approach has been to use the botanical information: phytoliths and macroplant remains, compared to former pollen results. Sampling of modern taxa and soils and taking into account the taphonomic biases have enabled us to reconstruct, in detail, the vegetation in very restricted geographical areas and time slices. Beginning at 1.785 Ma and spanning several tens of thousands of years, the vegetation at the locality FLKN was open woodland, similar to Lake Manyara today, with lots of monocots, grasses and a few herbs and trees. During this time locality HWKE was open woodland with grasses, herbs and sedges, and HWKEE was similar but had palms and a richer understory vegetation. The latter area dried out and became more open grassland. VEK was also open woodland but with more sedges and saline-tolerant grasses and subjected to lake inundations. This area also died out and became more open grassland. MCK was open grassland but much more species rich than occurs in the area today.

Pastoralism, Seasonality and Fire: The Ashmound Neolithic of Southern India

Marco Madella

The Neolithic pastoral settlements of Southern Deccan (India) have very characteristic formations called ashmounds. The ashmounds have been recognised as a great archaeological interest since the 18th century. Since then, a number of archaeologists have tackled the issue of their formation and the nature of the human habitation associated with them. However, the type of human occupation at these sites is still ambiguous. Some of the ashmounds may represent a form of seasonal encampment while others are related to permanent settlements.

The ashmounds are formed by the accumulation of burned dung. There are a number of different types of ashmound sites: some consists only of the heaped deposits of dung and stand alone in the open landscape, others are at the base of hills with villages on the top of the hill while others are set next to permanent occupations. The analysis of phytoliths helps in the understanding of the patterns and seasonality of occupation, the dynamics of the sites and the past social constructs.

Vegetation Reconstruction from Phytolith Assemblages of a 45,000 year-old Crater Lake's Core in Tanzania (Lake Masoko)

A. Alexandre, L. Brémond, A. and D. Williamson

Grasslands were, at the global scale, more widespread during the Last Glacial maximum (LGM: 22-18 ka BP) than today. However a few proxies are able to trace the different types of grasslands and especially C3- *vs* C4-grasslands. Phytolith assemblages' analysis from Late Quaternary sediments can help to better understand grassland dynamics and to further constrain the vegetation-climate interactions.

Quantitative relationships between phytolith assemblages, vegetation and climate parameters in inter-tropical Africa were calibrated previously. Especially, phytolith index Ic was assessed as a reliable proxy of C3/C4 grasses settlements along a tropical East-African altitudinal gradient. Using these relationships, we analyse phytolith assemblages from a 45,000 year-old sedimentary sequence from a crater lake in Tanzania (Lake Masoko: 9°S; 33°E,

780m a.s.l.) in order to reconstruct past tree cover density and C3/C4 grass changes. Phytolith data are compared to other proxies from the same sequence.

Modern phytolith assemblages from five top cores of the lake show a large range of Ic (17±5%) with values higher than those found for a set of soil samples (A1 horizon) collected on the basin (3±4%). This may be explained by the contribution of aquatic Cyperaceae phytoliths, showing a shape close to the Poaceae rondel type, to the lacustrine phytolith assemblages. This highlights the need to take into account the aquatic input when interpreting phytolith assemblages from lacustrine cores.

The phytolith record shows that from 45 ka up to ca.13 ka BP, Ic was subject to variations inside a range of values higher than or close to the modern Ic values. Ic values of the LGM were higher than the modern ones by more than 10%. From ca.13 ka BP up to ca. 2,3 ka BP Ic decreased to reach values lower than the modern ones by about 5%, and increased again later to reach modern values.

This record suggests that C3 grasses were more widespread than today around Lake Masoko, during the LGM, and started to clearly decrease after ca 13 ka BP only. C4 grasses were more widespread than today from 10 cal. ka BP up to ca. 2 ka BP. Such a spread of C3 grasses during the LGM is also evidenced in South Africa by Scott (2002), while several investigations on lake sediments from higher East-African sites, based on d13C analyses of organic matter, evidenced an increase of C4 plants.

These results suggest spatial diversity in C3/C4 plants and C3/C4 grasses development during the LGM and points out the need of better constraining local environmental parameters responsible of C3/C4 plants and C3/C4 grasses distribution.

Paleoenvironmental Reconstruction of Hungarian Kurgans on the Basis of the Examination of Paleosoils and Phytolith Analysis

A. Barczi, A. A. Golyeva and Á. Pető

Our research team seized the opportunity to examine several kurgans located in the Eastern region (Great Hungarian Plain) of Hungary. Two of them–the Csípő- and Lyukas-mound–have been examined in precise details through the involvement of experts of various disciplines. Due to international cooperation, we have been able to extend our research and knowledge on the biogenic genesis of paleosoils and paleoecology concerning our kurgan studies.

Our aim was to elucidate the construction of both mound-bodies, to describe modern soil development, to analyse the buried soil under the formations and to reconstruct the ancient paleoenvironment of their surroundings. Therefore, we utilized biomorphic analysis along with pedological investigations.

To reconstruct the formal environment, data was acquired from the buried soil profile and the cultural layers of both kurgans.

Though differences in sampling methods were significant, the existence of a buried, ancient, undisturbed soil profile can be stated. The mound-body and the surrounding area of Csípő-mound was sampled through drillings, whereas Lyukas-mound was excavated and the cross-sectional model was prepared. In this case sampling was easier and occurred to be more precise. Samples for biomorphic analysis weres taken from the upper section of each horizon of each soil profile buried under both kurgans and from the presumably separate cultural layers of the mound-body.

The biomorphic analysis is a suitable but not yet widely used method in Hungary to gain data from paleosoils concerning paleoenvironmental reconstructions of the Holocene. Mineral biomorphic analysis is the microscopic investigation of sponge spicules, diatoms and silicified plant tissues, such as phytoliths. Complemented with the preparation and observation of organic biomorphs, such as detritus, pollens and spores, the total multiple biomorphic analysis can yield data on the biogenic genesis of soils and landscapes. Complemented with data acquired from (paleo)pedological surveys, the paleoenvironment–especially with regard to pedological and paleovegetational patterns–can be reconstructed to a greater extent.

According to a precise description of soil morphological details that was done after the kurgan's excavation and drillings, we conclude that both the modern and paleosoils of the kurgans belong to Chernozem type soils, formed

under predominantly arid steppe vegetation. Unlike previous theories, no evidence of Luvisol development was detectable. Due to this fact we assume that the ancient environment of both kurgans was similar in many points with the modern landscape and its development was determined by climatical and vegetational factors typical for steppe land environment. Results of biomorphic analysis have supported the existence of an ancient steppe environment and the Chernozem type soil development along with the existence of the undisturbed paleosoil.

Taphonomical Aspects of Silica Phytoliths in Loess Sediments of the Argentinean Pampas

M. Osterrieth, Marco Madella and Debora Zurro

Loess is a deposit of aeolian origin that covers most of the pampas plain. The origin and the sedimentological and chemical characteristics of this sediment have been thoroughly studied from the beginning of the last century. Even though silica phytoliths were observed and mentioned, the study of their content and characteristics has not been done in depth. This paper focuses on certain morphologies that are repeatedly encountered in the loess of the Late Pleistocene-Holocene of the pampas, specifically looking at them from a taphonomical perspective and their possible informative role for the formation of the pampas deposits.

Using Soil Phytolith Analysis to Infer Vegetation and Disturbance Regime Changes over the Past 200 Years

Lesley Morris

Historical ecology is a field of research that seeks to explain how change is manifest upon the landscape over time. Its interdisciplinary synthesis of information drawn from the human and the biological archive helps define reference conditions and the historic range of variability that informs management decisions and drives restoration efforts. The human archive is the record of historic conditions contained within written, oral and photographic sources. The biological archive is the record of historic conditions contained within the natural environment and is discovered through dendrochronology, packrat middens, palynology or soil phytolith analysis. The methods in historical ecology cover a wide range of temporal and spatial scales. However, the methods for more recent time scales (less than 200 years) are largely limited to the human archive and some dendrochronology evidence which can be subject to human bias, limited in spatial extent or inappropriate for non-forested systems. Filling this gap would provide important information for understanding the vegetation changes in the Western United States since settlement in the 1800s. This research seeks new methods for historical ecology that employ the soil phytolith assemblage as a tool for inferring vegetation and disturbance regime change over the more recent past. It examines the use of known historical events and conditions for hypothesis testing and inference back in time. For example, this research asks if phytoliths of introduced and invasive species can be used as a time marker in the soil profile since the timeframe of their introductions are known? Also, it examines if historic fires, changes in rangeland conditions and woodland cover are recognizable in the phytolith assemblages within the soil profile.

Modern and Past Grass-dominated Biomes Distribution Recorded by Phytoliths and Stable Carbon Isotopes; Preliminary Results

Laurent Bremond, Arnoud Boom and Juan Carlos Berrio

Nowadays grasslands are the most widespread continental floral associations. They were more abundant during the different past glaciations than they are today. Although proxy indicators of past environments can be derived from fossil records, the reconstruction of grass-dominated biomes is difficult as pollen cannot distinguish between grass subfamilies. The main objective of this project is focused on the Quaternary dynamics of grass-dominated biomes in South America and Colombia, in particular, in order to better understand the relationships between climate change and vegetation dynamics (e.g. C3/C4 grass distribution) in tropical areas. For this purpose, quantitative data and vegetation models will be coupled.

Calibration of statistical relationships between modern phytolith assemblages, stable carbon isotopic signatures of modern soil derived organic carbon, botanical statements for several grassland biomes and climate data will be performed. Regression equations between climate parameters, the quantitative phytolith and d13C proxy of C3/C4 grasslands will be estimated. In a second stage, we will apply the

calibrated relationships to several soil profiles from several elevation transects where the change in C3/C4 grass dominance over the last 10,000 years has been recorded. Finally, the reconstructed vegetation and climate parameters will be compared with several scenarios derived from two vegetation models (BIOME 3 and LPJ-GUESS). This process of data-model comparison will include investigating changes in precipitation, temperature and atmospheric CO2 concentrations. The comparison between simulation and data enables in turn, by inversion of the model, to reconstruct the parameters best as coherent as possible with the data. The application and development of the phytolith proxy in tropical South America will also allow comparison with recent synthesis studies that have primarily focused on pollen data alone.

Ancient Climate Capsules: A Phytolith-Occluded Carbon Glacial Record of Atmospheric 13CO2

John A. Carter

The best records of atmospheric change of glacial cycles are those from ice cores. However, missing from these records are definitive data indicating changes in 13CO2. There are, however, a number of temporally limited, or of low-resolution or chemically compromised records (Friedli *et al.* 1986, Fisher *et al.* 1999, Indermuhle *et al.* 1999, Smith *et al.* 1999, Trudinger *et al.* 1999). One of the least understood and important influences on the changes to the isotopic composition of atmospheric CO2 is that of vascular plants. While marine benthic d13C records have been used to infer past changes in terrestrial vegetation (Shackleton 1977, 1992), accurate estimation of changes in carbon storage on land during ice ages has proved elusive. Other estimates have been made using reconstructing terrestrial biomes from pollen records (Adams *et al.* 1990, Crowley 1991, van Campo *et al.* 1993), but a large discrepancy between marine- and land-based estimates remains. The method described here to generate a late glacial record of atmospheric carbon 13 could possibly be used to answer the question of how much CO2 was sequestered on land during the last glacial cycle. The 13CO2 record of the last glacial cycle presented here is derived from the analysis of carbon trapped within phytoliths (plant micro-fossils).

Phytoliths are microscopic opaline particles formed in plant cells. They are produced in many plants as their cell fill with silica, forming a solid body. Fragments of the original cellular material are often trapped inside the silica body. Phytoliths are highly resistant to decomposition, thereby protecting the original cellular material from post-depositional contamination, and these phytoliths are released directly to the adjacent soil when a plant dies and decays. When plants assimilate atmospheric CO2 they fractionate against 13C, leaving the atmosphere relatively enriched in 13C. Therefore, any record of isotopic change in plant tissue can be used as a proxy for change in atmospheric 13CO2 and by extension a record of changes in global vegetation.

A relationship was established between the carbon isotopic ratios of the leaf tissue and the phytolith-occluded carbon for a number of modern indigenous grasses, trees, shrubs and ferns. These show distinctive differences in fractionation, with grasses recording a more negative differentiation than trees. Phytoliths were extracted and occluded carbon analysed from a 7.4m loess core, generating a ~100,000 year 13C record. A formula was then developed and applied to separate the plant physiological factors and the embedded atmospheric 13CO2 from the phytolith-occluded carbon.

Calibration of the Relationships between δ18O of Phytoliths from Wood, Atmospheric Temperature and δ18O of Forming Water

J. Crespin, A. Alexandre, F. Sylvestre, C. Sonzogni and David Hilbert

Phytoliths are commonly used as biological proxy, through shape counting, but merely used as terrestrial geochemical proxy through analysis of the oxygen isotope composition (δ18O) of their hydrous silica structure. The P.O. Box 780 Atherton QLD 4883 Australia 18O value of surface minerals relies on atmospheric temperature and δ18O of forming water and can be used as a paleoenvironmental proxy.

Two groups of studies (Shahack-Gross *et al.*, 1996; Webb & Longstaffe, 2002) have demonstrated that the δ18O signature of phytoliths from the non-transpiring stems of Poaceae relies on the atmospheric temperature and on the δ18O value of soil water. The globular granulate phytoliths, investigated in our

study, are produced by the wood (non-transpiring tissue) of dicots and represents more than 90% of phytolith assemblages produced by tropical forests. We present here a new calibration of the relationships between the δ18O value of these phytoliths, atmospheric temperature and δ18O of soil- and rain-waters.

First, a phytolith lab standard is analysed to set up a new laser-based O2-extraction protocol. Second, wood phytoliths from a growing chamber (controlled conditions) and modern phytolith assemblages from Australian rainforest soils collected along a temperature and precipitation gradient are analysed.

Because phytoliths are hydrous silica particles and contain exchangeable oxygen, an equilibration procedure is required prior to oxygen extraction. Phytoliths are then melted and vaporized under an Infra Red laser beam of 17W in a BrF5 atmosphere. Molecular oxygen is analysed by Isotope Ratio Mass Spectrometry. Twenty-nine analyses of 1.6 mg of samples are processed over 4 days. The laser heating technique involves a lower amount of material and is less time-consuming than the conventional one used up to now for analyzing fine grains powders.

External precision (±1σ) of the whole procedure is lower than 0.35‰. This result is close to the external precision obtained using the conventional fluorination method (0.2-0.3‰).

The δ18O analyses of the phytoliths from the growing chamber and from the Australian rainforest soils are in progress. The δ18O values of the phytoliths will be correlated to measured atmospheric temperatures and δ18Owater values measured and obtained from the IAEA. Statistical analysis will help to discuss the environmental meaning brought by the δ18O signature of tropical rainforest phytolith assemblages.

Ecological Significance of Short-cell Phytoliths in South African Grasses (Poaceae)

Lloyd Rossouw and Louis Scott

A range of constant morphological characters, based on observations using polarizing light microscopy, was isolated from short-cell phytoliths of 105 different genera, comprising five grass subfamilies in South Africa. Phytolith types were described following the ICPN 1.0. The selected morphologies were correlated with inherent biochemistry and environmental factors related to climatic adaptation of individual grass species. The results show that specific as well as certain suites of phytolith morphotypes correlate well with photosynthetic pathway, moisture availability, relative aridity and ambient temperature.

Calcium Oxalate Crystals Content in Native and Exotic Vegetal Species of the Southeast of Buenos Aires Province, Argentina

Natalia Borrelli, Margarita Osterrieth and Jorge Marcovecchio

The aim of the present study is to describe the occurrence of calcium oxalate crystals in both the native (*Celtis tala*, Gill) and the exotic (*Acacia melanoxylon*, R. Brown and *Eucalyptus globulus*, Labill.) vegetal species developed within typical Argiudolls on the southeastern Buenos Aires province, in Argentina. The leaves from the different species, diaphanized and clarificated with a 50% sodium hypochlorite solution were studied. Both, optical microscopy and scanning electronic microscopy were used to describe the obtained crystals. All the species have shown a high density of calcium oxalate crystals with diverse morphologies disperse in the leaves mesophyll. Moreover, druses were observed ramdomly dispersed in *Celtis tala* and *Eucalyptus globulus*, while bipyramids were in *Acacia melanoxylon* and associated to vascular bundles in *Eucalyptus globulus*. In addition, high cystoliths density was recorded in the epidermal tissue of *Celtis tala*. The significant production of these biominerals not only from vegetal species but also from fungus ones developed in the organic horizons of these soils, together with their susceptibility to weathering, results in an important contribution of calcium to the system, which remains available in the soil and can be re-injected into the biogeochemical cycle.

Absolute-Dating of Phytoliths From Archaeological Sites: Is It Possible?

E. Boaretto, V. Chu, E. Mintz, R. M. Albert, A. Gilboa, I. Sharon and S. Weiner

The accuracy of a radiocarbon date depends first and foremost on the archaeological context from which the sample is recovered. Many phytolith-

rich layers have been identified at Tel Dor (Shahack-Gross et al; Albert et al.) and other tell sites in Israel. These represent well defined loci and would therefore be one of the best candidates for radiocarbon dating. In unburnt phytoliths there is sufficient organic material for radiocarbon dating using Accelerator Mass Spectrometry. The process between identification of the phytolith-rich layers in the field and the measurement of their radiocarbon contents with the accelerator, represents a challenge for radiocarbon dating method.

The procedure for cleaning, separating and preparing the sample, together with the use of spectroscopic analytical tools to characterize the material and its quality for dating will be presented with some results

Phytolith Analysis of Coarse Ash Samples from Neolithic Budihal South India

M. D. Kajale and S. P. Eksambekar

This is a humble attempt to understand the origin of coarse ash found in various stratigraphic sequences of the ash mound at Budihal located (Lat. 16°.22˝ N; Long 76°.23˝ E) in the Shorapur region of Gulbarga District in the state of Karnataka, South India.

Concurrently with excavations, the representative ash samples were divided into three size fractions so as to understand the frequency distribution of diagnostic phytolith types and subtypes. The frequency of Panicoids was high as compared to other morphotypes in the three fractions.

Segregated phytoliths of Panicoid dumbbells with short shaft and crosses types were observed in the fine fraction. The other types included Elongate with serrated edges, Festucoids and Chloridoid types in minimum quantity. Panicoids of bilobates, trilobates and polylobate forms including crosses were predominant in the medium fraction. The other types present were flat cells of short amorphous unicellular types and a few aggregate forms.

Phytoliths in their anatomical context were common in the coarse fraction (> 50 µm). Panicoids with subsidiary cells were also noted. The other types included dumbbells parallel along the longitudinal axis, elongated with one side having serrated margins. The epidermal long cells with small rounded projections are noteworthy. Rods and trichomes were occasionally noted.

A scatter diagram analysis has been undertaken. There is a positive correlation between phytolith assemblages from the coarse ash and the modern cattle faeces from the area under study, thereby suggesting that coarse ash may have predominantly originated from the cattle droppings.

Incorporating the ICPN: A Critical Step for Advancing our Discipline

Terry Ball (Invited talk)

The development of the International Code for Phytolith Nomenclature (ICPN) is arguably one of the most significant achievements in the discipline of phytolith analysis in the last decade. This document provides a much needed standard protocol for naming and describing phytoliths. Incorporating the ICPN into our dialogue, presentations, and publications is a critical step for advancing our discipline. In order to successfully incorporate the ICPN it must be made readily accessible to all researchers. Researchers then need to familiarize themselves with it, use it, and recommend it when reviewing articles for publication.

Use of Space in Archaeology: Phytolith Studies in a Traditional Village in Northern Greece and at Tel Dor, Israel

Steve Weiner (Invited talk)

An ethnoarchaeological study focused on phytoliths in a village in northern Greece (Sarakini) has enabled us to develop new tools to recognize different uses of space. Some of these concepts have been applied to a study of phytolith-rich layers at Tel Dor.

RECENT PUBLICATIONS

Chandler-Ezell, K., D. M. Pearsall, and J. A. Zeidler. 2006. Root and tuber phytoliths and starch grains document manioc *(Manihot esculenta)*, arrowroot *(Maranta arundinacea)*, and llerén