MU Phytolith Classification System: Notes and Guidelines for Use

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Introduction: The MU Phytolith Classification System

The MU phytolith classification system was developed as a desktop identification aid, a hierarchical classification system, to provide consistency in classifying phytoliths, and to serve as a mechanism for keeping track of unknowns. **It is not a key to identifying plant taxa.** There were initially 11 major categories in the classification (Pearsall and Dinan 1992), expanded to 25 categories by the final update in 2012. These are the categories:

10 Epidermal quadrilaterals (large cells of the epidermis, quadrilateral, square to elongated, often very two-dimensional in appearance, variable surface and edge characteristics)

11 Epidermal quadrilaterals, three-dimensional (variable surface and edge characteristics)

12 Epidermal quadrilaterals, carbon-occluded (not further divided; includes all shapes and sizes of cells in 10 and 11)

20 Epidermal, nonquadrilateral (originally all nonquadrilateral cells of the epidermis, later restricted to leaf epidermis; irregular in shape, usually two-dimensional in appearance)

21 Epidermal nonquadrilaterals, leaf epidermis, fragments (variable surface characteristics)

22 Epidermal nonquadrilaterals, seed or fruit epidermis (variable surface and edge characteristics; irregularly shaped, polyhedral in top view, cylindrical; includes Poaceae fruitcase and glume bodies)

23 Epidermal nonquadrilaterals, carbon-occluded (not further divided; includes plates and cell walls of other tissue origins, such as parenchyma)

24 Epidermal nonquadrilaterals, three-dimensional/blocky (rounded and angled edges)

25 Mesophyll (not further divided)

26 Epidermal nonquadrilaterals, rhizome, tuber, or root epidermis (cylindrical and flat)

30 Short cells (Poaceae, produced in the leaf vein area)

31 Intercostal cells (quadrilateral, rounded)

40 Dermal appendages (prickles, hairs, edge spines, including base cells)

50 Bulliform cells (Poaceae, located in the mesophyll or epidermis, usually three-dimensional in appearance, highly silicified, shapes variable: rectilinear, rounded, flared)

60 Anatomical origin unknown (a category for plant silica of unknown origin in the plant)

70 Honeycombed material (amorphous silicified material, usually of irregular shape, lightly silicified, breaking easily)

80 Stegmata and other spheres (mesophyll cells of spherical-spheroidal shape; troughed bodies, conical bodies)

90 Other biogenic silica (diatoms, sponge spicules, and the like)

100 Crystalline bodies (cystoliths [silicified outgrowths of cell walls, occurring in the epidermis and subepidermis, variable shape, usually nodular surfaces], raphids, other crystals)

110 Sclereids (sclerenchyma cells, varied in form, but often elongated and angled; not subdivided)

120 Stomata

130 Silica casts of parenchyma (for artifact residue applications)

140 Silica casts of transport tissues (xylem, phloem, for artifact residue applications)

150 Fibers (for artifact residue applications)

160 Secretory cells

Major categories are defined primarily based on cellular origin of phytoliths, with lower order divisions based on morphological details. Second order divisions are given Roman numerals, third order divisions capital letters, fourth order divisions lower-case levels, and so on. Within each category, phytoliths are assigned unique number codes (names), which indicate how similar each is to other phytoliths in the category. Here is an example of the classification from category 10, epidermal quadrilaterals:

10I. long (two to four times width)

10IA. Four smooth edges

a. smooth surface

1. no projections

00. not tapered

01. tapered one edge

02. short edges pointed and interdigitating (Arecaceae)

03. long edges pointed and interdigitating

b. grainy surface

1. tapered

2. not tapered

c. uneven surface

10IB. two irregularly undulating edges; two smooth edges

a. long edges undulating; smooth surface

1. slightly undulating

2. moderately undulating

b. short edges undulating; long edges smooth

c. perforated

d. wrinkled

e. uneven

f. grainy

g. striated (UC Riverside type)

10IC. Two serrated or sinuous edges; two smooth edges

a. smooth surface; long edges serrated or sinuous

1. moderately serrated

2. moderately sinuous

3. slightly sinuous

00. smooth short edges

01. concave short edges

A.slightly concave

B.moderately concave

02. one edge smooth; one edge concave

5. very deeply serrated [sic: no 4]

6. very deeply sinuous

00. rounded sinuous

01. blunt sinuous

7. slightly serrated

b. short edges sinuous; long edges smooth

d. perforations [sic: no c]

1. serrated edges

2. sinuous edges

e. wrinkled surface; slightly sinuous

f. uneven surface; slightly sinuous

g. grainy surface; irregularly sinuous edges

10ID. Four sinuous, serrated, or undulating edges

While the MU paleoethnobotany laboratory was in active operation, the classification system was contained in two card file boxes. For each type there is an index card with a sketch and description of the type, and one or more photographs of representative examples. The system is not a polished document, more like a lab notebook written in by myself and students over the years. As new phytoliths were added, numbers of existing types were changed as needed. A common change was to add a lower classification level: for example, 80IE (original irregularly angled/folded sphere) became 80IEa (original type, Zingiberales diagnostic) and 80IEb (angled/folded sphere with nodules). For phytoliths that were very similar, notes were added on how to distinguish between types and an orange card alerted the user to check alternatives. Diagnostic phytoliths (see below) were also flagged. Consistency in descriptions was maintained by developing an in-house dictionary of standard terms, and by using botanical and geometric terms in their precise meanings. The classification was eventually compiled as a Word document. Beginning after the 2012 update, all the original cards and photographs were digitally imaged and inserted into the text portion of the classification by Howard Wilson, with assistance from myself and Laurel Wilson, and pdf files of each category produced. This project was finished in April 2015.

Over the 20 years of its use, the MU phytolith classification system fulfilled its primary goal, to maintain consistency in how phytoliths were classified from one research project to the next. The type numbers appear cumbersome, but with use become familiar. Having to write a number on a quick-scan form, or tick off a type from a list on a counting form, takes the researcher through a series of decisions. Moving back and forth between comparative phytolith slides and type descriptions reinforces criteria critical for correct classification. The classification provides context for the comparative collection, and helps insure that tallies of phytoliths observed in new plant taxa are comparable to those studied previously. The system proved quite flexible. It was easy to expand, and different levels could be used during scanning (for example, epidermal quadrilaterals could be tallied all together [10], or by length [10I, 10II]). Whatever form descriptions and names take, they are an essential part of phytolith research. See Bowdery et al. 2001 and Madella et al. 2005 for discussion of phytolith naming and description, and standard terms and approaches.

This digital version of the MU classification system was created for several reasons. The classification system is part of the record of how phytolith research was conducted by myself and students and research collaborators, and will be part of the digital archive of the laboratory. The photographs and descriptions in the system document the morphologies of many types tallied in

phytolith production tables (see elsewhere on MU phytolith website). This will permit researchers to draw comparisons to other data sources. The desktop version of the classification system helped students and lab visitors learn about phytoliths, and the digital version may do the same.

There are a few cautionary notes/disclaimers for the digital version of the system. **The classification is not a key to plant species.** Most of the photographs are of representative examples. No corrections were made to cards or photographs as they were digitally imaged; the system is presented in its working, unedited form, spelling errors, inconsistencies, and all. This was the only realistic way to make the card file available digitally. Finally, and most importantly, this tool is no substitute for a phytolith comparative collection.

Notes and Guidelines for Use of the Classification System

Images of Index Cards and Photos

The digital version of the classification is set up as a series of Adobe Acrobat files. For each, the file name indicates which categories of the classification are contained in the file. For several large categories, more than one file was made (i.e., Part 1, Part 2) to facilitate downloading. The first pages of each file are the text of the classification, followed by the digital images of the cards and photographs of the types. If the category is contained in more than one file, the text of the entire classification is repeated at the beginning of each file.

Each imaged photograph and card is labeled with the type name, which is located beneath the image on the left. If multiple cards or photographs were present for a type, these were numbered consecutively (i.e., photo 1, photo 2; card 1, card 2). Whether the image is the front (f) or back (b) of the photo is also indicated with the name. Photos are arranged on the pdf pages with the front on the left, the back on the right. The name, made up of numbers and letters as described above, corresponds to the position of the type in the classification. So, for example, photos of 10IAa100 show an epidermal quadrilateral phytolith (10) that is long (10I), has four smooth edges (10IA), a smooth surface (10IAa), no projections (10IAa1), and is not tapered (10IAa100). Photos of 10IAa101 show phytoliths that are very similar, but are tapered on one edge. Types can be compared at each level of the classification. For example, to see all epidermal quadrilaterals that have four smooth edges, one would look at the images of all types that begin with 10IA.

There are also type names (classification numbers) handwritten on the type cards and the backs of the photographs. If a handwritten name is different from the photograph/card label, that is because the name was changed at some point after the type was established. As mentioned earlier, ***no editing was done to cards or photos before they were imaged.*** The photograph/card label, located on the left beneath the image, is the name that corresponds to the 2012 (final) classification.

In general, a card was made when a new type was encountered during scanning, and photographs were taken. Types were often established during study of plant specimens. In that case, the name of the plant, the plant part (leaf, fruit/inflorescence), and its comparative collection number were to be written on the back of the photograph. If no plant part is listed, it is most likely a leaf specimen. An Excel spreadsheet of all processed comparative specimens was

maintained during the active operation of the lab. This spreadsheet contains more information on the specimens (e.g., herbarium or Pearsall field collection number, country of origin) and corrected names. Types were also established during study of archaeological samples. In this case, the name of the project (sometimes the project principal investigator's name) and/or the sample number (phytolith soil number) was to be written on the photo. An Excel spreadsheet was also maintained for archaeological phytolith samples, which contains information such as site names and full sample proveniences. Most photos were labeled with plant or project names, but there are some inconsistencies. A photo logbook was maintained for each microscope (Nikon, Zeiss), in which basic information of the kind mentioned above was entered when photos were taken. These logbooks were eventually entered into Word. I hope to make all these documents available on the MU phytolith website in the near future.

All photographs were taken using black and white film at a standard magnification, and were printed in-house at the same scale (1:5). The prints in the file thus corresponded to approximately the same area in the centers of the negatives. All prints were reproduced for the digital version of the system at the same size. Phytolith types can thus be compared in terms of their relative sizes from one photograph to the next throughout the system. Phytolith type photographs were always to be centered on the type, which was often circled on the prints. Other markings on photo backs include film roll number and frame number (e.g., R150-26: roll 150, frame 26), which tie the photos to logbook entries. Film speed and exposure were also sometimes noted.

Category 30

Category 30, grass short cells, is set up somewhat differently than the other categories in the system. Phytoliths in the first sub-category (30I), regular short cells, are not numbered using the hierarchical system. "Regular" short cells are those in which the standard (or planar) face and the opposite face are the same (e.g., bilobate in both standard view and opposite face), or the opposite face is simple (i.e., flat or with a simple keel). Regular short cells can be grouped into three classes, panicoid, festucoid (pooid), and chloridoid, based on the shape of the standard face. At the MU lab we counted regular short cells using a modified version of the Twiss et al. (1969) short cell classification. As part of this count, we also typed cross-variants using Piperno's (1984) system, and separated chloridoid and Bambusoideae/Arundinoideae saddles by the ratio of height to width and panicoid and bambusoideae bilobates on the basis of shaft characteristics following Piperno and Pearsall (1998). This is the classification for regular short cells:

PANICOID

bilobate (semi-rounded to squared lobes with distinctive shaft)

nodular

crenate

3-lobed

cross

variant 1

variant 2

variant 4

variant 5/6

variant 7

unilobate

FESTUCOID/POOID

round to oblong

square to rectangular

long, sinuous

CHLORIDOID

saddle, squat (H < W, or H=W)

BAMBUSOIDEAE

Bambus. bilobate (squat, no or indistinct shaft)

BAMBUSOIDEAE AND ARUNDINOIDEAE

saddle, tall (height > width)

Photos of regular short cells are labeled by class and numbered consecutively within each class. "rot." indicates a short cell in rotation (otherwise short cells were photographed or drawn in standard view).

In the MU system the other major sub-category of short cells is "complex" short cells (30II). Complex short cells are those for which a distinctive difference exists between the standard face (lobed, rondel, saddle) and the face opposite to it. The opposite face often has "spikes" or projections, or in some other way is not simple, as characterized earlier. These are short cells that do not "fit" the Twiss et al. (1969) classification. Complex short cells are named using the hierarchical classification system. They are first classified by the characteristics of the standard face, referred to as the "base" (e.g., 30IIAa, lobed base, simple bilobate), then by characteristics of the opposite face, referred to as the "top" (e.g., 30IIAa2, spiked top), followed by other morphological features (e.g., 30IIAa200Ac, spiked top tall, three spikes). These numbers replaced earlier numbers (e.g., Old MU Type 10P) assigned during a collaborative study with Dolores Piperno of lowland Neotropical grasses (Piperno and Pearsall 1998). Data tables from grasses studied at MU used these old numbers (see data tables on website). Most images in this part of the system are of cards created from the original drawings and descriptions of the complex short cells identified during that project. These drawings show multiple views of each type. After examining the distribution of these complex short cells in our study collection, I determined which were diagnostic (e.g., occurred in panicoid grasses) and which were redundant (i.e., could not be classified to class) (Pearsall 2004, see report on website). These determinations

are in the lower right hand corner of the cards. Diagnostic complex short cells were added to our short cell counting form (see forms on website).

Diagnostic Phytoliths

As emphasized already, the MU Phytolith Classification System is *not* a key to identifying plant taxa, but a way to name phytoliths in order to track their occurrence in plants and archaeological samples. Most of the photographs in the system are of representative examples. However, the system also includes all the diagnostic phytoliths--those that do permit identification of plant taxa--that were recognized and counted at the MU lab. Here is an example from Category 20, epidermal non-quadrilateral, discrete cells of leaf origin, to show how diagnostic phytoliths are designated within the classification system (I've added **bold type** to the diagnostics):

20I. smooth surface

20IA. Sinuous edge; anticlinal cells

a. not elongated, smooth to grainy in appearance **(dicots)**

b. elongated

20IB. polyhedral cells

a. smooth to grainy surface **(dicots)**

b. with rounded projections (bases) **(dicots)**

c. with perforations **(Humiriaceae, *Humiriastrum procerum*, family level diagnostic)**

20II. Honeycombed surface

20IIA. Thin, almost transparent edges; sinuous edges on interlocked cells

20IIC. Comprising many irregular honeycombed bodies [sic: no B]

20IID.rounded bodies with honeycombed surfaces

20V. surface projections [sic: no III or IV]

20VA. Tend to be quadrilateral in top view; single conical projection (“hat”) **(Cyperaceae leaf)**

20VB. Conical projection; carbon concluded

20VC. Sinuous double outline; one side smooth; one side bumpy

a. occurring singly; hat-like; rounded in rotation **(Ulmaceae, *Celtis schippii*, species level diagnostic)**

b. 2 conical or triangular cells joined symmetrically at bases **(Ulmaceae, *Celtis schippii*, species level diagnostic)**

c. masses of hat-like bodies **(Ulmaceae, *Celtis schippii*, species level diagnostic)**

d. conical; oval in rotation **(Boraginaceae, *Cordia lutea*, species level diagnostic)**

e. conical with rounded bottom; round in rotation.

20VD. Round or triangular in top view, edges rounded; round edges faint, cup-like triangular, edges heavily silicified **(Bombacaceae, *Pachira aquatic*, genus level diagnostic)**

20 VE. Single rounded projection on "hat;" rounded in top view **(Lauraceae, *Caryodaphnosis fosteri)*** Note: this is a family-level diagnostic.

Notice that in this example the taxonomic levels of the diagnostics vary, from a large class of plants, the dicots, to the family, genus, and species levels. Diagnostics are scattered throughout the classification system, numbered to reflect their tissues of origin and similarities and differences to phytoliths of similar origins and appearance. Phytoliths in Category 30 (short cells) and Category 50 (bulliforms) are all diagnostic to Poaceae, the grass family.

If in any doubt about the diagnostic level of a phytolith type, or whether a type is diagnostic, consult the MU Phytolith Database. This database, launched on the Phytoliths in the Flora of Ecuador website in 2000, is a database of diagnostic phytoliths. As we developed it, and added new diagnostics to the classification system, printouts of database entries began to replace or supplement cards and photographs in the system file boxes. A few of these "cards" were digitally imaged; they can be recognized by their standard layout, which includes a photo and fields for family, genus, and species names, as well as comments and descriptions. However, in the interest of time, most were not imaged, since all diagnostics may be found in the on-line database. So, if there is no photo or card for a phytolith type, and it is a diagnostic, go to the database.

Artifact Residue Applications: Categories 130, 140, 160

There are three categories of phytoliths in the system that were developed specifically for artifact residue applications: silica casts of parenchyma (130), silica casts of transport tissues (140), and fibers (150) (Chandler-Ezell et al. 2006). These are generalized classes of silicified tissues that may be difficult to recognize reliably in soil or sediment samples. In a case in which processing of plant tissues can be reasonably inferred, they can provide insight into food use.

Conclusion

The MU phytolith classification system was developed as a desktop identification aid to provide consistency in classifying phytoliths, and to serve as a mechanism for keeping track of unknowns. It has been digitally imaged, unedited, in the hope that students and novice phytolith researchers may find it a useful tool for learning to recognize phytoliths, and distinguish among similar forms.

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