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International Code for Phytolith Nomenclature 1.0

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• *Background* Phytoliths (microscopic opal silica particles produced in and between the cells of many plants) are a very resilient, often-preserved type of microfossil and today, phytolith analysis is widely used in palaeoenvironmental studies, botany, geology and archaeology. To date there has been little standardization in the way phytoliths are described and classified.

• *Scope* This paper presents the first International Code for Phytolith Nomenclature (ICPN), proposing an easy to follow, internationally accepted protocol to describe and name phytoliths.

Key words: Phytoliths, nomenclature, systematic, description, code.

INTRODUCTION TO THE INTERNATIONAL CODE FOR PHYTOLITH NOMENCLATURE 1.0 (ICPN 1.0)

A discussion on phytolith nomenclature arose during the 3rd International Meeting on Phytolith Research (IMPR) in Bruxelles (August, 2000). The majority of the delegates agreed that standardizing and harmonizing the naming and describing of phytoliths would improve communication between researchers and facilitate the comparison of phytolith types and analyses. Presently, those studying phytoliths are faced with a considerable volume of names, including countless numbers of synonyms and homonyms. To further complicate the situation, there are often inconsistencies in the application of these names. The number of people working with phytoliths is growing fast, as is the exchange of data and communication between research groups. Standardizing the nomenclature is therefore urgently needed to avoid further confusion and allow easy, uniform and correct usage of phytolith names. Such stability can only be achieved by the application of a generally accepted (international) nomenclature protocol and glossary.

For this purpose, during the 3rd IMPR and with the sponsorship of the Society for Phytolith Research (SPR), a working group in charge of developing an International Code for Phytolith Nomenclature (ICPN) was created. The International Working Group on Phytolith Nomenclature (IWGPN) was to develop:

1. A **standard protocol** to be used during the process of naming and describing a new (or already known) phytolith type.
2. A **glossary of descriptors** (nouns and adjectives) to be used in naming and describing a phytolith type.

It is anticipated that the work of the IWGPN will be refined and the protocol and glossary improved by an ongoing committee appointed by the SPR. The standard protocol

and glossary of descriptors developed by the first Working Group are presented here as the International Code for Phytolith Nomenclature 1.0.

The protocol suggested below follows the example of many other protocols already in use in other scientific disciplines. The protocol supplies the researcher with clear, easy-to-follow guidelines to apply when describing and naming a new or already published phytolith type. In cases where a phytolith type has been described in earlier works using a different terminology, citations of the earlier works should be included.

The publication of a new phytolith type requires two elements: an accurate description and an appropriate name.

PHYTOLITH DESCRIPTION

1. Descriptive tools

The nouns and adjectives supplied in the Glossary at the end of this paper should be used. These are called descriptors. To ensure the utility of the Glossary by the international community, terms with Latin or ancient Greek roots are used. The Glossary will be updated regularly by the current IWGPN and future committees, and new descriptors may be added when necessary.

2. Description procedure

When describing a phytolith type, certain kinds of characteristic information need to be supplied.

Shape. A description of shape using terms from the Glossary or from geometrical forms should be supplied. The 3D phytolith form should be observed and described. Analysis in liquid mounting should be performed to facilitate the rotation of the phytoliths in this process and to ensure that all orientations are observed and described. Distinctive 2D characteristics should also be included in the description.

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Texture and/or ornamentation. A description of distinctive ornamentation should be given using the terms supplied in the Glossary. Weathering features should not be described as ornamentations or texture but can be noted if distinctive. Presence of inclusions may be described, although they are not generally considered diagnostic.

Symmetrical features. Distinctive lines of symmetry should be included in the description.

Morphometric data. Measurements of size and shape with descriptive statistics, such as ranges and means, may be included in the description if an adequately large sample has been analysed. To verify that a statistically sound population has been sampled, a calculation such as the one below is recommended:

$$n_{\min} = z_{\alpha/2}^2 s^2 / e^2$$

Where n_{\min} = minimum adequate sample; $z_{\alpha/2}^2 = 1.64$, which is the square of the two-tailed Z-value at $\alpha = 0.10$; s^2 = variance; and e^2 = square of the desired margin of error, usually 0.05 times the sample mean.

Illustrations. Description of a phytolith type must be accompanied by illustrations. Illustrations need to be optical microscope photographs and/or 3D detailed line drawings portraying all possible orientations of the phytolith. Scanning electron microscope photographs can also be used as a complement to the main illustrations; but because most of the routine work in phytolith identification is done at the optical microscope, SEM photographs should not be used as a substitute for optical photographs. All illustrations must show a scale bar and a note with magnification and authorship.

Anatomical origin. The description of a phytolith type needs to explicitly state the anatomical origin of the phytolith (at tissue structure or cell level) *only* if the phytolith type has been directly observed *in situ* or if this origin has been already *clearly demonstrated* in previous, fully-referenced publication(s).

3. Taxonomic significance

Researchers should use caution in assigning taxonomic significance to a phytolith type. A phytolith type may be observed in a given taxon, but to be diagnostic it must be exclusively present in that taxon (e.g. if a phytolith type is considered diagnostic at family level, it must occur in all the genera of that particular family, and be absent in other families belonging to the same order or group). Geographically observed types can also be identified when the flora of a specific geographic area has been investigated (e.g. Tropical Africa, New World Tropics, etc).

The Working Group is very aware that, because of multiplicity and redundancy (Piperno, 1988), such an unequivocal production *can often be impossible* or very time-consuming to verify. When a phytolith type is observed in a plant and there is not sufficient information to corroborate any wider taxonomic significance, the researcher should avoid generalizations. For example, if a phytolith is observed in a

species but no other comparative studies are available, then the phytolith should be published as *observed* in that species and *not as diagnostic* of that species or genus, family, etc:

observed: found in a taxon but maybe present in other taxa;
diagnostic: only present in that particular taxon.

Note I. When taxonomic significance cannot be assigned to a single phytolith type, a group of phytolith types and their frequencies (phytolith assemblage) may have taxonomic significance and this should be considered.

Note II. Silica skeletons (articulated phytoliths) maintain the cell architecture of the original tissue. The single cells forming the silica skeleton can be described using the same procedure as for single cells. A description of the silica skeleton using anatomical terms for the articulated cells (e.g. stomata, hair, papillae, etc) may also be useful.

NAMING

1. Naming a phytolith type

The name given to a particular phytolith type should be formed by a maximum of up to three descriptors. Each descriptor can be a single word or a combination of words listed in the following order.

1. The first descriptor should describe the **shape** (this can be a 3D or a 2D descriptor whichever is more indicative and it can also include the symmetry, if indicative). The main orientation used when naming the phytolith type should be illustrated in the publication.
2. The second descriptor should describe the **texture and/or ornamentation** if characteristic or diagnostic and if not an artifact of weathering. Weathering features should not be described as surface ornamentation and they should not be part of the name. However, distinctive weathering features may be noted in the description.
3. The third descriptor should be the **anatomical origin** *when this is clear and beyond doubt*. When the descriptor for anatomical origin also conveys a shape then an additional shape descriptor may not be needed. For example, 'bulliform' is a word established in the botanical literature to describe a particular type of cell found in the epidermis of the grass leaf. For this particular case, the word conveys both an anatomical—that particular cell in the grass leaf—and a descriptive meaning—the cell is shaped like a bubble/drop.

A preliminary list of common phytolith types together with their names following the ICPN rules and coding is given in Table 1.

Nomina conservanda. Exceptionally, a name commonly used and made by descriptors not included in the Glossary can be preserved such as when a *name has become so meaningful* and internationally accepted that changing it might create confusion. The *nomina conservanda* rule will be applied in very exceptional cases at the discretion of the ICPN Working Group. The following is a list of

TABLE 1. Naming after ICPN: examples

Schematic drawings*	ICPN names	Former nicknames
	Bilobate short cell	Dumbbell or bilobate
	Trapeziform short cell	Square or rectangle
	Cylindrical polylobate	Polylobate
	Trapeziform polylobate	Polylobate
	Trapeziform sinuate	
	Elongate echinate long cell	Elongate spiny or elongate sinuous
	Cuneiform bulliform cell	Bulliform or fan-shaped
	Paralleipedal bulliform cell	Bulliform
	Acicular hair cell	Point-shaped
	Unciform hair cell	Point-shaped
	Globular granulate	Spherical rugose
	Globular echinate	Spherical crenate
	Cylindric sulcate tracheid	Tracheid

*Several drawings are made after Fredlund and Tieszen (1994).

nomina conservanda names accepted by the first ICPN Working Group:

bulliform
papillae
dendritic
cross
saddle
rondel.

2. Publication of the name

A phytolith type named according to the International Code for Phytolith Nomenclature is considered the published name when the article has been distributed on printed matter to the general public (e.g. peer-reviewed journals, books or

TABLE 2. Nomina conservanda

Schematic drawings*	<i>Nomina conservanda</i>
	Cross
	Dendritic
	Papillae
	Rondel
	Saddle

*Several drawings are made after Fredlund and Tieszen (1994).

proceedings). Publication is not fulfilled by communication at a public meeting (e.g. conference), by web publication, by naming reference collection material or by the issue of microfilms made from manuscripts, typescripts or other unpublished material (e.g. university theses).

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GLOSSARY

Here is presented a first draft of the Glossary of descriptors (nouns and adjectives) for the description and naming of phytolith types. This Glossary is partially based on Bowdery *et al.* (2001). The descriptors used in the Glossary have a

Greek or Latin root. This is to facilitate translation in as many languages as possible without loosing the original meaning. Some descriptors are accompanied by simple, schematic line drawings (patterns can be regular or not).

The descriptors are divided into several categories to facilitate the use of this Glossary.

1. First descriptors: shape
 - 1a. Descriptors for 3D shape
 - 1b. Descriptors for planar or 2D shape
2. Second descriptors: texture and ornamentation
3. Third descriptors: anatomical
4. Other descriptors
5. Prefixes

1. First descriptors: shape

1a. 3D shape

	acicular	needle-shaped
	carinate	keel-shaped
	clavate	club-shaped; gradually thickening from a slender base
	conical	cone-shaped, widest at the base and tapering to the apex
	cubic	three-dimensional shape with six equal square sides
	cuneiform	wedge-shaped
	cylindric	elongate and circular in cross-section
	globular	spherical or nearly so; spheroid
	parallelepipedal	four-sided geometrical figure in which every side is parallel to the side opposite
	pyramidal	with quadrilateral base and a pointed top
	reniform	kidney-shaped
	scutiform	shield-shaped

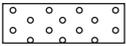
1. Continued

	stellate	star-shaped
	tabular	thin and flat like a table
	trapeziform	having the outline of a trapezoid, with four unequal sides, none of them parallel
1b. Descriptors for planar or 2D shape		
	elongate	much longer than wide
	lobate	having lobes
	bilobate	having two lobes
	polylobate	having more than two lobes linearly arranged
	quadra-lobate	having four lobes, with double mirror symmetry
	fusiform	spindle-shaped; swollen in the middle and narrowing towards the edges
	lanceolate	shaped like a lance-head, several times longer than wide, broadest above the base and narrowed to the apex
	oblong	longer than broad and with nearly parallel sides
	orbicular	circular
	ovate	oblong but broader at one base; egg-shaped
	unciform	shaped like a hook
	stellate	star-shaped
	square	having four sides of the same length, with 90° angles
	rectangle	having four sides, with 90° angles. Each side is the same length as the one opposite to it

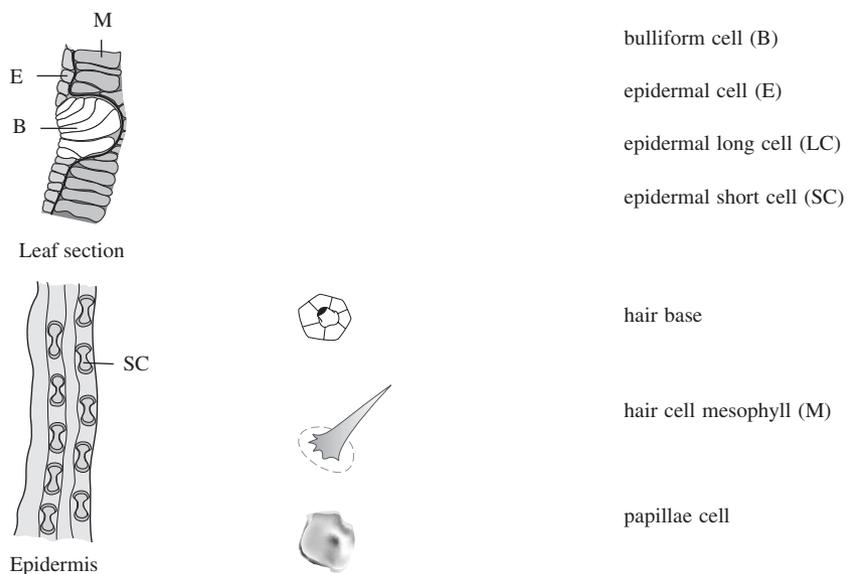
2. *Second descriptors: texture and ornamentation*

	castellate	having square-to-rectangular processes
	cavate	having one cavity within; hollow
	columellate	having straight-sided rod or pillar-like processes that are longer than they are broad
	corniculate	having horn-like projections
	crenate	notched or scalloped; dented with the teeth much rounded
	dendriform	dendritic; having many finely branched processes
	dense	closely compacted together
	echinate	beset with prickles
	equal	uniform or even
	extended	spread out
	facetate	having several flat areas forming the surface
	favose	honeycombed
	fine	consisting of particles smaller than 2 μm diameter
	flat	
	granulate	having a granular surface, composed of fine knobs or knots; grainy
	gross	composed of particles with diameter >2 μm
	irregular	without formal arrangement
	lacunose	marked with small depressions, pitted
	lamine	bearing or covered with layers
	linear	narrow with parallel margins
	papillate	having papillae (minute rounded or acute protuberances)
	pilate	having rod-like processes with concave sides
	psilate	having a smooth, or sub-smooth surface; smooth
	process	a protuberance

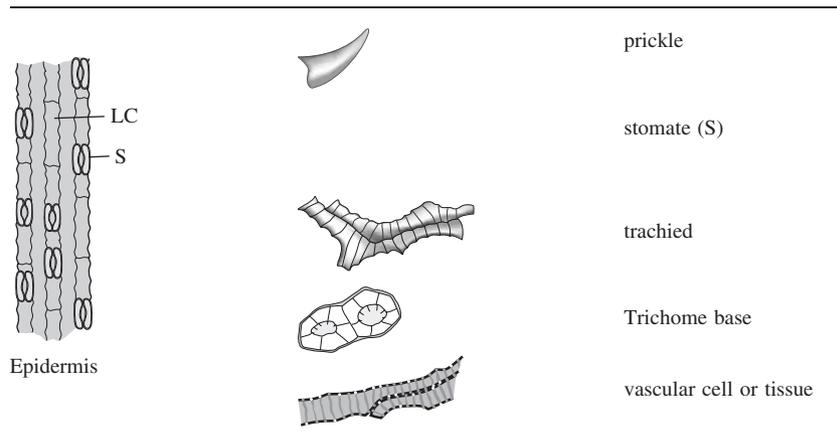
2. Continued

	radiating	to spread like radii from a centre
	regular	conforming in arrangement, symmetrical recurring at fixed intervals, orderly
	reticulate	having horizontally elongated elements forming a net-like pattern
	rugulate	having horizontally elongated elements in an irregular pattern
	ruminated	having a chewed appearance
	scrobiculate	pitted
	sinuate	having a margin with alternating but uneven concavities and convexities
	sparse	thinly scattered or distributed
	spiralling	a curve traced by a point which runs continuously round and round a fixed centre while constantly receding from or approaching it
	striate	having horizontally elongated elements in a parallel pattern
	sulcate	furrowed
	tabular	having a table-like surface; flat
	tuberculate	having tuber-like processes
	verrucate	having irregularly shaped, wart-like processes (<i>clavate, uneven, verrucose, rough</i>)

3. Third descriptors: descriptors for anatomical terms



3. Continued



4. Other descriptors

abaxial	away from the axis or central line
abbreviated	shortened
abnormal(ly)	departing from the usual
abrupt	terminating quickly
accentric	off-centre; cf. eccentric
acuminate	taper-pointed; gradually terminating to a point
acute	sharp-pointed; terminating quickly to a sharp point
adaxial	towards the axis or centre
alate	winged
ampliate	enlarged
angulate	with angles
anterior	front; on the front side
apex	point or tip
articulated	joined; attached
asymmetrical(ly)	lack of correspondence in the shape of parts on opposite sides of a plane (plane of symmetry may be specified)
attenuate	tapering
base	having to do with the part upon which something stands or rests
bifid	cleft in the middle
bisected	completely divided into two parts
bulbous	having a round, enlarged bulb at the end
central	in the middle
compressed	flattened lengthwise
concave	surface curved inwards in the middle
continous	unbroken; having the parts in immediate connection
contorted	twisted or bent
convex	surface curved outwards in the middle
depressed	flattened vertically
disarticulated	not joined; separated
dorsal(ly)	having to do with the higher (top) surface
gibbous	very convex
horizontal(ly)	in a plane parallel to the horizon
interrupted	broken; intermittent

4. Continued

lateral(ly)	having to do with the side
margin	edge
marginal	having to do with the edge
obtuse	blunt
planar	horizontally level or flat
posterior	at or toward the back
reflexed	curved
segmented	having internal divisions or sections
solid	having the interior filled up, not hollow, free from cavities
symmetrical(ly)	having correspondence in the shape of parts on opposite sides of a plane (plane of symmetry may be specified)
tenuis	slender, thin
terminal	having to do with the end
transverse	lying across the body
truncate	terminating abruptly, as if broken off
ventral(ly)	having to do with the lower (or anterior) surface
vertical(ly)	perpendicular to do the plane of the horizon

5. Prefixes

a-	without or lacking
ab-	away from
ad-	to or toward
bi-	two
dis-	between or away from
hyper-	above or beyond
hypo-	below
inter-	between
poly-	many
semi-	half
sub-	below, nearly, almost