PHYTOLITHIC EVIDENCE FOR THE INTRODUCTION OF *SCHOENOPLECTUS CALIFORNICUS* SUBSP. *TATORA* AT EASTER ISLAND

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Rapa Nui is a volcanic island situated on the East Pacific rise by 27° 07′ S and 109° 22′ W making it the most isolated inhabited place in world. Formerly forested (Selling 1961; Flenley and King 1984; Flenley et al, 1991; Orliac 2000), it now presents an open grassy landscape with several introduced plants such as banana, sweet potatoes and sugar cane. As to the sedge species ngaʻatu (*Schoenoplectus californicus* subsp. *tatora* (Kunth) T. Koyama syn. *Scirpus californicus*) the status of this species appears more controversial.

Schoenoplectus is widespread around the Pacific. The South American ethnobotany of *S. californicus* records a broad variety of uses: food for man and his animals, house and boat making, mats and fire ... (Heiser 1979). Tracing the latter species in the vegetation history record of Rapa Nui could be of special interest for documenting the human occupation of the island. The sediments of two crater lakes, Rano Aroi and Rano Raraku, and a caldera, Rano Kau, in combination with archaeological deposits, allow such research. While Flenley et al. (1991) proposed that *Schoenoplectus* is an idiochore species, Dumont et al. (1998), based on a multidisciplinary study of a lake core taken in Rano Raraku, proposed it was introduced by man from the South American continent during the second half of the 14th century. This proposal is supported by:

  − an increase in the biodiversity visible from a depth of 135 cm coinciding with the presence of *S. californicus* fragments from the top of the core till a depth of 135 cm;

  − the identification of two diatom species (*Navicula goeppertiana* (Bleisch) H. L. Smith and *Pinnularia latevittata* Cl.) until now known only for the American continent.

  − a ^{14}C AMS dating of 588 ± 60 BP after calibration assigned to AD 1300-1450 with a 95% confidence interval.

The identification of macro-remains of *Schoenoplectus californicus* is of major importance, but it should be noted that, although their anatomy allows us to distinguish them from the other sedge species actually present on the island, this could not be the case if other *Cyperaceae* species were once present on the island. Phytolith analysis conducted for archaeological samples taken at several sites on the island were conclusive (Cummings 1998). Therefore, it was asked if this process could provide new evidence on the arrival of *S. californicus* at Easter Island.

Previous phytolith analyses on samples from Easter Island concerned material taken in different archaeological contexts: caves and ceremonial structures (*ahu*), households and field gardens (Cummings 1998). The spectra studied attest the presence of phytoliths indicative of grasses of the subfamilies *Panicoideae*, *Chloridoideae* and *Pooideae* and palms. The banana phytolith

(*Musa* sp.) was also suspected for one sample from the La Pérouse area (Cummings ibid., 102). The present research was undertaken to establish whether phytolith analysis could provide new evidence concerning the introduction of *Schoenoplectus* as formulated in the hypothesis by Dumont and collaborators (1998).

PREVIOUS STUDIES ON *CYPERACEAE* PHYTOLITHS

According to Metcalfe (1971:13-16), sedge phytoliths are restricted to the epidermal cells overlying the vascular *sclerenchyma*. This author also reports a wide array of morphotypes: conical-shaped with or without satellites, nodular, wedge- or bridge-shaped, hemispherical verrucate or echinate. Van de Vijver (1999) came to similar conclusions. She also recorded the regular occurrence of a hemispherical echinate morphotype in the genus *Scleria*. Some redundant morphologies were noted: bilobate and bilobate alate, rods, spheroidal with a radiating ornamentation, cell wall fragments and perforate cell wall fragments were observed. Also worth mentioning are the regularities involving disc-shape and rod morphotypes.

Ball (2002) extracted phytoliths from *Schoenoplectus littoralis* leafs, establishing the genus to be silica-accumulating. The *S. littoralis* spectra involves redundancy and multiplicity but is remarkable by including cone-shaped, polyhedral and anticlinal morphotypes (Table 1 and Plate 1). The morphology of *S. californicus* restricts the use of these

Table 1. Morphological description after Ollendorf 1992 of the cone-shaped phytolith illustrated by Ball (2002). Base: A = angular; R = rounded; Elevation: P = pointed; D = rounded; Surface texture: X= psilate; Surface ornamentation: S = satellites present; W = satellites absent.

| Species			F. Runge	
Schoenoplectus littoralis	R?XSM S$_p$	cylindrical verrucate polyhedral anticlinal	G7	A2
Cyperus conglomeratus	RPXSM S$_p$	trapezoid bi– and polilobate	G7	G
	RDXSM S$_p$	parallelepiped	G7	A1
C. irea	RPXSM S$_p$	parallelepiped spherical other	G7	A1 B
C. longus	RP(?)XSM S$_p$	parallelepiped other, unknown	G7	A1
Junallus laeviogatus	A?VSI RPXSM S$_p$	parallelepiped other	G7	A1
	RD(?)XSM RPXSI S$_p$	unknown	G7 G7	

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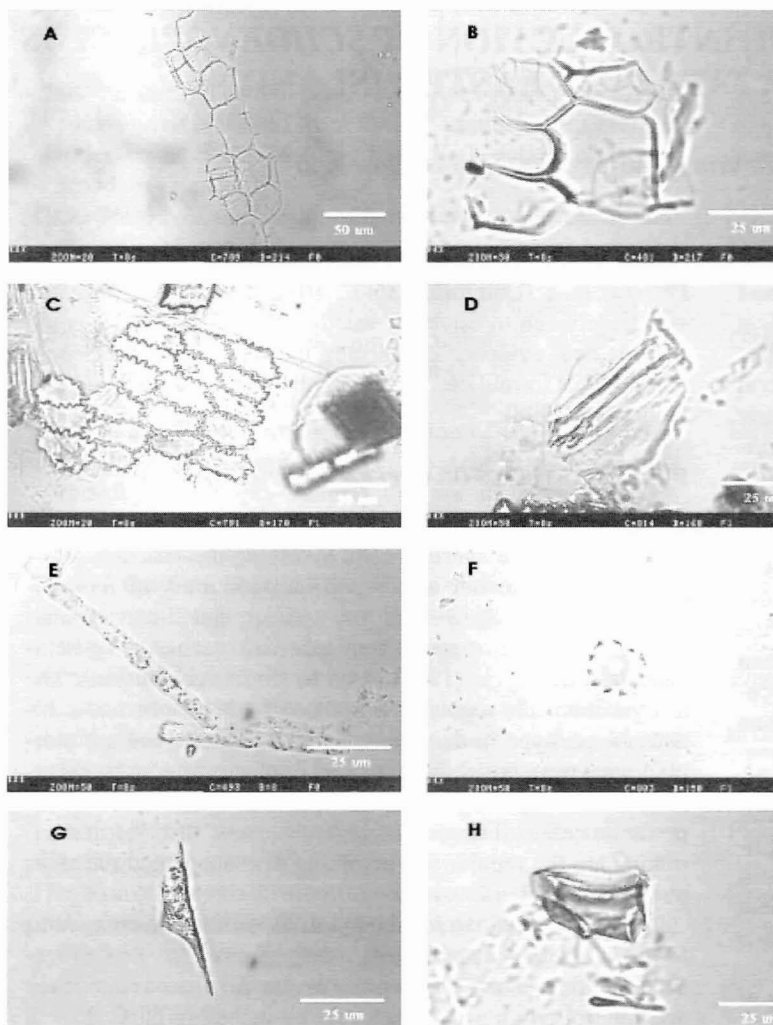
Plate 1. Morphotypes extracted from *Schoenoplectus litoralis* (Photograph T. Ball, 2002). A, B, and C: E2; E and F: E5; G: A6; H: U14. (for the legend of the morphotypes see Tables 3 and 7.

data as its leafs are reduced to their sheath. Moreover, a review of the published descriptions of the conical-shaped phytoliths (Ollendorf 1992; Vrydaghs 2003) suggests that such cone-shaped phytoliths might be redundant in *Cyperaceae* (Table 1, see R?XSM) because, at the generic and specific level, multiplicity is evident. The redundancy of conical-shaped phytolith was revisited by Hart (1990) who reports such phytoliths in *Mimosoideae* (*Acacia schinoides*), *Proteaceae* (*Banksia oblongifolia*) and *Casuarinaceae* (*Casuarina distyla*). The produced quantities vary from rare to abundant. Hart (ibid.:749) concluded that the conical-shaped phytolith "can not be considered to be specific to the *Cyperaceae* in Australian vegetation". It should also be noted that some authors warned for the possible confusion of conical-shaped phytoliths with the *Poaceae* papilla phytoliths (Ball et al. 1996:623; Runge 1999:39).

Piperno's (1989:151) study of phytoliths extracted from the reproductive organs of tropical angiosperms attracted the attention to the achene phytoliths, probably resulting from intracellular and cell wall silicification. At the genus level, these phytoliths seem not to present multiplicity or redundancy. Sedges are represented among the material studied by Piperno .

From the foregoing, it results that several morphotypes could be indicative for *Cyperaceae*, but redundancy seems to be an important problem, particularly with regard to conical-shaped phytoliths. The palynology also reports for each of the Easter Island lacustrine deposits the presence of *Casuarina* (Flenley et al. 1991:101-103) and as said, this genus produced conical-shaped phytoliths.

MATERIAL AND METHOD

For comparative purposes, herbarium specimens of five *Cyperaceae* species were selected: *Schoenoplectus californicus* subsp. *tatora* (syn. *Scirpus californicus* (C. A. Meyer) *Steudel* subsp. *californicus*) [thought to have been introduced] (Dumont et al. 1998) and four species firmly believed to be idiochores (Zizka 1990): *Pycreus polystachys* (Rottboell) Beauvois; *Kyllinga brevifolia*; *Cyperus eragrostis* Lamarck (syn. *C. vegetus* Willdenow) Rottboell; *C. cyperoides* (L.) O. Kuntze. The specimens were taken from the Herbarium of Ghent University (Table 2).

To avoid confusion in the *Schoenoplectus* identification, the morphological approach was completed by considering various circumstantial data originating from several locations of the island. Beside the lacustrine deposits offered by the phytolith analysis of the South West and North West cores, archaeological garden pits, ceremonial contexts and pedological horizons were approached. This material should represent periods prior, contemporaneous, and after the introduction of *S. californicus* proposed by Dumont et al. (1998).

The lacustrine material originates from the South West and North West cores taken in Rano Raraku lake. The sampling strategy, method and study results of the Rano Raraku South West core were published in Dumont et al. (ibid.). As to the North West core, it was sampled with a 10 cm interval between 1.10 m and 2.40 m for phytolith analysis.

The samples from garden pits and pedological horizons are from the La Pérouse area. They were provided by Christopher Stevenson (Virginia Department of Historic Resources) and Joan Wozniak (University of Oregon, Department of Anthropology) and derive from two locations: the North Facing Valley (NFV) and East Facing Valley (EFV). Various pe-

Table 2. Reference material studied.

Species	Accession	Origin
Pycreus polystachys	S. Llatas 367 (GENT)	Peru
Kyllinga brevifolia	M. Lewis 88708 (GENT)	Bolivia
Cyperus eragrostis	K. De Waele 1063 (GENT)	France
C. cyperoides	A. Blomme 170 (GENT)	DR Congo
Schoenoplectus californicus subsp. *totora*	P. Nunez & L. Delgado. 7989 (GENT)	Peru

dological horizons were sampled: Hor. A, Ap, Ap2, Ap/BC, AB and Bt. Nine radiocarbon and 44 hydrated obsidian dates indicate several occupation periods for the La Pérouse area. They range from the 12th century (settlement activities) to the 17th century (ceremonial and settlement activities) with some dates as recent as the 18th and 19th century. The studied La Pérouse samples cover all these periods (Stevenson et al. 2000).

The samples representing ceremonial contexts (NPC2; 3; 4; 5; 6; 7 and SEPC2; C4; 6.1; 6.2; 6.3) were transmitted by the Ahu o Rongo project (D. Huyge and N. Cauwe of the Royal Museum of Art and History of Belgium). Ahu o Rongo is located on the southwest coast of Easter Island. Radiocar-

submitted to HCl and H_2O_2 and embedded in Eukit. The sedimentary material from ceremonial context, archaeological garden pits and pedological horizons was only mixed with a dispersal agent (Calgon) and described under light microscopy (LM) in suspension in de-mineralized water according to Bowdery (1999).

The microscopic analysis of the sedimentary and the reference material was conducted with an Olympus light microscope equipped with Nomarski at magnifications x250, x400 and x1000. The description of the reference material involves SEM observations on the Jeol JSM-5800LV scanning electron microscope (SEM) of the Belgium Royal Botanical Garden of Meise. The material was gold coated. Operating conditions were: accelerating voltage between 10 to 25 KV, beam current of 15 mA and a beam diameter usually in order of 1-2 mm. SEM observations on the Rano Raraku material was not conducted as the material was mounted in Naphrax before SEM observations were planned.

The phytolith description method was largely qualitative. No measurements of the reference material were taken. A non-taxonomic description was adopted for the first description level. In a second step, naming of the phytoliths submitted to identification was conducted according to the International Code for Phytolith Nomenclature (I.C.P.N. 1.0. Madella et al., 2003 a and b). To name phytoliths, the I.C.P.N. 1.0 protocol proposes to use three groups of descriptors, shape, surface texture and ornamentation and an anatomical one if the phytolith has been directly observed in situ or if its origin has been already clearly demonstrated in previous publication (I.C.P.N. 1.0 2003). The detailed description system of cone-shaped phytoliths refers to the Phytolith Systematic book (Ollendorf 1992).

Table 3. Morphological description of the phytoliths extracted from the studied reference material. Base: A = angular; R = rounded; Elevation: P = pointed; D = rounded; Surface texture: X= psilate; Surface ornamentation: S = satellites present; W = satellites absent, S_a = apex satellites; S_p = peripherical satellite, S_i = interapical satellite; Platelets: M = occurs in platelets, I = occurs as individual.

Species	A. L. Ollendorf	system	F. Runge	system
Schoenoplectus californicus	SIP		C3	
Pycreus polystachys	APXSM S_a, S_p and S_i	parallelepiped	G7	G4.1
Kyllinga brevifolia	RPXSI S_p and S_i RPXSM S_p and S_i	parallelepiped trapezoid other	G7	G4.1 G1.7
Cyperus eragrostis	RPXSM S_p and S_i RDXSM S_p, S_i and S_a	parallelepiped other	G7	G4.1 G1.7
C. cyperoides	RPXSM S_p RPXWM	parallelepiped	G7	G4.1

bon and obsidian hydration provide chronometric dates between the later part of the 13th century and the 15th centuries (Huyge and Cauwe 2002).

The plant tissues providing the reference phytolith material were shredded and put in a H_2SO_4 bath for some hours. Afterwards, some HNO_3 was added and, after the reaction, the solution was heated until it become clear. When needed, H_2O_2 was added to improve the extraction process. The method used compares well with the one published by Piperno (1988:125).

Slides of the South West core prepared for diatom analysis were provided for the study of their phytolith content after publication of Dumont et al. (1998). The SW Rano Raraku core samples were submitted to a classical acid treatment and embedded in Naphrax medium (Dumont et al. ibid.) while the sedimentary material of the North West core was

The phytoliths observed in the sedimentary material were classified according to the soil phytolith content inventory published by Runge (1999).

RESULTS

The Easter Island Cyperaceae reference record of phytoliths

Phytoliths were extracted from all the tissues in the *Cyperaceae* reference collection (Table 3). A Sheet Irregular Psilate was the only morphotype extracted from the *Schoenoplectus californicus* specimen (Plate 2; Figures 1 to 4). The margin junctions are frequently Y-shaped. *Sensu* sheets are phytoliths formed on the epidermal surfaces as the result of deposition from watery exudes while the Sheet Irregular Psilate is understood as thin pieces resulting from the cell wall mineralization (Kaplan et al. 1992:155). No Sheet Irregular Psilate phytoliths were extracted from the other reference ma-

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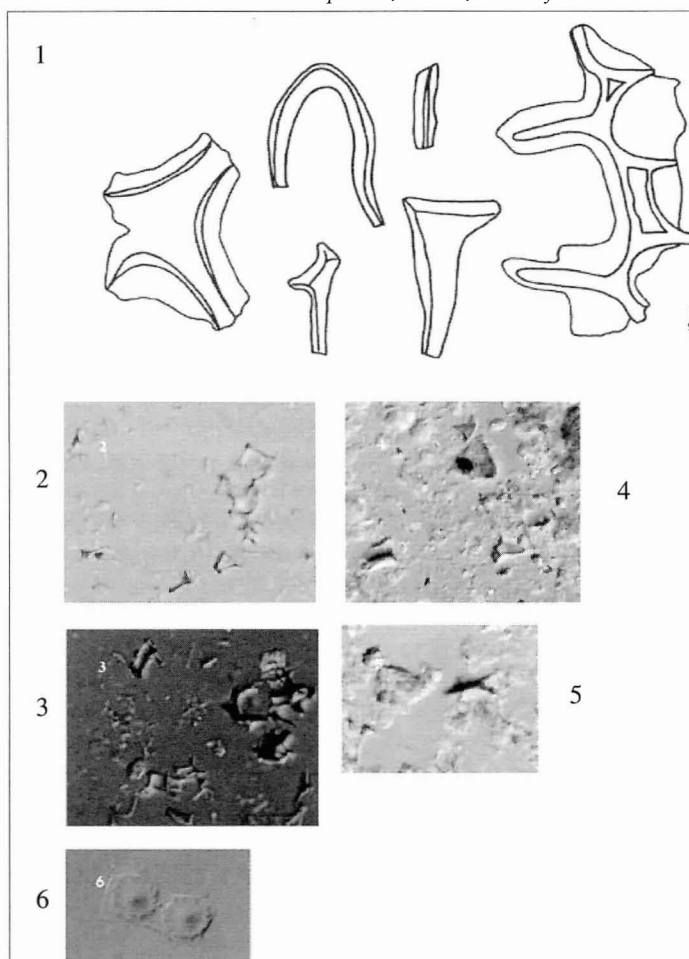
1.*Schoenoplectus californicus* subsp. *Tatora* (reference material)
2.*Schoenoplectus californicus* subsp. *Tatora* (reference material)
LM (x400))
3. *Schoenoplectus californicus* subsp. *Tatora* (Rano Raraku 113 cm depth LM(x400)
4. *Schoenoplectus californicus* subsp. *Tatora* (Rano Raraku 113 cm depth LM(x400)
5. *Schoenoplectus californicus* subsp. *Tatora* (Rano Raraku 113 cm depth LM(x400)
6. Cone-shaped phytolith (*Pycreus polystachys*, reference material (x1000)

terial but conical-shaped phytoliths and other morphotypes were observed (Table 3 and Plate 2; Figures 7 and 8). Multiplicity and redundancy were recorded between the idiochorous sedges. Multiplicity involves parallelepiped phytoliths, trapezoids and other morphotypes such as the disc-shape psilate ones (Table 3). The studied reference collection establishes morphological differences between the *Schoenoplectus californicus* phytolith and these of the Easter Island idiochorous *Cyperaceae*.

A body morphologically similar to the Sheet Irregular Psilate phytolith was recorded only in the Rano Raraku samples (Plate 2, Figures 5 and 6). The Runge's inventory fit it in C3. In the South West core, it appears at 137 cm depth and it can be followed to the top of the core. In the northwest core, it was noted only in the 110 cm depth sample. The foregoing establishes a vertical and horizontal distribution of the Sheet Irregular Psilate at Rano Raraku. No conical-shaped phytoliths (G7 in Runge inventory) have been observed in any of the analysed sediments.

A phytolith with a pentagonal or hexagonal base presenting a lateral rib sculpturing and a nearly central knobby apex was recorded for the South West core from 129 cm to 93 cm depth. It appears to be the achene phytolith, classified as G8 in Runge's inventory and said to be typical for *Cyperaceae*. Piperno (1989 and pers. com.) confirmed the identification and attribution.

CIRCUMSTANTIAL DATA

The Easter Island phytolith inventory
Of the seven categories inventoried by Runge in tropical soils, A, B, D and G were recorded. The A phytoliths are elongated bodies. The observed forms are the A2, 3, 7.1 and 7.2 but cannot be attributed.

The B morphologies are spherical with and without ornamentation. The spherical bodies without ornamentation are regular and psilate. Their size varies from 5 to 13 µm. They correspond with the B1 subcategory. The B ornamentation consist of projections and indentations. As far as optical microscopy allows interpretation, a central fossa straight to radiating is the only observed indentation. The phytoliths presenting this ornamentation have a regular outline and are broader than 20 µm. They have no equivalent in the Runge's inventory and were therefore labelled Bo10. Other B forms are spheroidal. Some reniform occurrences were also recorded. The ornamentation is now composed of spines: short or long with a rounded (verruca) or pointed (conula) apex. The density of the spines on the phytolith surface varies. These characteristics allow us to distinguish 13 morphologies: B3, B5.2, B8 and B9 and Bo1 to Bo9. The latter forms are without equivalent in the Runge's system.

The B3 (and maybe B5.2 and Bo9) phytoliths are indicative of *Palmae* (Runge 1999, 33). The B9's are cystoliths. The General Key for the Plants of the New World Tropics (Piperno 1988, 248-255), suggests that they originate from *Urticaceae* and/or *Moraceae* (see also Bozarth 1992: 208, illustration D).

The D category presents the D4 volcano phytolith, typical of *Musa* (Mbida et al. 2001; Denham et al. 2003).

The G morphotypes are from *Poaceae* or *Cyperaceae* or both. The observed morphologies are G1.1, 1.2, 1.4, 1.7, 2, 3, 4.1, 5 and 8. The G1.1 and 1.2 forms are indicative of the *Panicoideae*, G1.4 of *Chloridoideae*, G1.7 are redundant morphotypes. The *Poaceae* inflorescence produces G5 phytoliths and the different types of trichome, prickle and prickle base are G3 phytoliths. The G4.1 are parallelepiped elements of *Poaceae* or *Cyperaceae* origin. Two more morphologies, not described in the Runge's inventory, were recorded and labelled Go1 and Go2. The Go1 phytolith is a crenate phytolith. Go2 is a sheet phytolith with lunular sided reinforcements Both are typical of *Pooideae* (*Festucoideae*) (Cummings 1998:104; Fredlund and Tieszen 1994:325 and 326 type E1; Piperno and Pearsall 1999:3).

The phytolith distribution (Tables 4 and 5)
No phytoliths were observed in five samples of the

Table 4. General distribution of B morphologies. ARCH: archaeological samples. PEDO: pedological samples. LP: La Perouse. AOR: Ahu o Rongo. RR: Rano Raraku. SW: South West core. NW: North West core. Column in grey indicates the typical B morphologies.

			B.1	B.3	B.5.2	B.8	B.9	Bo1	Bo2	Bo3	Bo4	Bo5	Bo6	Bo7	Bo8	Bo9	Bo10
ARCH																	
	LP	31 - CS2 - Feat.3	X	X	X				X		X		X	X			
		30 - CS3 - Feat.3	X	X	X		X		X		X			X			
		31 - 52 Ext	X		X				X		X			X			
		31 - 52 Ext - Feat.3	X	X	X		X		X		X			X			
		31 - 52 Ext - Feat.1	X	X	X		X		X		X		X	X			
	AOR	NPC2	X		X		X				X			X	X	X	
		NPC3		X	X						X			X		X	
		NPC4	X		X		X		X		X		X	X	X		
		NPC5		X	X		X		X		X			X	X	X	
		NPC6		X	X				X		X		X	X	X	X	
		NPC7		X	X		X		X		X			X	X	X	
		SEPC2	X		X		X				X		X	X	X	X	
		SEPC4		X	X		X		X		X		X	X		X	
		SEPC6.1			X			X	X		X		X	X			
		SEPC6.2		X	X				X		X			X			
		SEPC6.3			X				X		X		X	X	X	X	
RR	SE	89		X		X	X		X		X		X				X
		93		X	X			X	X		X		X				X
		97		X		X	X		X								X
		101		X		X			X								X
		105		X	X	X	X		X		X		X				X
		109		X	X	X	X		X	X	X	X					X
		113		X	X	X			X		X	X					X
		117		X	X		X		X		X		X				X
		121		X	X	X	X		X		X		X				X
		125		X	X	X	X		X		X	X					X
		129		X	X	X	X		X		X			X			X
		133			X		X				X						X
		137		X	X	X			X		X			X			X
		141		X	X	X			X				X	X			X
		145		X	X						X						X
		149		X					X		X						X
		153															X
		161															X
		165		X							X						X
		169												X			X
	NW	110		X	X		X		X		X			X			
PEDO	LP	31 - CS2- A	X	X	X		X		X		X			X			
		31 - 52 Ext - Ap	X	X	X		X		X		X		X	X			
		31 - CS2 - Ap2	X	X	X		X		X		X			X			
		31 - 52 Ext - Ap/BC	X	X	X		X		X		X			X			
		31 - CS2 - AB	X	X	X		X		X		X						
		30 - CS4 - AB	X	X	X	X	X		X		X		X	X			
		30 - CS3 - LMG		X	X				X		X			X			
		31 - 52 Ext - Bt															

5

Table 5. General distribution of B morphologies. ARCH: archaeological samples. PEDO: pedological samples. LP: La Perouse. AOR: Ahu o Rongo. RR: Rano Raraku. SW: South West core. NW: North West core.

|			G 1.1	G 1.2	G 1.4	G 1.7	G 2	G 3	G 4.1	G5	G 8	Go1	Go2
ARCH	Arch	31 - CS2 - Feat.3	X			X			X				
		30 - CS3 - Feat.3	X	X	X	X			X				X
		31 - 52 Ext							X				
		31 - 52 Ext - Feat.3				X			X				X
		31 - 52 Ext - Feat.1	X						X				
	AOR	NPC2				X		X				X	
		NPC3											
		NPC4											
		NPC5											
		NPC6											
		NPC7											
		SEPC2				X						X	
		SEPC4							X				
		SEPC6.1											
		SEPC6.2											
		SEPC6.3											
RR	SE	89	X		X	X		X	X			X	
		93	X	X		X			X	X	X	X	
		97	X			X	X	X	X	X	X	X	
		101	X			X		X	X	X	X	X	
		105	X						X		X	X	
		109	X			X		X	X		X	X	
		113	X					X	X		X	X	
		117	X			X			X		X	X	
		121	X	X	X	X			X		X	X	
		125	X	X	X	X			X		X	X	
		129	X	X					X		X	X	
		133				X		X	X				
		137							X				
		141							X				
		145						X	X				
		149							X				
		153											
		161							X				
		165	X						X				
		169							X				
	NW	110				X			X				
PEDO	LP	31 - CS2- A	X	X		X			X	X			X
		31 - 52 Ext - Ap							X				X
		31 - CS2 - Ap2											
		31 - 52 Ext - Ap/BC											
		31 - CS2 - AB											
		30 - CS4 - AB				X							
		30 - CS3 - LMG							X				
		31 - 52 Ext - Bt											
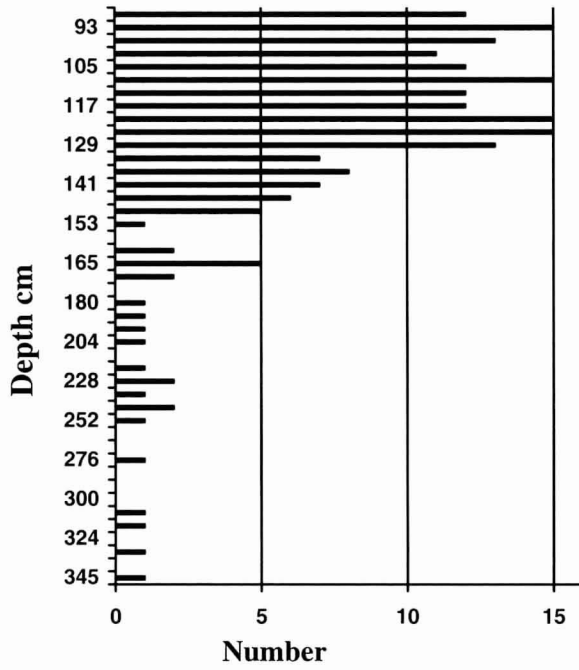
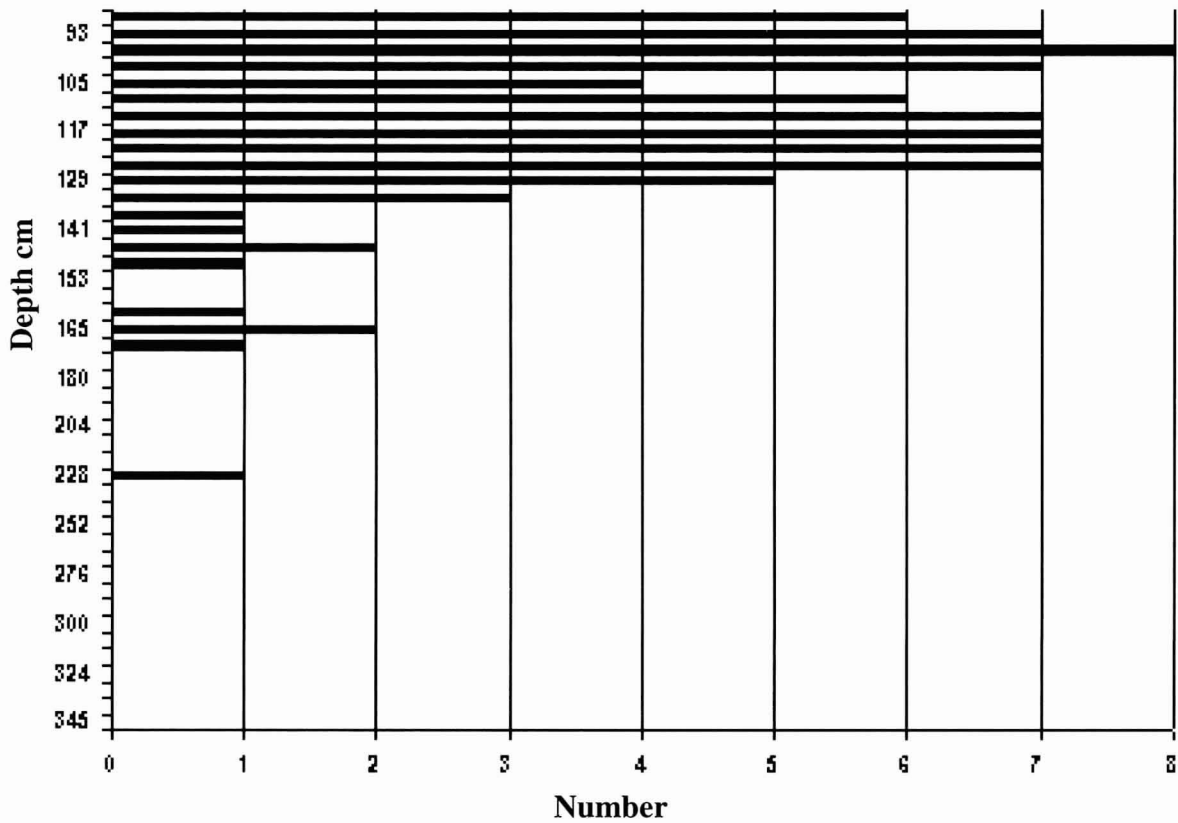Figure 1A. General diversity.
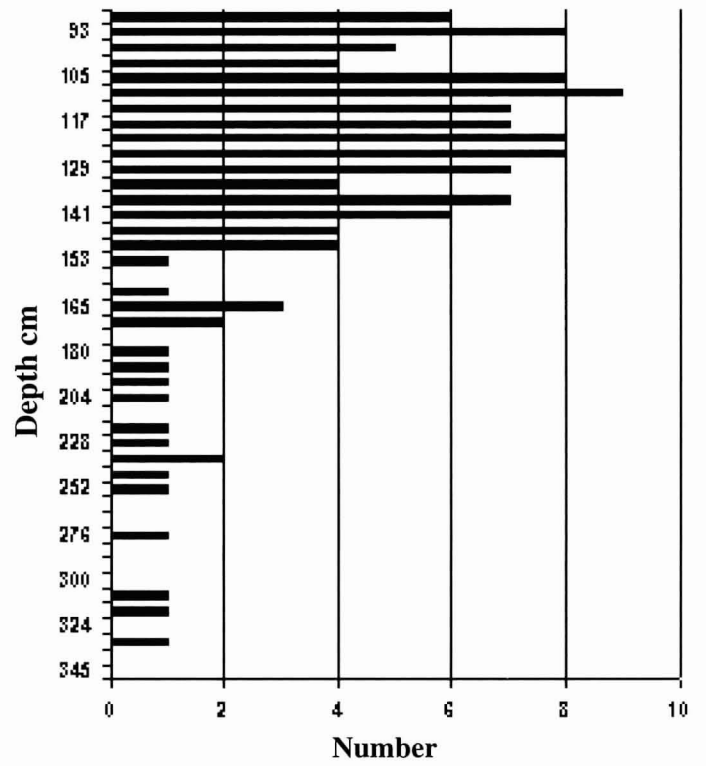
Figure 1B. B diversity.

Figure 1C. G diversity.

Figure 1. Morphological diversity of the Rano Raraku deposits.

7

South West core (260, 268, 284, 292, 300) and in the samples of the North West core except at 110 cm depth. They are also absent from samples 31-52 Ext-Bt of the NFV location at the La Pérouse site. In all other samples phytoliths were present. B and G phytoliths are the most diverse and frequent morphotypes. Their distributions are listed in Tables 4 and 5.

The B3, 5.2, 9, Bo2 and Bo4 were common to all the sedimentary material studied. Bo10 is recorded from the Rano Raraku samples but not from the La Pérouse and Ahu o Rongo samples. The B1 morphology is always absent from the Rano Raraku deposits but common in the archaeological and pedological samples.

Four zones can be distinguished in the diversity histograms of the South West core (Figure 1). Zone 1 starts at the bottom of the core to an approximate depth of 180 cm and is characterized by a low diversity of phytoliths. As no sample was available at a depth of 173 cm, it has been impossible to establish if the Zone 1 upper limit occurs at a depth of 180 or 173 cm. From 169 cm to 153 cm, Zone 2 is situated, in which we observe an increase in the diversity followed by a decrease. The core section between 149 cm and 133 cm depth forms Zone 3 marked by a general increase of the diversity. From 129 cm up to the top of the core, the highest phytolith diversity is observed.

The report of the B and G categories on the diversity histogram (Figure 1) reveals that the differentiation between Zones 2 and 3 is mainly due to B morphologies. G morphologies starting from 169 cm depth contribute to the delimitation of Zones 2 and 3, but they are the main factor of the diversification of Zone 4 starting from 129 cm depth. The increasing morphological diversification records in our view changes in the Easter Island environment. [At a depth of 157, 173, 212, 324 and 340 cm, no sample was available. It has been impossible to attribute the 173 cm depth to Zone 1 or 2. The relevancy of the 157 cm depth to Zone 2 was not in question because at 161 cm and 157 cm the decrease in morphological diversity is clearly marked. At a depth of 149 cm a clear diversification of B morphologies is noted. If this diversification remains equivalent or more important till the top of the core, the G diversification becomes much more important at a depth of 129 cm to the top of the core].

Identification

The *Schoenoplectus* phytolith is a Sheet Irregular Psilate body that cannot be confused with phytoliths of the idiochorous Easter Island *Cyperaceae*. As said a Sheet Irregular Psilate body morphologically similar to the *Schoenoplectus californicus* phytolith is observed in the Rano Raraku deposits down to a depth of 137 cm. It behaves like the other phytoliths in the core. Brought into evidence by acid treatment, its presence coincides with the increasing phytolitarian morphological diversification defining Zone 3. The Sheet Irregular Psilate is characteristic of the Rano Raraku sediments and presents a horizontal distribution for it has been recorded in both cores. It is concluded that this Sheet Irregular Psilate body under discussion is the *S. californicus* phytolith.

DISCUSSION

Morphological evidence

Except for *Cyperus eragrostis* Lamarck (syn. *C. vegetus* Willdenow), essentially American in distribution, the *Cyperaceae* species studied are widespread in the tropics and the subtropics. Several herbarium collections indicate that these species have been collected on Easter Island since 1917 (Zizka 1990). *Cyperus cyperoides* and *Pycreus polystachyos* are lacking in the collection made by Agassiz in 1904, whereas only *P. polystachyos* is lacking for the one made by Fuentes in 1911. This discrepancy may be explained by the restricted and patchy distribution of the *Cyperaceae* which seems to be typical for the Easter Island original floral components (Zizka ibid.:192). Palynological evidence indicates that *Cyperaceae* has been present on Easter Island since remote times (Flenley 1991:102).

The Sheet Irregular Psilate phytolith is understood as resulting from cell wall mineralization in *Schoenoplectus californicus*. Similar phytolith formation loci are known for other sedges, e.g. *Scleria, Diplasia karataefolia, Parapamapania parvibracteata* and *Schoenoxiphium lehmannii* (Van de Vijver 1999, 2000) and probably for the genus *Cyperus* (*C. conglomeratus, C. longus, C. mucronatus* and *C. papyrus*). In the present state of research (Van de Vijver 1999), morphological analogies of Sheet Irregular Psilate's have been seen only in leaf phytoliths of *Schoenoxiphium lehmannii*. However, other morphotypes (conical-shaped, rods, dumbbell, trapezoid and trichome) contribute to the phytolitarian definition of *S. lehmannii* (ibid.). Such multiplicity is not observed in the Rano Raraku deposits. Thus the possible confusion with *S. lehmannii* is avoided. The actually known distribution of genus *Schoenoxiphium* restricted to tropical and southern Africa and Madagascar (Mabberley 1993:528) supports this argument.

Sheet Irregular Psilate morphotypes have also been reported in *Guattera dumetorum* (*Annonaceae*) (Piperno 1988:33, 241). In the studied *Guattera* organs (leaf, fruit and seed), opal phytoliths were extracted only from the leaves. The spectra Sheet Irregular Psilate phytoliths, hair-base, disc-shaped and rods defines *Guattera* (Piperno ibid.). Hair-base and disc-shaped are not part of the Rano Raraku phytolith inventory and the palynological columns (Flenley et al. 1984; 1991) and charcoal analysis (Orliac and Orliac 1996; 1998) do not provide evidence for *Annonaceae*. They are hence few chances to confuse the Easter Island phytolith identified as *Schoenoplectus* with the Sheet Irregular Psilate of *Guattera*.

As a result of volcanic activity, glass shards may be formed. They "consist of the walls of tiny broken bubbles or the junctions of bubbles developed by the vesiculation of silicic magma" (Fisher and Schmincke 1984:96). The stratigraphy of the Rano Raraku core reports two 1 cm thick bands of glassy volcanic ash at a depth of 5 meters (Flenley et al. 1991:89-90) and the possibility exists that some dispersed ash fragments were taken for the *S. californicus* Sheet Irregular Psilate. Petrographic analysis of Easter Island lava rocks classified them as basalts s.s., hawaiitic basalts, benmoreitic flows and comenditic rhyolites (De Paepe and Vergauwen 1997). Only the benmoreitic flows display vesiculation that could lead to glass shard formation. From a morphological point of view, the glass shards appear as cuspate (pointed) or crescent
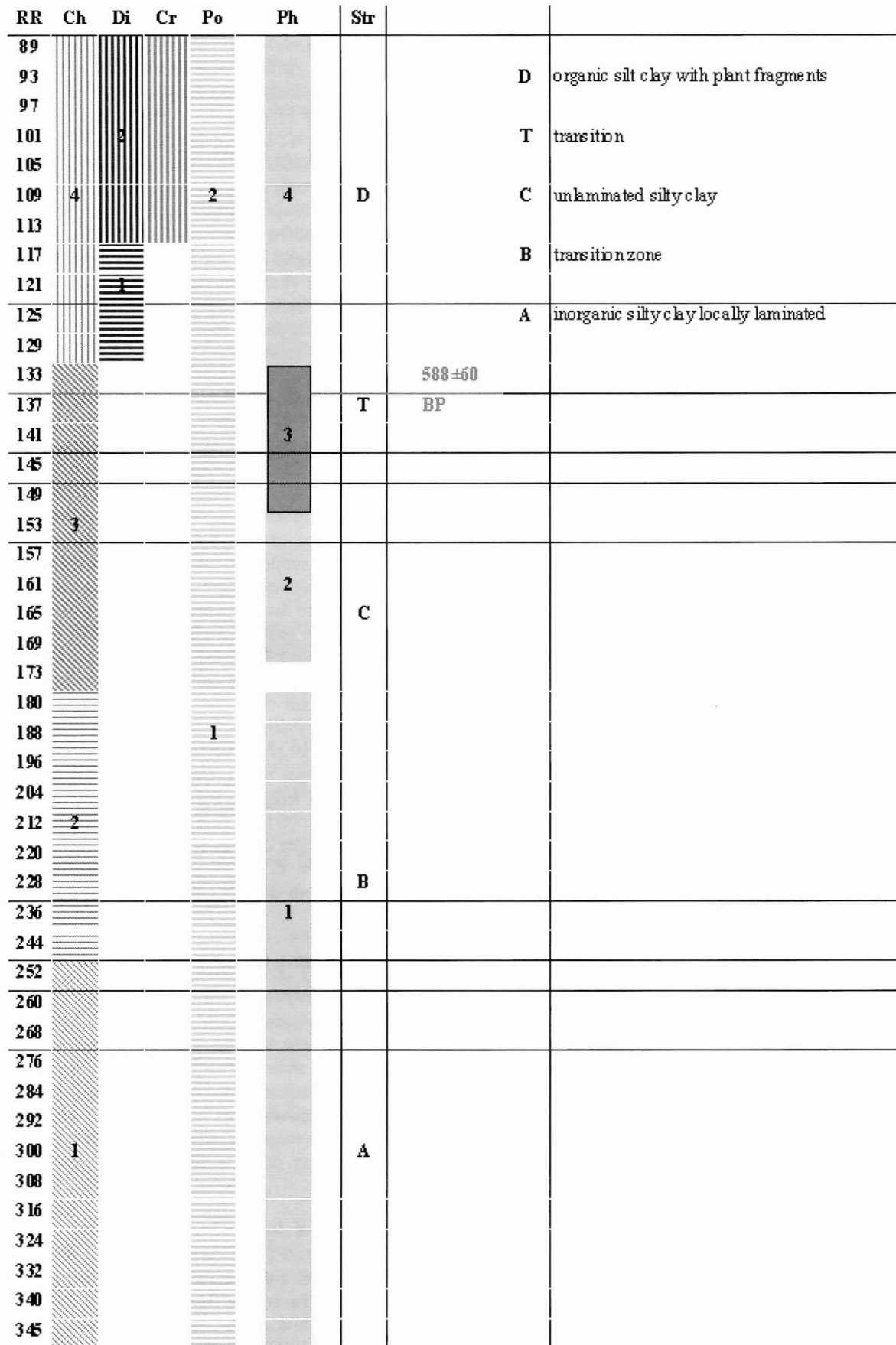
RR	Ch	Di	Cr	Po	Ph	Str			
89									
93								D	organic silt clay with plant fragments
97									
101		2						T	transition
105									
109	4			2	4	D		C	unlaminated silty clay
113									
117								B	transition zone
121		1							
125								A	inorganic silty clay locally laminated
129									
133							588±60		
137						T	BP		
141					3				
145									
149									
153	3								
157									
161					2				
165						C			
169									
173									
180									
188				1					
196									
204									
212	2								
220									
228						B			
236					1				
244									
252									
260									
268									
276									
284									
292									
300	1					A			
308									
316									
324									
332									
340									
345									

Figure 2. Correlations between phytolith core zones and the zones of Dumont and collaborators (1998).
Ch: Chrysophycae. **Di**: Diatoms. **Cr**: Crustacean. **Ph**: Phytoliths. **Str**: Stratigraphy.

9

(lunate-shaped) fragments, Y-shaped in cross section, flat plates or small pumice fragments with a fibrous or cellular structure. This description does not fit the Sheet Irregular Psilate extracted from *Schoenoplectus*. Moreover no pertubation of the Rano Raraku deposits have been reported which might have reworked into the deposits (Flenley 1984:49; Flenley et al. 1984:89). The conclusion is that glass shards cannot be a source of confusion.

Circumstantial evidence
The Easter Island phytolith inventory

With respect to the inventory resulting from the analysis, some differences with previous Easter Island phytolith inventories (Cummings 1998) are noted. They concern the morphological diversification of the B and G spectra.

According to Cummings (ibid.), the B category is represented only by the palm phytolith (B3) which dominates her spectra. The present study also observed spectra dominated by B morphologies but with an important morphological diversity (15 morphologies). It might reflect a greater floristic diversity than generally accepted for Easter Island. Results of charcoal analyses come to a similar conclusion (Orliac and Orliac 1996, 1998; Orliac 2000).

Despite the fact that Cummings (ibid.) identifies the same grasses subfamilies, *Panicoideae*, *Chloridoideae* and *Pooideae* (*Festucoideae*), the present study records smaller G diversity than that found by this author (1998). Cummings may have more experience in dealing with phytolith of grasses and also her samples were taken in typical archaeological contexts and not lacustrine. What ever is the case, the differences in phytolith spectra do not affect the identification of *Schoenoplectus californicus*.

Phytolith distribution

A distinction is here made between characteristic, common and other morphologies. A phytolith is defined as characteristic when recorded for only one site and as common if present in more than half of the samples for all the sites. For the La Pérouse material, the sample from the Bt-horizon is not considered, as usually this horizon does not contain phytoliths, probably as a result of pedological processes. For the Rano Raraku cores, the definition is applied from the first appearance of the morphology in the record. The other phytoliths are those that do not coincide with the definition of a characteristic or common morphology. The Bo10 conforms to the definition of a characteristic morphology. The B3, 5.2, 9 and Bo2 phytoliths are common (Tables 4 and 5).

Appearing at 137 cm depth, the Sheet Irregular Psilate can be followed to the top of the South West core; it is also present in the 110 cm sample of the North West core but absent from the La Pérouse material and Ahu o Rongo. The Sheet Irregular Psilate is therefore characteristic of the Rano Raraku deposits. Easter Island samples originating from various archaeological contexts of the La Pérouse and Te Niu areas were previously submitted for phytoliths analysis: *Ahu*, Surface cave, Field garden and Household (Cummings 1998; Martinsson-Wallin 1998; Wozniak 1998). These phytoliths can be classified in the A, B, D and G categories. No C category phytoliths were observed, this supports the recognition of the Sheet Irregular Psilate which fits in the C category as char-

acteristic of the Rano Raraku deposits.

The inventories establish a morphological diversification dividing the South West core in four zones (Figures 1 and 2). The diversity criterion used assumes that the poorest morphological diversity of the zone is equivalent or superior to the richest diversity of the previous zone and takes into account the separate diversities of the B and G morphotypes in the upper part of the core, corresponding to zones 3 and 4. Despite a morphological diversification of G morphologies starting at 149 cm depth, the distinctiveness of the third zone is due to the B morphologies (Figure 1) and a dominance of the common against the characteristic morphologies (Figure 3). Sample 133 marks the transition between Zone 3 and 4. The distinctiveness of the latter zone is now due to the G morphologies. Compared to the bottom of the core, Zone 3 and 4 are characterised by an important morphological diversification.

The analysis of the chrysophyte stomatocysts of the South West core (Dumont et al. 1998) reveals zones which also testify to a morphological diversification for the upper part of the core. The first zone extends from the bottom of the core 340 cm to 250 cm, the second from 250 to 180 cm, the third from 180 to 130 cm and the fourth from 130 cm to the top. The studies of the diatoms, zooplankton remains and plant pigments support the delimitation of these fourth zones but propose a fifth one from 115 cm up to the top of the core (Figure 2). These divisions are consistent with the lithology of the Rano Raraku sediments (Dumont et al. 1999:415).

The first phytolith zone coincides with zones 1 and 2 as described by Dumont and collaborators (1998). Zones 2 and 3 coincide with their third one and Zone 4, with the upper one. Both zonation systems are not in contradiction and recognise clear increases in the diversity of the various biological remains for the upper zones (Dumont et al. 1999).

The Sheet Irregular Psilate body appears at a depth of 137 cm as part of the onset of the phytolith diversification noted for the upper core and close to the top of third phytolitarian zone. The first *Schoenoplectus* macrofragment is recorded at a depth of 135 cm, also in the third phytolitarian core division

ARCHAEOLOGICAL IMPLICATIONS

The dating

As said, a radiocarbon date was obtained from a Polygonum fragment at 135 cm. The first phytolith of *S. californicus* was found at a depth of 137 cm, indicating that sedge might have been introduced earlier than previously accepted. Based on the sedimentation rate proposed for the upper part of the core (0.7 to 0.88 mm y^{-1}). Dumont et al. (1998:415), the 13th century may now be advanced for the introduction of *Schoenoplectus*.

The Rano Raraku deposits

The B3 (and possibly the B5.2 and Bo9) phytolith is typical for palms. Starting in Zone 2, B3 becomes a common component of the record. However, in Zone 3, palm pollen become rare while in the lower deposits they predominate (Dumont et al. 1999:413; Flenley and King 1984:47; Flenley et al. 1991:101) (Figure 7.3). It is obvious that the palm phytolith and pollen signals are not synchronous in the Rano Ra-

raku deposits. The location of the South West core may help to explain the observed discrepancy. Considerable inwash of rock debris has been noted in all studied cores due to quarrying activities (Flenley et al. 1991:106). In the South West core the top of the inwash is situates between 130 and 135 cm (Dumont et al. 1999:417). It coincides with the upper limit of the third phytolitarian zone which is also marked by a clear dominance of morphologies common to the lacustrine, pedological and archaeological sediments. Therefore at least part of Zone 3 can be interpreted as the result of human activities and therefore also as an archaeological deposit. As the lower limit of the quarry inwash was not defined, it is impossible to assess if other zones of the Rano Raraku sediments could be of an archaeological nature. The discrepancy in the *Palmae* record of Zone 3 could be due to the intensive exploitation of palm trunks by man for the moving of *moai*, resulting in deforestation and reduced palm pollen production. The discrepancy in Zone 4 would be due to comparable but reduced anthropic causes. As to the increasing diversity of G phytoliths synchronous with that of grass pollen in Zone 4, it might be due to natural causes. The first occurrence of the *Schoenoplectus* phytolith was recorded at a depth of 137 cm near the top of Zone 3.

CONCLUSIONS

The phytolith analyses of two cores of the Rano Raraku record the presence of Sheet Irregular Psilate, morphologically similar to the phytolith extracted from *Schoenoplectus californicus* subsp. *tatora*. Contextual considerations point to the fact that Sheet Irregular Psilate behaves like a phytolith and is characteristic of the Rano Raraku deposits. Appearing as the morphological diversity of phytolith starts to increase, the Sheet Irregular Psilate cannot be confused with volcanic glass shards. As other plant species from which Sheet Irregular Psilate phytoliths could derive are not reported for Easter Island, the Sheet Irregular Psilate can be identified as the *Schoenoplectus californicus* phytolith.

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FOOTNOTES

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