CHAPTER 15: THE PHYTOLITH ASSEMBLAGE

A Powers (1987)

15.1 INTRODUCTION

Phytoliths are silica particles which develop in plant tissue and their analysis is relatively new to British archaeology. Very few studies have been carried out with the exception of work by Armitage (1975), MacPhail (1981), Murphy (1986), Robinson & Straker (1991) and the unpublished investigation of Scaife and Murphy. There have not been any previous studies in Britain or overseas of phytoliths in the modern and ancient sediments of coastal dune sequences.

Phytoliths may form within cellular tissues as a result of normal plant growth or as a response to water stress; microbial or insect attack, or mechanical damage (Powers & Gilbertson 1987). The phytoliths assumed the shape of the host tissues in which they form and because of the diversity of cell morphologies, an identifiable range of phytolith morphotypes are produced (Figure 84).

On plant death the phytoliths may be incorporated into the sediments on site (Baker 1959 a & b; Dimbleby 1967; Jones & Beavers 1964 a & b; Kalisz & Stone 1984; Twiss 1983; Smithson 1956; 1958; 1961; Witty & Knox 1964; Yeck & Gray 1972), or they may be finally deposited elsewhere if the plants have been grazed or gathered for consumption or utilisation.

The study of phytoliths has considerable potential in the field of archaeology, both because of their unusual resistance to decay and the potential types information which they can yield (see Rovner 1983). The non-organic (silica) matrix of the phytoliths results in a microfossil that is comparatively resistant to microbial attack, decomposition, oxidation, leaching, attrition, breakage or disintegration. It appears to be chemically stable in a wide range of deposits from acid peats (Powers *et al* 1989) through to very alkaline sands, up to pH 9.8 so far analysed, (Powers & Gilbertson 1987). The wide range of conditions under which phytoliths are relatively inert is in contrast to the preservational behaviour of some other microfossils such as pollen. As a result of their carbon-based structure, pollen and spores are highly susceptible to microbial destruction and oxidation and the recovery of pollen grains is largely limited to depositional conditions which inhibit these destructive forces, eg peat bogs or lake sediments.

In conditions where pollen does not survive, for example in calcareous sand dune sequences at Baleshare and Hornish Point, phytoliths may be the only source of direct evidence for the presence of plants and hence for obtaining details concerning palaeoecological reconstruction of patterns of plant or land use. In addition, the preservation and recovery of phytoliths are potentially universal and not dependent on a specific combination of conditions, necessary for example for the accidental carbonisation of plant macrofossils.

Unlike pollen however, phytoliths are not *species-specific* and because of this they have to be studied not as single examples but as *suites* (assemblages) of the different phytolith shapes (phytolith morphotypes). Despite a general lack of individual specificity, in the study of one particular plant family - the Gramineae (grasses) - phytolith analysis is superior to pollen analysis. The recognition of wild and cultivated taxa in this family is neither simple nor totally reliable in standard palynological approaches, whereas phytolith analysis may, in certain circumstances, distinguish sub-families, genera and species (see Smithson 1958 and Piperno 1985).

Considerable effort has been undertaken in America in an attempt to rationalise *phytolith suite analyses* to obtain accurate correlations between phytolith suite components and the individual plant species from which they originate (see Brown 1984; Rovner 1983). With the exception of one or two species (eg maize) this approach is believed by Rovner (pers comm) to have been largely unsuccessful.

An alternative approach to the use of phytolith analysis is the basis of this account. Instead of attempting to distinguish separate species, we have attempted to encompass wider issues; the potential of phytolith analysis for the elucidation of coastal ecological zones; identification of anthropogenic levels in coastal machair and dune deposits; and the identification of the precise nature and origin(s) of the organic-rich layers.

It may be possible to make precise palaeo-geographical reconstructions based on ecological models or to investigate ancient pastoral or agricultural practices and the transport to, and consumption of, plant and animal remains within the fragile and ecologically important dune and machair systems which fringe the Atlantic seaboard of the Western Isles.

Phytoliths have been recovered from three different types of archaeological sources: from remnants in pottery (Dimbleby 1967; Fujiwara 1982), in food residue from teeth (Armitage 1975; Scaife 1984 unpub) and from the actual archaeological sediments themselves. This study uses Correspondence Analysis and Cluster Analysis to investigate the phytolith suites associated with modern analogue materials and archaeological sites in the machair of North and South Uist. It demonstrates that areas of ancient human occupation and activity are characterised by concentrations of phytoliths which are orders

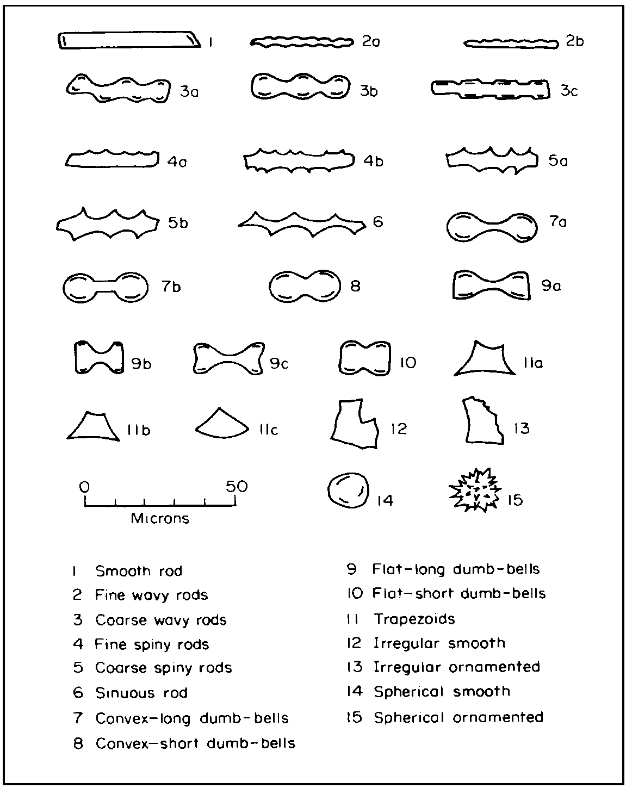


Figure 84. Phytolith morphotypes

Block	Block type	Context No.	Sample No.
6	Windblown sand	001	3751
5	Dumped deposits	004	3507
		011	3508
		016	3512
		035	3516
		027	3519
24	Dumped deposits with midden-site deposits	031	3526
		037	3521
		032	3524
		038	3537
		039	3533
2	Midden-site deposit	055	3558
		072	3562
		059	3566
		076	3570
		082	3599
1	Cultivated deposit	068	3574
23	Windblown	267	3555
		268	3544
		269	3545
		270	3546
		272	3548
		271	3547
22	Cultivated	277	3554
		278	3648
		279	3649
		280	3650

Table 30. Baleshare. Provenance of phytolith samples

Block	Block type	Context No.	Sample No.
13	Midden-site deposit	002	5002
		003	5003
		075	5075
		304	5207
12	Midden-site deposit	306	5206
		305	4226
		015	5015
		134	5034
		52	5153
10	Cultivated deposit	016	5016
09	Midden-site deposit	017	5017
		020	5020
		026	5026
		027	5027
		036	5036
		043	5043
		029	5029
		045	5045
		037	5037
		030	5030
		023	5023
05	Cultivated deposit	079	5148
		083	5083
		080	5080
		092	5092
		089	5089
01	Cultivated deposit	057	5057

Table 31. Hornish Point. Provenance of phytolith samples

of magnitude higher than occur naturally in coastal dune systems. Some aspects of ancient human activity can be distinguished, ie the introduction of peat, turves, plant or animal waste, and possibly differences in grazing/pasture in the area.

15.2 RESEARCH QUESTIONS

Initially two questions were posed by the excavator in the context of the excavations of the ancient coastal sand dunes at Baleshare and Hornish Point;

i) Whether or not it is possible to discriminate between different sedimentary origins on the basis of postulated differences in the likely frequencies of phytoliths. In particular to distinguish between assumed stable *humic* layers, believed to represent periods of soil formation and/or human occupation and *non-humic* sands, believed to represent the free accumulation of dune sand in a more open, less vegetated depositional environment.

ii) To what extent is it possible to recognise associations between the relative abundance of various phytolith morphotypes and deposits from dune environments?

Subsequently, a third question was also posed;

iii) To what extent is it possible to identify the source of the humic material in the archaeological deposits on the basis of abundance and diversity of phytoliths?

Twenty seven samples were chosen from each of the two sites of Baleshare and Hornish Point. Their provenances are shown in Tables 30 & 31. The 'Block' and 'super-Block' terminology employed here is that employed in the field by the excavation team.

15.3 RESULTS

Details of the raw data counts can be found in Powers *et al* 1986, Tables 10-23. Originally, relative abundance counts were plotted up from the raw data with the frequency of each morphotype expressed as a percentage of 250: the total phytolith count per sample (*ibid,* Figures 20 & 21, Table 25). However, despite the obvious advantage of being able to present the data in the form of two concise diagrams, relative abundances can be misleading. For example, an apparently significant variation in the overall frequencies of Trapezoids between the Baleshare and Hornish Point samples (*ibid,* Table 25) actually resulted from a depression of the percentage of Trapezoids in the Baleshare samples by a significant increase in the proportions of Medium Smooth Rods and Fine Spiny Rods. Therefore, absolute frequencies of phytoliths have been plotted (Figures 86 & 88) as a means of presenting the data. These bar charts can provide a means of making visual

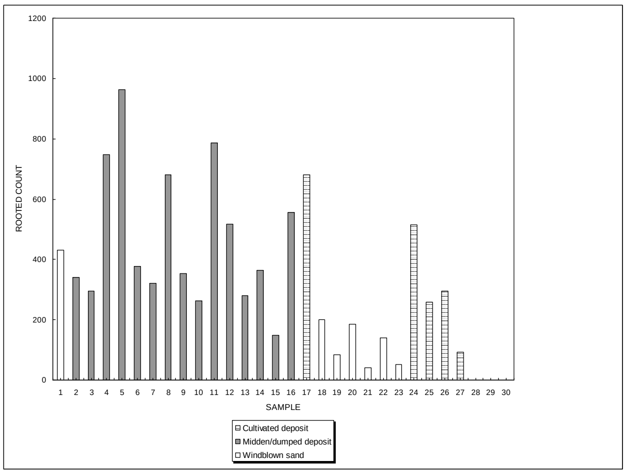


Figure 85. Baleshare; concentration of phytoliths per gram (rooted)

comparisons between samples within blocks, between blocks and between sites in order to attempt to identify any patterns of difference and/or similarity that may exist.

15.3.1 Inter-, and intra-site variability

This section provides a review of a statistical analysis of the results together with discussions of any patterns or trends in total abundance and composition of phytolith suits that are present. Intra-site variations are outlined first (Baleshare then Hornish Point), followed by details of inter-site variations on both a general then more detailed level. Included in the latter section is an investigation into the likelihood of isolating and defining 'Block-specific' phytolith suites. This is of interest in terms of equating archaeological deposits with their origins, after the unexpected results achieved from the modern analogues (Noltland and Ainsdale) which negated the present attempt to define different ecological zones from phytoliths because of the paucity of these particles in dune sands. The final part of this section deals with a comparison of the archaeological data with modern organic samples in an endeavour to determine the exact origins of the material recovered from the organic horizons.

15.3.2 Statistical structure of phytolith data from archaeological deposits

In addition to visual comparisons, the data was subject to statistical analysis by Ms Joanne Padmore, Department of Probability and Statistics, University of Sheffield (Padmore 1987). Two statistical analyses were performed;

i) Correspondence Analysis; essentially a scaling technique for displaying the rows and columns of a data matrix as points in corresponding low dimensional vector space. The approach allows the different properties of samples spaces to be superimposed to obtain a joint display which may be interpreted visually (Greenacre 1984; Padmore 1987).

ii) Cluster Analysis; using two separate techniques, Ward's Method and Iterative Relocation. The techniques were used to simplify the data by separating it into its constituent groups. Samples are clustered using the information for each sample given by its variable (for further details see Padmore 1987 and Powers *et al* 1989).

15.3.3 Intra-site variations: Baleshare

The range of phytolith concentration per one gram of sediment was 2,000 to 938,000 for the Baleshare samples (see Figure 85). It is possible to rank the Baleshare blocks according to the general total phytolith concentration (per one gram of sediment) of each Block (Table 32). With the exception of the single sample that constitutes Block 01, the ranking of blocks divides into two halves: (1) the windblown sands and cultivated (2) the midden-site and dumped deposits. The low frequencies of phytoliths in the windblown sands and cultivated deposits were expected from previous modern analyses (Powers & Gilbertson 1987) and are unlikely to be an artefact of preservation or age.

Analysis of the compositions of the phytolith suites recovered form the Baleshare samples indicates that there is considerable overlap in the proportions of the various morphotypes that constitute the suites, for example large proportions of smooth rods and Trapezoids as compared with low proportions of Sinuous Rods (see Figure 86). However, a combination of visual appraisal of the bar charts and statistical analysis to support these observations, concluded that four Baleshare blocks possessed minor suite differences which could distinguish the samples from these blocks from the remaining samples. In addition to the standard patterns of common/uncommon morphotypes these four blocks had unusually high or low proportions of certain morphotypes (Table 33).

In addition to those blocks which had significantly different phytolith suites when compared with all blocks, there were a further number of separate Block comparisons where variations also appeared (Table 34). These relative differences in suite composition highlight the range of the variation within the Baleshare samples. Although all the samples overlap one another in terms of total suite composition, they possess differences in respect of one or two morphotypes that are only significant when the 'extremes' of the spectrum of values recovered for that particular morphotype are compared with one another.

Block	**Block type**	**Phytoliths per gram**
23	Windblown sands	few
22	Cultivated deposit	^
06	Windblown sands	^
02	Midden-site deposit	^
01	Cultivated deposit	^
24	Dumped/midden-site deposit	^
05	Dumped deposit	many

Table 32. Baleshare. Ranking of Blocks based on phytolith concentrations

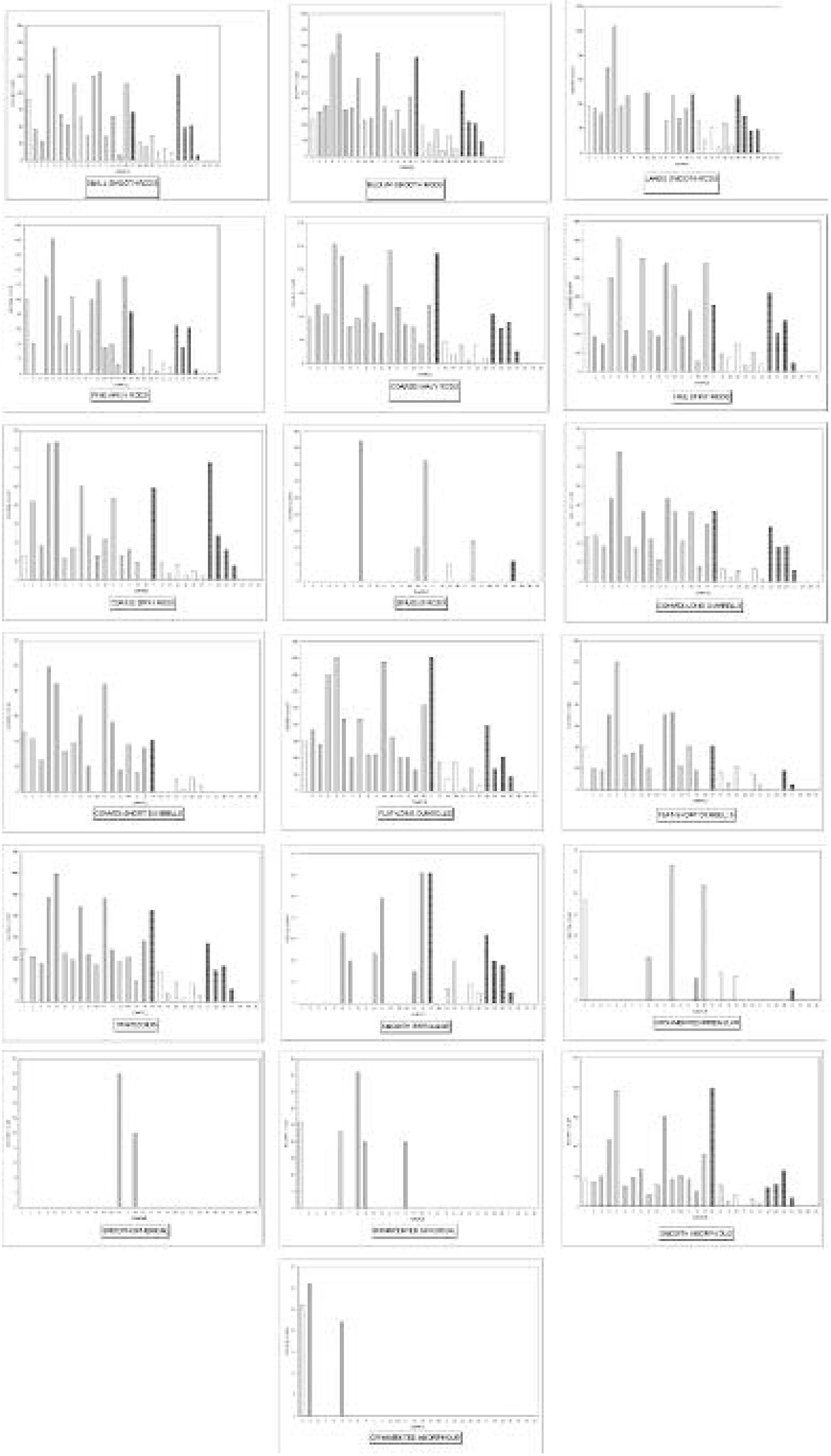


Figure 86. Baleshare; absolute phytolith frequencies (for key see Figure 85)

Block No.	Block type	Component which is significantly different from norm
06	Windblown sands	more Ornamented Irregulars
05	Dumped deposit	fewer Fine Spiny Rods
23	Cultivated windblown sand	fewer Trapezoids
23 22	Cultivated windblown sand & cultivated deposit	higher ratio of Fine Spiny Rods to Coarse Wavy Rods

Table 33. Baleshare. Blocks with phytolith suites significantly different from other Baleshare samples

	Block no. & type	vs	Block no. & type
1 *Morphotype*	05 Dumped deposit *few Fine Spiny Rods*		23 Windblown sands *many Fine Spiny Rods*
2 *Morphotype*	24 Dumped/midden *few Coarse Spiny Rods*		22 Cultivated deposit *many Coarse Spiny Rods*
3 *Morphotype*	02 Midden-site *few Coarse Spiny Rods*		22 Cultivated deposit *many Coarse Spiny Rods*
4 *Morphotype*	01 Cultivated deposit *few Fine Spiny Rods* *many Coarse Wavy Rods*		06 Windblown sands *many Fine Spiny Rods* *few Coarse Wavy Rods*

Table 34. Baleshare. Blocks shown by Correspondence Analysis to have specific suite components that are at opposite extremes of the range of values recorded

Block	GROUP 1	GROUP 2	GROUP 3
06	001	–	–
05	027	004, 011, 016, 035	–
24	037, 032	031, 038, 039	–
02	055, 059	072, 076	082
01	–	068	–
23	–	267	268, 269, 270, 272, 271
22	–	277, 278,279,280	–

Table 35. Baleshare. Cluster Analysis

Block	Block type	Phytoliths per gram
01	Cultivated deposit	few
09	Midden-site deposit	^
13	Midden-site deposit	^
12	Midden-site deposit	^
10	Cultivated deposit	^
05	Cultivated deposit	many

Table 36. Hornish Point. Ranking of Blocks based on phytolith concentrations

The morphotypes exercising the greatest influence on the statistical Correspondence Analysis of the Baleshare samples were;

i) Fine Spiny Rods (correlating with low frequencies of Coarse Wavy Rods and Coarse Spiny Rods).

ii) Small and Medium Smooth Rods.

iii) Trapezoids.

iv) Ornamented Irregulars.

The cluster analysis of the Baleshare samples resulted in a three group solution that was essentially identical for both the Ward (Table 35) and the Relocate method. The only difference was a transposition of samples 22.227 (ie sample from Block 22, [277]) and 23.272 in the Relocate ordering.

Only one multi-sample Block (Block 22) lay entirely within one group, indicating substantial overlap between samples from different blocks. In addition the cluster analysis reveals that;

i) The Blocks are divided into three groups along general stratigraphic lines.

ii) Blocks 06, 05, 24, 02, 01 and 22 have phytolith suites whose composition share common features.

iii) Block 23 stands out as being significantly different from the rest of the Baleshare Blocks.

iv) Block 06 is significantly different from Block 23.

v) Block 06 may be different from Blocks 5, 24 and 02 but it is impossible to be sure as the single sample from Block 6 overlaps with a few contexts from the other Blocks.

vi) The samples from Block 22 (all within group 2) are very homogeneous in terms of their phytolith suites.

vii) The samples from Block 23 (mainly within group 3) are very homogeneous in terms of their phytolith suites.

viii) The samples from Block 2 exhibit the least intra-Block homogeneity but the division into three groups orders the samples according to sample number ie the 50's, 70's and 80's. This may or may not be significant.

15.3.4 Intra-site variations: Hornish Point

The range of phytolith concentrations per 1 gram of sediment was 3,000 to 750,000 (Figure 87). It is possible to rank the Hornish Point samples according to the general total phytolith concentration (per 1 gram of sediment) of each Block (Table 36).

The relative absence of phytoliths from the single-sample Block 1 separates it from the remaining Hornish Point blocks. Block 9 is similarly separated from its neighbours by a low (but not as low as Block 1) phytolith concentration.

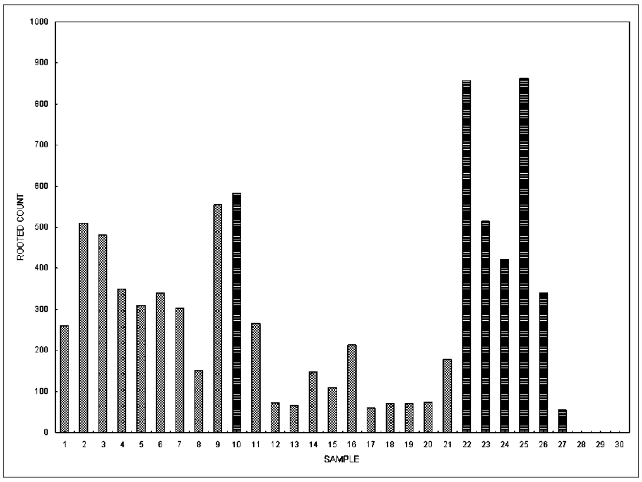


Figure 87. Hornish Point; concentration of phytoliths per gram (rooted) (for key see Figure 85)

Blocks 13, 12, 10 and 05 are grouped together on the basis of total phytolith concentrations which is not surprising since these form part of a 'super-Block' (Block 2). In general terms there is a decrease in phytolith concentration per gram of sediment with increasing age of the sediment. However, this is far from a perfect correlation. For example Block 1, with the lowest concentration of phytoliths, is the oldest, but the richest samples were those derived from the next oldest Block, Block 5.

Variations in phytolith concentrations between samples are probably best explained not by age but by the origins of the samples themselves. The relative absence of phytoliths from Block 1, a cultivated deposit, was expected from the results of phytolith analyses of modern cultivated (vegetated) dune horizons (Powers *et al* 1989). The richness of the two remaining cultivation horizons (Blocks 5 and 10) from Hornish Point is less easy to understand, but it may stem from differences in type and/or density of vegetation cover and whether or not the vegetation cover was natural or managed.

As with the Baleshare samples, the Hornish Point samples share many components of their phytolith suites (see Figure 88); components that are similarly recovered in common proportions (eg many Trapezoids and Smooth Rods, few Sinuous Rods). This overlap in phytolith suites (see Padmore 1987) is not surprising because five out of the six blocks sampled for phytoliths constitute part of the Super-Block 2.

It has been possible however to recognise significant minor differences in the suites on the basis of visual appraisal and Correspondence Analysis. This has resulted in the division of the blocks into two groups on the basis of the proportions contained of the two morphotypes Medium Smooth Rods and Fine Spiny Rods;

Group 1 – Blocks 13, 12, and 10 few Medium Smooth Rods many Fine Spiny Rods.

Group 2 – Blocks 09, 05 and 01 many Medium Smooth Rods few Fine Spiny Rods

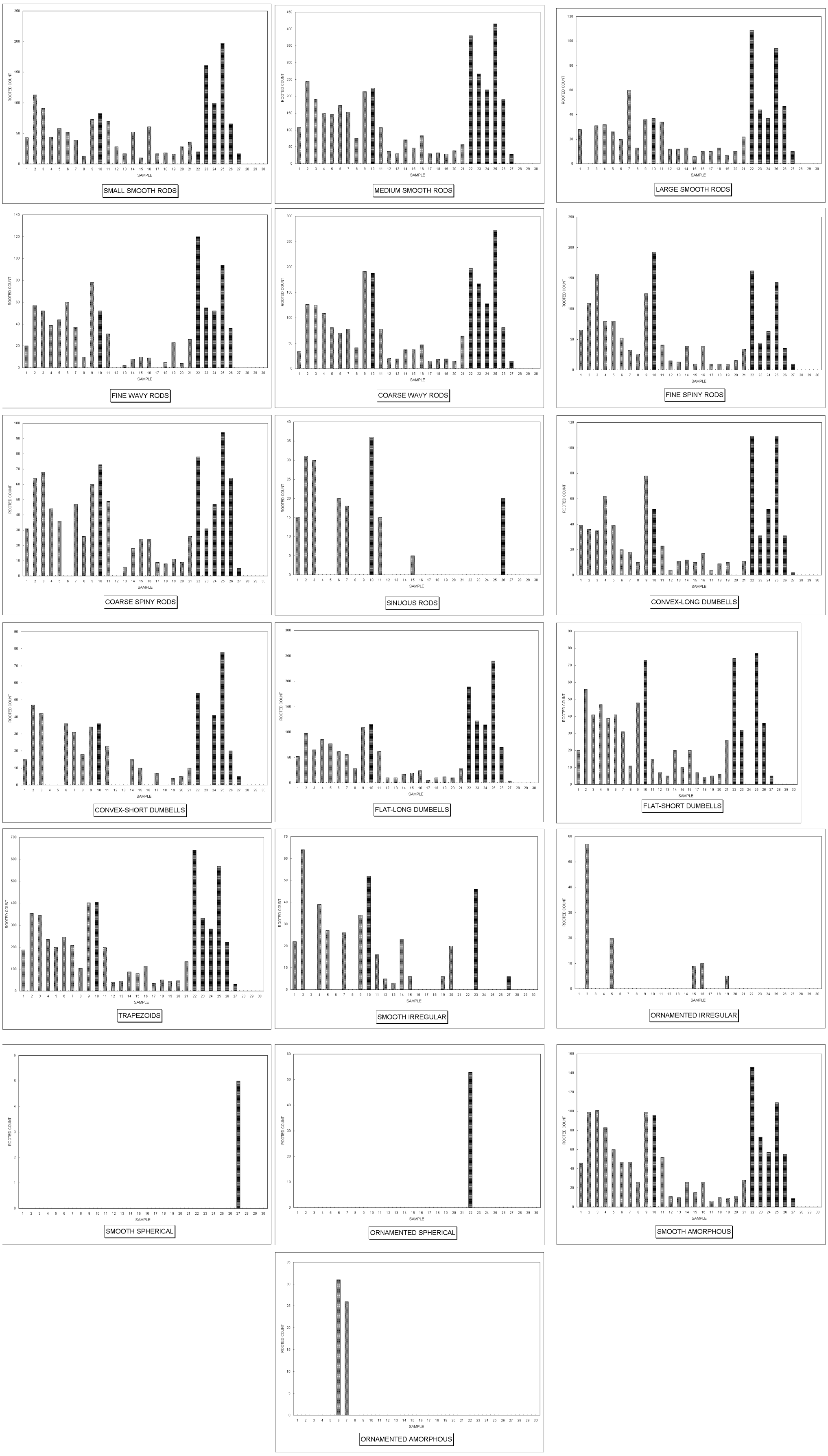
The samples from Block 12 actually overlap between the two groups, a not unexpected feature because the blocks belong to Super-Block 2, which has other Block elements from both groups.

As a result of the homogeneity of the Hornish Point samples only one Block, 01, possessed a phytolith suite with elements which were significantly different from those of all the remaining Hornish Point blocks. This difference was in respect of two morphotypes, namely the presence of the Smooth Spherical morphotype and the fact that it possessed few Convex-long Dumb-bells. Block 1 however, possessed minor differences in its suite composition that made it stand out by comparison with other Hornish blocks, namely that it possessed the Smooth Spherical morphotype and that it had low frequencies of the Convex-long Dumb-bell. In addition to Block 01; which was different to the rest of the Hornish Point samples, there were two further Block comparisons involving four different blocks (see Table 37) indicating that in respect of several morphotypes the contrasting Block pairs represent the opposite extremes of a range of values.

Of great interest is the fact that the samples from Hornish Point blocks exhibit temporal ordering in respect of four morphotypes. The proportions of Fine Spiny Rods and Coarse Weavy Rods were seen to decrease with increasing age of sediment while those of Medium and Small Smooth Rods increase with increasing age. These changes through time are exemplified by the comparison of the two single-sample blocks, Block 1 being the oldest Block sampled for phytoliths and Block 10 originating from near the top of the stratigraphy (see above). Both of these blocks have been designated as cultivation deposits but their proportions of Fine Spiny and Coarse Wavy Rods to Medium and Small Rods are clearly reversed (see above).

	Block no. & type	**vs**	**Block no. & type**
1	10 Cultivated deposit		01 Cultivated deposit
Morphotypes	*many Fine Spiny Rods*		*few Fine Spiny Rods*
	many Coarse Wavy Rods		*few Coarse Wavy Rods*
	few Medium Smooth Rods		*many Medium Smooth Rods*
	few Small Smooth Rods		*many Small Smooth Rods*
2	13 Midden-site deposit		05 Cultivated deposit
Morphotypes	*many Fine Spiny Rods*		*few Fine Spiny Rods*
	few Medium Smooth Rods		*many Medium Smooth Rods*
	few Small Smooth Rods		*many Small Smooth Rods*

Table 37. Hornish Point. Blocks shown by Correspondence Analysis to have specific suite components that are at opposite extremes of the range of values recorded



SMALL SMOOTH RODS

MEDIUM SMOOTH RODS

LARGE SMOOTH RODS

FINE WAVY RODS

COARSE WAVY RODS

FINE SPINY RODS

COARSE SPINY RODS

SINUOUS RODS

CONVEX-LONG DUMBELLS

CONVEX-SHORT DUMBELLS

FLAT-LONG DUMBELLS

FLAT-SHORT DUMBELLS

TRAPEZOIDS

SMOOTH IRREGULAR

ORNAMENTED IRREGULAR

SMOOTH SPHERICAL

ORNAMENTED SPHERICAL

SMOOTH AMORPHOUS

ORNAMENTED AMORPHOUS

Figure 88. Hornish Point; absolute phytolith frequencies (for key see Figure 85)

Block	GROUP 1	GROUP 2	GROUP 3	GROUP 4
a) Ward's method				
13	002, 003, 075, 304	–	–	–
12	306, 134, 052	305, 015	–	–
10	016	–	–	–
09	017, 036, 023	–	026, 043, 045, 037	020, 027, 029, 030
05	089	–	079, 083, 080, 092	–
01	–	–	–	057
b) Relocate method				
13	002, 003, 075, 304	–	–	–
12	306	305, 015	134, 052	–
10	016	–	–	–
09	017	–	026, 036, 043, 045, 037, 023	020, 027, 029, 03
05	–	–	079, 083, 080, 092, 089	–
01	–	–	–	057

Table 38. Hornish Point. Cluster Analysis

The morphotypes that exercised greatest influence on the Correspondence Analysis of Hornish Point samples were;

i) Medium and Small Smooth Rods

ii) Fine Spiny Rods

iii) Coarse Wavy Rods

iv) Convex-long Dumb-bells

The cluster analysis of the Hornish Point data resulted in a four group solution. The results using the Relocate method and Ward's method produced slightly different four group solutions, with Groups 2 and 4 being identical in both cases but groups 1 and 3 being slightly different (Table 38).

The Cluster Analysis of the Hornish Point samples revealed that;

i) The Blocks may be divided into four groups in general stratigraphic order.

ii) Blocks 13, 12, 10, 9 and 5 have samples whose phytolith suites share common features.

iii) Block 1 may be very different from Blocks 13, 12, 10 and 5 although it consists of only one sample.

iv) Blocks 1 and 9 have certain samples with common suite features.

v) Block 13 may be very similar to Block 10 (although the latter consists of only one sample).

vi) Block 13 may be very different from Block 1 (although the latter consists of only one sample).

vii) Block 13 exhibits the greatest intra-Block sample homogeneity of all the Hornish Point blocks sampled.

viii) Block 5 also exhibits considerable intra-Block sample homogeneity.

ix) Block 9 exhibits the least intra-Block homogeneity.

x) Samples 305 and 15 from Block 12 are not only distinctive from the rest of Block 12 but from all the remaining Hornish Point Blocks.

Phytolith concentration

There is considerable intra-site variation in the concentration of phytoliths in the Baleshare and Hornish Point samples, but the data indicates no significant inter-site separation. The sites exhibit extensive overlapping in the range of phytoliths recovered per gram of sediment; the results for Baleshare were 2,000 to 938,000 and those for Hornish Point 3,000 to 750,000 phytoliths per gram (Figures 85 & 87). Of the two sites, Baleshare possessed less within site homogeneity than Hornish Point in terms of concentration of phytoliths per sample. Baleshare produced both the sample with the least and with the most number of phytoliths per gram (contexts 270 - windblown sand; and 05 - midden-site deposits respectively).

It is possible to rank all the blocks analyses on the basis of total phytolith concentration per gram of sediment (Table 39) but there is no direct and absolute correlation between sample origin (as indicted by the excavation team) and phytolith concentration per gram of sediment. If there were, one would expect an ordering of samples according to type. There is no evidence of a significant difference between those samples described by the excavator as 'dumped deposits' and those labelled 'midden-site'. In terms of phytolith concentrations the midden and dumped deposits greatly overlap with the dumped deposit blocks containing some samples with slightly more phytoliths than the plain midden-site blocks. Generally (though far from exclusively) there is a ranking of blocks according to type, ie windblown sand and cultivated deposits have few phytoliths per gram while midden-site and dumped deposits have many. However, an appraisal of Figures 85 and 87 soon highlights the many and various exceptions to this ranking. For example, Hornish Point Block 9,

Block	**Block type**	**Phytoliths per gram**
B 23	**Windblown sands**	**Few**
HP 01	**cultivated deposit**	^
HP 09	**midden-site deposit**	^
B 22	**cultivated deposit**	^
B 06	**Windblown sands**	^
B 02	**midden-site deposit**	^
HP 13	**midden-site deposit**	^
HP 12	**midden-site deposit**	^
HP 10	**cultivated deposit**	^
B 01	**cultivated deposit**	^
B 24	**Dumped/midden site**	^
HP 05	**cultivated deposit**	^
B 05	**dumped deposit**	**Many**

B = Baleshare; HP = Hornish Point

Table 39. Baleshare & Hornish Point. Ranking of Blocks according to phytolith concentrations

midden-site deposit, is very poor in phytoliths while Baleshare Block 6, windblown sand, is rich in them in comparison with blocks 23, windblown sand, or 22, cultivated deposit. Similarly, the richness of Hornish Point Block 5, a cultivated deposit, exceeds all other blocks from that site even the midden-site deposits.

Significantly, all the archaeological samples possessed higher concentrations of phytoliths per gram of sediment than occur in the modern samples, both equivalent (ie modern windblown sands versus ancient windblown sand) and parallel samples (ie modern organic deposits such as peat and faeces, versus ancient organics midden deposits see Powers *et al* 1989 for further details).

Suite composition

All the samples from the sites of Baleshare and Hornish Point have similar patterns in phytolith suite composition. The suites have high frequencies of Trapezoids and either Small or Medium Smooth Rods, with lesser numbers of the Edge Ornamented Rods. The four types of Dumb-bells are consistently present but at fairly low frequencies, while the less distinctive groups of irregular, spherical and amorphous morphotypes are intermittently represented at low frequencies, with an emphasis on the smooth rather than ornamented forms.

Despite these consistencies within suites, it is possible to differentiate between samples from Hornish Point and those from Baleshare. Two distinct differences between Baleshare and Hornish Point samples (‘a’ and ‘b’ below) were very obvious and noted easily by visual appraisal of the bar charts (Figures 86 & 88). These variations were confirmed as significant inter-site differences by Correspondence Analysis (see Padmore 1987 for full set of analyses) which also highlighted a further significant variation in suite composition (‘c’ below).

Group	**Block**	**Block type**
1	**B** 06	Windblown sand
2	**B** 24	Dumped/midden site deposit
	B 02	Midden-site deposit
	B 23	Windblown Sand
	B 22	Cultivated Deposit
3	**B** 05	Dumped deposit
	B 01	Cultivated deposit
	HP 13	
	HP 12	
	HP 10	Cultivated deposit
	HP 09	
	HP 05	Cultivated deposit
4	**HP** 01	Cultivated deposit

B = Baleshare; HP = Hornish Point

Table 40. Baleshare & Hornish Point. Cluster Analysis of material

Samples from Baleshare have significantly higher proportions of three morphotypes in their suites’;

a Fine Spiny Rods

b Small Smooth Rods

c Coarse Wavy Rods (less influential than *a* & *b*)

There is no evidence to suggest that samples of differing origins within each archaeological site have specific morphotypes associated with them. This is not true of samples which originate from natural as opposed to anthropogenically disturbed areas. This aspect is discussed below.

There is evidence to suggest that different archaeological sites may exhibit variations in the phytolith suites of their samples as noted by the variations between the frequencies of Fine Spiny Rods and Small Smooth Rods (Baleshare possessing higher frequencies of these morphotypes than Hornish Point). Similarly there is evidence from a pilot study of modern dune samples (see Powers *et al* 1989) that samples of similar age and type can vary in phytolith frequency and composition in comparison with similar samples taken from different geographical locations.

Such variations in suites from natural and archaeological samples whose type (or origin) is supposed to be the same may be a reflection of various factors. These include variations in seasonal availability of vegetation, local environment, micro-climate and degree of shelter (particularly important for coastal sites) affecting species colonisation, availability and phytolith production, access to plants and, or, grazing preferences of ruminants

Cluster analysis of the full data set

The Cluster Analysis (using Ward’s method) of Baleshare and Hornish Point samples utilising mean proportional counts for each Block, resulted in a four group solution, see Table 40. There is no clear separation of blocks according to designated

Sample type	Abundance of phytoliths	Dumb-bells present\absent
Windblown sands	very low	absent
Vegetated surface deposits	low	largely absent
Peat (not dessicated or compacted)	fairly high	present
Sheep faeces	high	generally present
Catttle faeces	high	generally present
Prehistoric middens	very high	present

Table 41. Characterisation of dune samples by concentration and types of phytoliths recovered

sediment type, with a mixture of midden-site deposits with windblown sand and cultivated deposits in the two multi-Block groups (numbers 2 and 3). It is difficult to assess the significance of the two single-Block groupings (numbers 1 and 4) as the blocks themselves are only single-sample blocks. Therefore, these two samples have not undergone the 'smoothing' effect of averaging the data, plus there is no way of assessing whether the results are 'typical' for their respective blocks. The breakdown of blocks into groups 2 and 3 appears more significant. In general terms the blocks are divided by site not sediment type. This is a direct result of the proportions of Fine Spiny Rods, which are more numerous in the majority of Baleshare samples as compared with the Hornish Point samples. The Cluster Analysis does not indicate a clear correlation between relative proportions of phytolith morphotypes and sediment type. Such a correlation may be resolved by further studies of the mechanics of deposition in dune systems and a refinement of phytolith classification.

Clarification of the organic archaeological horizons

In an attempt to answer the third question posed by the excavator namely, to determine the origins of the rich organic layers in the archaeological sites (those blocks designated 'midden-site' and/or 'dumped deposit'), phytolith analyses of modern comparative material were also performed (see Powers *et al* 1989 for full details). The samples originated from dune environments in the Uists and consisted of random samples collected by the excavator of windblown sands, cultivated (grassland) surface samples, cattle and sheep faeces and a peat core. Results of these analyses revealed that;

i) Modern windblown sand and vegetated surface layers contain very few phytoliths. This was quite unexpected and indicates that the cycling of silica within dune environments is not fully understood.

ii) Modern sub-surface sediments contain very few phytoliths ie there is no downwards movements of phytoliths on plant death to the sub-surface sediments.

iii) Modern 'natural' (ie non-anthropogenic) dune samples such as windblown sands and vegetated layers generally do not contain any of the four Dumb-bell phytolith morphotypes.

iv) Peat contains phytoliths in quite high numbers ranging from 3,000 and 58,000 per gram for the samples analysed.

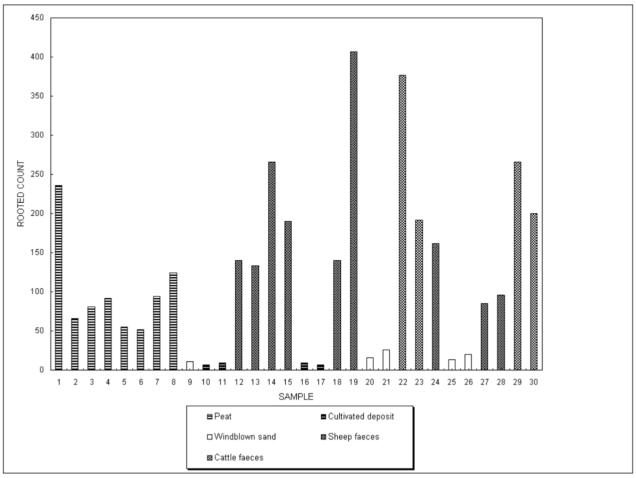


Figure 89. Modern samples; concentration of phytoliths per gram (rooted)

v) Phytoliths withstand chemical degradation and have been recovered from a wide range of sediment types, from acid peats to calcareous shell sands (up to pH 9.8 analysed).

vi) Modern faecal remains from cattle and sheep grazed on dune systems produce high numbers of phytoliths, up to 171,500 per gram for the samples analysed.

vii) Whereas peat and sheep faeces do contain Dumb-bells, cattle faeces generally do not contain Dumb-bells.

It is theoretically possible therefore, to differentiate between samples of certain origins within the dune environment on the basis of total concentration, and variations within suites, of phytoliths. In addition to the standard composition of suites (eg many Smooth Rods and Trapezoids, few Ornamented Amorphous or Irregular) some types of samples are defined by the presence or absence of a particular group of morphotypes – the Dumb-bells (see Table 41).

A comparison of the results of phytolith analyses of modern samples with those from archaeological deposits (see Table 41 above and Powers *et al* 1989 for details) revealed many interesting points. It was immediately obvious that the archaeological samples possessed higher concentrations of phytoliths than their modern equivalents (compare Figures 85 & 87 with 89). Also, observations obtained from a series of Correspondence Analyses (see Padmore 1987 for discussion) revealed that the archaeological organic layers (eg midden-site deposits) were not exclusively, or even principally composed of faeces or 'fresh' (undried) peat (Figures 90 & 91). That is not to say that the organic layers do not contain undried peat or faeces but the Correspondence Analysis indicates that there is a distinct separation of peat/faecal samples from midden samples on the basis of phytolith content.

The missing elements in the composition of the ancient organic deposits are likely to be introduced peat and once fresh plant material. The Correspondence Analysis (Figures 90 & 91) illustrates that fresh peat is closest to the ancient midden samples in terms of phytolith content of all the modern analogue materials tested. This suggests that desiccated and compacted (rather than non-desiccated) peat is likely to

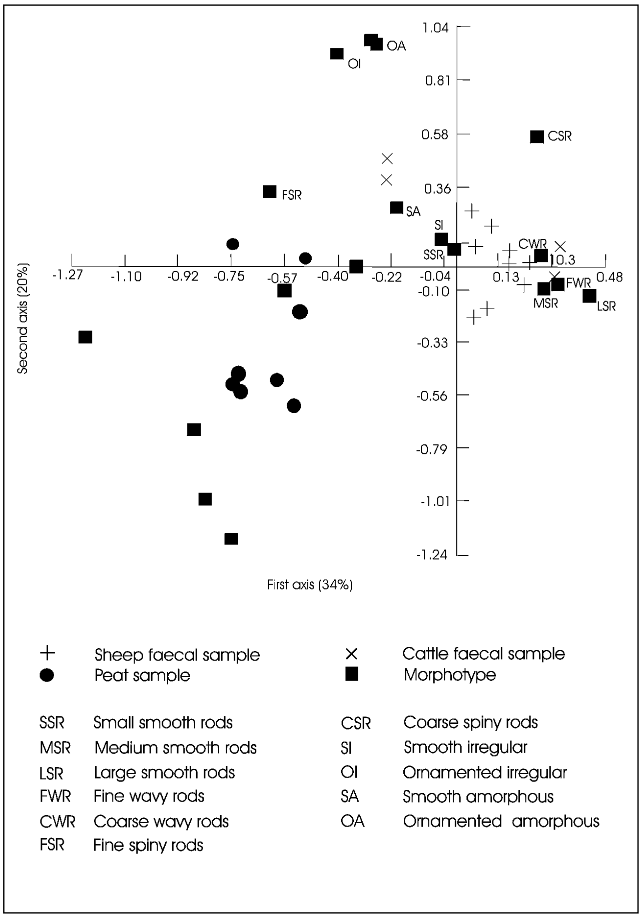


Figure 90. Correspondence Analysis of Baleshare midden and modern samples

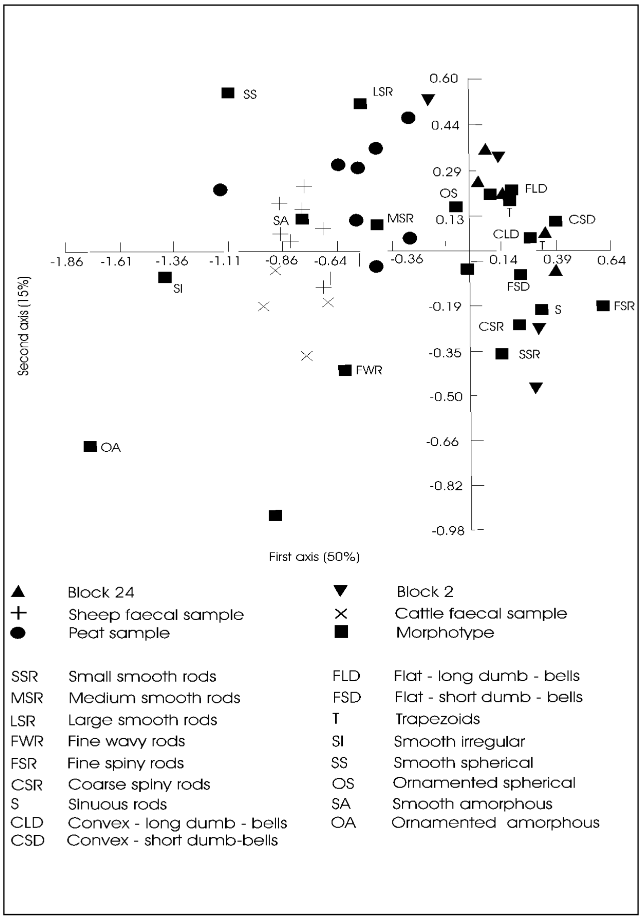


Figure 91. Correspondence Analysis of Hornish Point midden and modern samples

be a constituent of the middens. Similarly, fresh plant material may have entered bedding, byreing, thatching, etc. All these forms of plant waste will have brought with them their own collections of phytoliths.

The results of analyses of the modern and ancient samples have illustrated that in machair sand dune environments, the presence of high concentrations of phytoliths, and more significantly, the presence of Dumb-bell morphotypes, may be used (nine times out of ten) to indicate anthropogenic activity. The very rich archaeological deposits clearly stand out from the background 'natural' dune sediments, the only reservations concerning the use of dumbbells as an indicator of past anthropogenic activity would occur for example when a natural peat or faecal remains were encountered in the sampling programme. Otherwise, total phytolith concentrations, when used in conjunction with presence or absence of Dumb-bell morphotypes should be an excellent method of determining in core samples the location of archaeological sites buried in machair sand dunes.

15.4 CONCLUSIONS

As a result of this, and associated studies of phytoliths recovered from ancient and modern machair and sand dune samples (see Powers *et al* 1986; 1989), it is possible to advance the following conclusions;

i) Phytoliths, silica particles formed within the tissues of certain plant species, are not species-specific and are therefore studied as suites of multi-morphological particles called morphotypes which have been ordered and recorded according to a simple and robust classification. On plant death the phytoliths are deposited either directly or indirectly within sediments.

ii) Phytoliths are highly resistant to decay and decomposition from biological and chemical agents, and have been recovered from a wide range of sediment types and pH's, from acid peats to calcareous shell sands (up to pH 9.8 so far analysed). However, phytoliths are not present in large numbers in natural machair and dune sediments such as windblown sands and vegetated surface layers and, for unknown reasons assumed to be concerned with the recycling of silica in dune systems, very few phytoliths were recovered from apparently stabilised vegetated layers.

iii) Phytoliths are present in large numbers in archaeological deposits. Therefore, some aspect of human activity on the site, possibly the concentration of plant debris and animal and human dung, shelter from strong winds, reduced rain dispersion or an interruption of the silica re-solution and cycling, has prevented the presumed normal loss of phytoliths from the deposit.

Therefore, in ancient dune sediments the presence of very high concentrations of phytoliths in deposits may be taken to be indicative of past human activity. The sampled sediments must be shown to be neither natural peat or faecal remains.

iv) Most dune and machair samples share many common features in terms of suite composition, but it is possible to differentiate between archaeological and non-archaeological dune deposits on the presence or absence of dumb-bell morphotypes. Peat and sheep faeces also contain dumb-bells but their total phytolith concentration is generally less than that of anthropic organic deposits.

v) It has proved possible to differentiate between samples from Baleshare and Hornish Point on the basis of phytolith suite variations, which suggests either that some variation existed in the phytolith suites entering the deposits (ie different pattern of grazing, different use of plants), or that some mechanism has differentially influenced preservation on the two sites.

vi) There is no absolute correlation between archaeological sample origin, as defined by the excavator's definition of Block types, and total concentration of phytoliths. But, there is a trend towards increasing concentrations from windblown sands (low numbers) to cultivated deposits to midden-site and dumped deposits (high numbers).

vii) While the midden-site samples from Baleshare and Hornish Point were similar in many ways, they did vary in richness both within and between sites. Thus, it may ultimately be possible to identify phytolith suites exclusive to particular sites, or to particular ecological zones which were exploited by people, or to particular activities carried out by ancient people at the site.

viii) The contexts within individual blocks exhibited variation in phytolith frequency and composition which in some cases may be seen as normal variation between samples but that in others particularly some of the middens, may point to the desirability of sub-sampling the very rich deposits.

ix) There is considerable potential for the use of phytolith analysis for the location of archaeological sites buried within sand dune systems.