THE INTERPRETATION OF POLLEN SPECTRA FROM PREHISTORIC SETTLEMENTS (WITH SPECIAL ATTENTION TO LIGULIFLORAE)

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CONTENTS

1. INTRODUCTION

When applying pollen analysis to soil samples from prehistoric settlements and caves, it is necessary to be even more critical with the material than in the case of samples from peat or lake sediments.

Although habitation in general implies the accumulation of material, (this may also occur in uninhabited caves by erosion of walls and ceilings), conditions for the preservation of pollen are usually poor in settlements, especially in areas with dry, warm summers. In contrast to sedimentation under water, rapid oxydation of organic material takes place in such sites. The conditions for preservation, even for very resistant pollen, in the Mediterranean area are far from ideal.

This is in sharp contrast with areas with a moderate climate, as for instance the Netherlands, where pollen analysis of old surfaces from under burial mounds, or sods from these mounds, has been common practice for many years.

One could, however, imagine that these disadvantages are compensated at least to some extent by the accumulation of material as is found in caves or on tells, and that will keep the underlying part moist. Pollen analysis of culture layers in prehistoric settlements and caves generally as part of an archaeological excavation of such layers, has the same purpose as the palynological study of sediments, *viz.* dating and/or a reconstruction of the vegetation and climatic history. This research has been particularly, but done in France also in the Mediterranean and the Near East.

In this study I will discuss the value of some aspects of pollen diagrams or spectra from prehistoric settlements and caves situated around the Mediterranean.

Some factors which may influence the composition of such spectra will be discussed. A few special types, belonging to the Compositae, will be studied in detail. It will be seen how far such spectra yield reliable information, comparable with information from lake sediments.

2. THE PRESENCE OF HIGH POLLEN PERCENTAGES OF COMPOSITAE, IN PARTICULAR LIGULIFLORAE, IN SAMPLES FROM PREHISTORIC CULTURE LAYERS

Especially in France, much palynological research on material from caves and rock shelters has been done by Leroi-Gourhan, Renault-Miskovsky, and Paquereau (see Bibliography). Some of their diagrams are based upon large quantities of pollen, others on minimal numbers. Some diagrams are meant to reconstruct the local environment, others are used, for instance, to establish zones in the Würm-Glacial. In some cases the conclusions seem to be obvious, on other occasions they look rather far-reaching.

For this study a series of diagrams were selected. The following numbers correspond with a list (Table 1) showing the names of the sites and the respective authors.

France: 2,3,6,7,9,10,11,13,14,15,16,19,20,22,25.
Italy: 1,12.
Spain: 8.
Tunesia: 5.
Switzerland: 18.
Greece: 23,26.
Cyprus: 24.
Lebanon: 17.
Jordan: 4.

One of the most conspicuous characteristics of these diagrams, and the reason for their selection, is the dominant appearance of some pollen types of insect-pollinating plants belonging to the Compositae. Most important are the Liguliflorae, the *Carduus*-type, the *Matricaria*-type, and sometimes the *Centaurea solstitialis*-type. In the French studies Liguliflorae can sometimes be mentioned as Cichoriae, the *Carduus*-type as Carduaceae or Tubuliflorae, and the *Matricaria*-type as Anthemidae.

Special attention will first be paid to the phenomenon of the high Liguliflorous values.

Are these values related to special periods? To study the connection between Liguliflorous pollen percentages and time, all the 33 diagrams mentioned in the list (Table 1) are plotted against time.

TABLE 1. LIST OF SITES YIELDING DIAGRAMS WITH HIGH COMPOSITEOUS, ESPECIALLY LIGULIFLOREOUS POLLEN PERCENTAGES

1. Combe-Grenal (Dordogne), France (Bordes, Laville et Paquereau, 1966).
2. Caminade (Dordogne), France (Paquereau, 1969 b).
3. Grotte du Prince, Italy (Renault-Miskovsky, 1972).
4. Le Moustier (Dordogne), France (Paquereau, 1969).
5. Grotte de la Calmette, Dions, Gard, France (Renault-Miskovsky, 1972, 1973).
6. Grotte de Prélétang, commune de Presles, Isère, France (Arl. Leroi-Gourhan, 1966).
7. El Khiam, Jordan, (van Zeist, 1966).
8. El Guettar, Tunis (Leroi-Gourhan, 1958).
9. Grotte de Salpètre de Pompignan, Hérault, France (Renault-Miskovsky 1972).
10. Caminade-Est (Dordogne), France (Paquereau, 1970 a).
11. La Ferrassie (Dordogne), France (Paquereau, 1969).
12. Grotte de l'Hortus, Hérault, France (Renault-Miskovsky, 1972).
13. Laugerie-Haute (Dordogne), France (Paquereau, 1969).
14. Grotte de la Cueva Morin, Santander, Spain (Leroi-Gourhan, 1971).
15. Grotte de Renne, Arcy-sur-Cure, Yonne, France (Leroi-Gourhan, 1965).
16. Grotte de Lagopède, Arcy-sur-Cure, Yonne, France (Leroi-Gourhan, 1965).
17. l'Abri du Facteur à Tursac, Dordogne, France (Leroi-Gourhan, 1968).
18. l'Abri Mochi, Grimaldi, Italy (Renault-Miskovsky, 1972).
19. Belvis, Pyrenées, France (Jalut, 1974).
20. Flageolet II (Dordogne), France (Paquereau, 1970 b).
21. La Marche, Lussac les Châteaux, Vienne, France (Leroi-Gourhan, 1973 a).
22. Grotte de la Vache, Ariège, Pyrenées, France (Leroi-Gourhan, 1967).
23. l'Abri Cornille, Istres, Bouches-du-Rhône, France (Miskovsky et Renault-Miskovsky, 1974).
24. Jitta, Lebanon (Bottema unpubl.).
25. l'Abri de la Cure, Baulmes, Switzerland (Leroi-Gourhan et Girard, 1972).
26. l'Abri des Boeufs, Bouches-du-Rhône, France (Renault-Miskovsky, 1972).
27. Châteauneuf-les-Martigues, France (Renault-Miskovsky, 1972).
28. Limni Voivis, Thessaly, Greece (Bottema, unpubl.).
29. La Couronne, Martigues, Bouches-du-Rhône, France (Renault-Miskovsky, 1973).
30. Nea Nikomedeia, Macedonia, Greece (Dimbleby in: Rodden, 1962).
31. Grotte de Lion, Arcy-sur-Cure, Yonne, France (Leroi-Gourhan, Arl. et André, 1965).
32. Kalopsidha, Cyprus (Bottema in: Åström, 1966).
33. Midea, Dendra, Argolis, Greece (Bottema in: Åström, 1968).

For this purpose the broad period indicated by the respective authors for these diagrams is drawn schematically in fig. 1.

One diagram from a lake (28: Thessaly, Greece) is presented to compare its high Ligulifloreous pollen values with the 32 others from settlements. In the figure the information is arranged and presented according to age, starting with early Würm diagrams. It is clearly visible from fig. 1 that the presence of high Ligulifloreous pollen percentages bears no relation to time. This is also true for some Tubulifloreous types. It may be objected that the sources are scattered over a large area but the material studied is so far homogeneous that 22 of 32 sites are from France, and they are distributed in time quite evenly. The ever-present Liguliflorae and Tubuliflorae in the sites mentioned above, lose their values as indicators of certain vegetation types, steppes or other open vegetations. It is quite clear that steppe vegetation was not present constantly during the Würm-Glacial and Postglacial in Western Europe.

A test for the reliability of spectra from caves and settlements would be their comparison with suitable diagrams from nearby sediments. In practice, however, it turned out to be very difficult to find suitable sediments in areas with a Mediterranean or a steppe climate. There are either no sediments at all or they are found too far away. Pollen spectra of samples of the settlement of Nea Nikomedeia, Greece (Dimbleby in: Rodden,

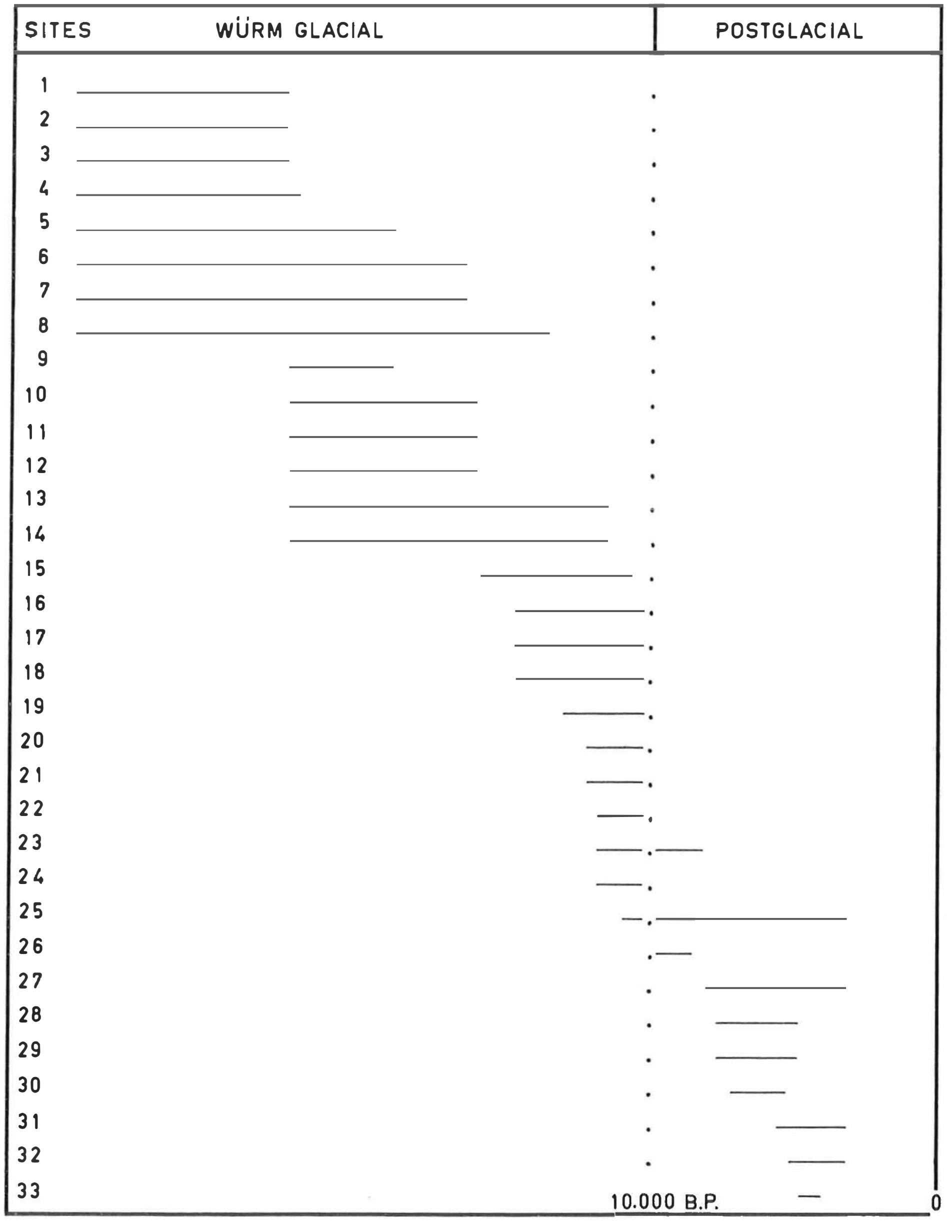


Fig. 1. General scheme of the time covered by the various diagrams from a series of prehistoric sites.

1962) do not correspond with the Giannitsa diagram from a sediment at about 7.5 km (Bottema, 1974). Dimbleby's analysis of the "Early Neolithic" layer yields 24 pollen types; the same period in the nearby diagram of Giannitsa yields more than 100 types. Whereas herb pollen dominates the settlement samples, in the lake sediment tree pollen is most important. In the first case Liguliflorae amount to 10-20% of the total pollen, in the second case 0-5% calculated on basis of a tree pollen sum. Dimbleby emphasizes the poor conditions for pollen analysis of the settlement material, which shows a low pollen concentration compared with the samples from the sediment.

From the eastern Pyrenees, spectra from the cave of Belvis can be compared with those of a core from le Bousquet at a distance of about 15 km (Jalut, 1974). Layers ascribed to the Older Dryas, in the cave as in the core, show high Liguliflooreous percentages. The levels on top of the Older Dryas in le Bousquet, however, are sterile. This may indicate selective corrosion already during the Older Dryas. In chapter 4.5 I will return to this subject.

3. THE REPRESENTATION OF LIGULIFLOREOUS PLANTS IN THE MODERN POLLEN RAIN

It is rather conspicuous that in pollen diagrams from peat or lake sediments which are clearly deposited under water, high pollen values of Compositae, including Liguliflorae, are seldom found. Such values generally fluctuate between zero and five per cent.

Differences in pollen composition, and we may count the discrepancy between Liguliflooreous values in samples from lake sediment and those of "dry" cave samples to such differences, are explained by Leroi-Gourhan (1973 b) as the difference between local and regional pollen precipitation. It might be interesting to check the local pollen precipitation by means of surface samples.

The study of surface samples has revealed that a moss cushion, acting as a pollen-trap may show an over-representation of local herbs.

It also appeared from such investigations that some trees or herbs are represented very badly in the pollen rain although they are present in the vegetation abundantly. It is clear that especially the zoogamous species will be found in this last group.

The part Liguliflooreous pollen plays in surface samples, originating from various regions, is rather restricted. The samples which are cited here as examples, come partly from areas which would have been forested under natural conditions and partly from steppe vegetation. The areas where forest is the climax vegetation, however, are often partly or completely deforested so that herbs play an important role in such vegetations too.

In Table 2 the Liguliflooreous pollen percentages are grouped for a series of samples from Greece (Bottema, 1974), western Turkey (verb.comm. van Zeist & Woldring), eastern Turkey (van Zeist, Timmers & Bottema, 1968), western Iran (Wright, McAndrews & van Zeist, 1967), and Syria and Lebanon (Bottema, unpublished).

TABLE 2. DISTRIBUTION OF POLLEN VALUES OF LIGULIFLORAE IN SURFACE SAMPLES

Source	number of samples	percentage groups
Greece	39	0.1- 1.0%
	27	1.0- 2.5%
	22	2.5- 5.0%
	13	5.0-10.0%
western Turkey	49	0.0- 2.5%
	7	2.5- 5.0%
	4	5.0- 7.5%
	2	7.5-10.0%
	1	10.0-12.5%
eastern Turkey	26	0.0- 5.0%
	12	5.0-10.0%
	2	10.0-20.0%
	1	20.0-25.0%
Syria/Lebanon	32 (incl. 7x 0)	0.0- 2.5%
	6	2.5- 5.0%
	3	5.0-10.0%
	1	10.0-25.0%
western Iran	37	0.0- 2.5%
	8	2.5- 5.0%
	8	5.0-10.0%
	4	10.0-20.0%
	3	20.0-30.0%

High percentages Liguliflooreous pollen (10-30%) which are seldom found in surface samples, are always connected with Liguliflorae growing over the collected sample.

Values up to 98% as found in subfossil samples from caves etc. cannot signify a natural vegetation dominated by Liguliflorae. In the first place such vegetation types are not known at the moment; secondly, there are no indications from standard-diagrams of Postglacial or Würm-Glacial age for such a vegetation type; and thirdly even local Liguliflorae will not yield such high values. The same thing can be said for some Tubuliflooreous Compositae.

4. FACTORS WHICH MAY INFLUENCE THE COMPOSITION OF POLLEN SPECTRA FROM SETTLEMENTS AND CAVES

4.1. *General*

Various factors exert their influence on the pollen spectra obtained from samples from culture layers. In fig. 2 these factors are drawn schematically. It is assumed that they apply not only to the situation in a tell but also to a cave or a rock shelter. Suppose that a botanist is interested in the pollen precipitation during a period A (fig. 2). His problem will be to define the role of these contaminating factors:

a. Pollen of older periods has arrived in the tell in building material.
b. Selected pollen types are buried by burrowing bees during period A and later.
c. Infiltration of pollen from layers younger than A.
d. (selective) Corrosion.
e. Passive transport of pollen by mammals.

4.2. *Contamination by building activities*

Accumulation of material is in itself a condition for pollen analysis; at least without accumulation there would be no relation of the pollen with time. If accumulation is stimulated by man, as in the case with a tell, then, apart from the normal pollen rain, pollen may arrive with building material, such as clay.

Clay for the construction of walls, etc. brought to the tell, at the time of period A, must be older than period A. The exact age, however, is unknown or very difficult to learn. Even secondary pollen grains may be present in the river-clay already.

When sampling prehistoric culture layers, one should avoid remnants of mud-bricks, clay-floors, etc., as much as possible. Only profiles with a very clear stratigraphy should be considered for sampling. I will return to this subject in chapter 6.

4.3. *Contamination by burrowing bees*

The influence of burrowing bees on pollen spectra from cave entrances, etc., may be very important. This is either unknown or ignored. When studying the pollen spectra from the sources mentioned above, the high percentages of zoogamous pollen are very conspicuous.

Especially the part of the Liguliflorae attracts attention. Investigations by Leroi-Gourhan (1958, 1965, 1966, 1967, 1971), Leroi-Gourhan and Girard (1971), Renault-Miskovsky (1970, 1972, 1974), Hoffert *et al.* (1973), de Lumley *et al.* (1973), Bordes *et al.* (1966), van Zeist (1966), and Bottema (1966; in: Åström, 1968) show Ligulifloreous values of up to 60-90% of the total amount of pollen. It should be stressed that Compositae may occur in lumps of 20 or more grains in such samples. Ogden *et al.* (1974) state that the pollen of some species, not normally airborne, is bound together by oil droplets, dispersed in clumps, and occasionally trapped in significant amounts on air samplers (e.g., *Taraxacum).* It is, on the other hand, highly probable that a large part of these pollen grains are burried by burrowing bees. Palynological investigation of the nest of a mason bee, *Chalycodoma*, (fig. 7a) from a Bronze Age settlement near Kalopsidha (Cyprus) showed 80% Ligulifloreous pollen, but the other samples from the site showed the same values (Bottema, 1966). Quite obviously these high percentages were present throughout the layers.

It will be useful to know a little more about such burrowing bees. Many species of these bees make nest-holes of about 20-60 cm depth, either in the horizontal or in the vertical plane, in sand or in boulder-clay, etc., dependent upon the species. This hole leads to a nest with oval cells (Friese, 1923).

According to Malyshev (1935) the depth of the main canal varies greatly. Even within the limits of the same genus it varies between a few centimeters (*Andrena cineraria* L.) and forty inches (*A. bicolor* T.). According to Sakagami and Michener (1962) and Michener (written communication) the depth of the burrows made by European species averages about 25-50 cm.

In every cell a certain amount of honey and pollen is deposited on which an egg is laid. The larva feeds on this storage, while the pollen walls which are not digested remain in the excreta (Faegri, 1964). Although different kinds of species may select various kind of soils, a rock shelter or

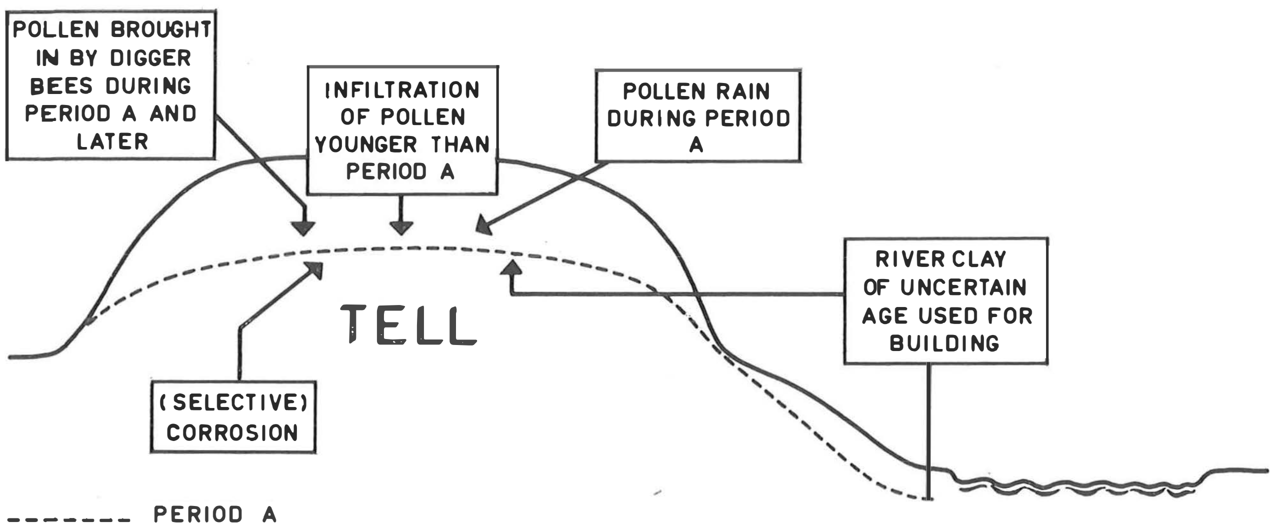


Fig. 2. Factors influencing the pollen content of samples from a period A in a prehistoric site.

the entrance of a cave, especially with a south-east or south-west exposure is very suitable (van der Vecht, written comm.). Malyshev (1935) states "that the maximum development of bee life is observed in regions having a steppe or almost desert character, and having therefore, a dry and warm, or hot, climate with an appropriate soil". From literary sources some information was gathered on four genera: *Halictus*, *Andrena*, *Panurgus*, and *Dasypoda*. In the field, species of the genera *Halictus* (figs. 4 and 7b), *Colletes* and cf. *Osmia* were studied.

Of the genus *Halictus*, more than 200 species are mentioned for Europe and Asia (Friese, 1923). *Halictus* and *Andrena* species in general dig holes up to 30 cm in length. Some species show a pronounced preference for a certain plant-species when it is flowering, others however, visit a list of plant-species or families. The numerous species of the genera *Halictus* and *Andrena* cover a large number of plants mainly belonging to the Compositae (a.o. *Taraxacum*, *Cichorium intibus*), Salicaceae (*Salix*), Cruciferae, Papilionaceae, Umbelliferae, Labiatae, Ericaceae, Rosaceae, and Campanulaceae (Stoeckhert, 1933, 1954).

Panurgus species build their nests in general in large colonies; Friese (1923) mentions a perpendicular hole, eleven cm deep, leading to the nest. These bees prefer yellow Compositae such as *Hieracium*, *Leontodon autumnalis*, and *Hypochaeris radicata* (Stoeckhert, 1933).

In the genus *Dasypoda* pollen collecting has been developed very strongly. *Dasypoda plumipes* builds its cells at the end of a tunnel with a maximum depth of 60 cm. The bee collects 10-23 centigr. pollen in 5 or 6 harvesting trips for each cell. Each time it carries half of its body weigth of 8 centigr. under the ground! *Dasypoda* species prefer *Hieracium*, *Leontodon*, *Cichorium*, *Scabiosa*, *Centaurea*, *Jasione*, *Succisa*, and *Knautia* (Friese, 1923; Stoeckhert, 1933, 1954).

It is quite clear that the activities of digger bees can be a serious source of contamination. It is not possible to date such contamination because the bees can have dug their nests at any time after the period of human occupation. Only when the depth from the surface to the layer studied exceeds their nesting range can one explain such possible contamination as not recent (fig. 3).

To study the effect of contamination I caught some bees which were about to carry pollen down to their nests, and cells from nests were also collected.

From a tell on the River Bossut, Vojvodina, Yugoslavia, a nest of cf. *Megachile* (see Table 3) was collected. The bee had dug its nest ca. 10 cm deep into a standing profile. The cells contained enormous amounts of pollen, as was the case with the cells of other species investigated. To study the pollen, samples were diluted to about 20,000 grains per slide. In Table 3 are shown the types

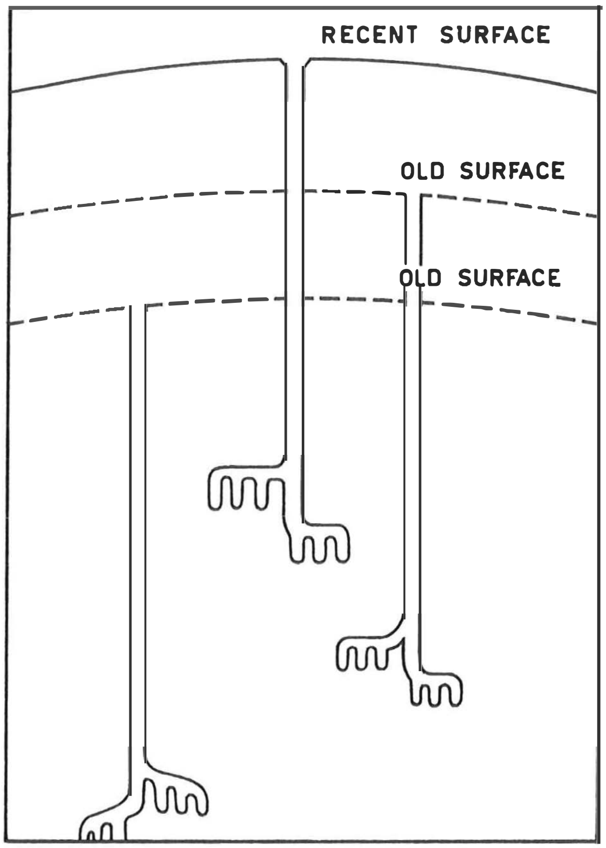


Fig. 3. Bee nests dug during various periods.

collected by the bee, given in percentages of a sum including all types. The spectrum is dominated by Papilionaceae, as is normal for the genus *Megachile* (Benno, 1969), in this case *Coronilla*-type and *Lotus*-type. During the excavation of Tell Gomolava (Vojvodina, Yugoslavia) August 1973, under the direction of Dr. B. Brukner, a number of nests of a *Colletes* species were observed by the present author in a square from 1972 at the level of the La Tène. Certain digger bees prefer bare areas, street sides, trodden pathways etc. and in this case no nests were found in the overgrown part of the tell.

Five bees carrying pollen down to their nests were collected. Samples made of their hind-legs were dominated by Liguliflorae with pollen of the *Carduus*-type in the second place (see Table 3).

In the spring of 1974 as well as in the fall some nests of a *Halictus* species (fig. 4) were collected. These bees had built about 50 nests in the masonry of a south-exposed wall of an old farm in Yde (Netherlands). In this wall loam was used instead of cement. I observed that a number of eggs laid at the end of the summer did not hatch at all, and much pollen remained unused in the shallow nest holes. The pollen content was completely dominated by the *Matricaria*-type, probably originating from a rich *Tanacetum*-stand at about 500 m. Some *Halictus* species tend to be gregarious. A single mixed colony of *Halictus quadricinctus* and *H. sexcinctus* measured 3,500 nests (Sakagami and Michener, 1962). The maximum density was about 100 nests per square meter.

Finally a nest of a mason-bee, cf. *Osmia*, (see also fig. 5) was collected (18-9-1974) from the same farm-wall. It contained, apart from 61.4% *Matricaria*-type, 37,5% *Quercus pollen* (see Table 3).

It is quite remarkable that the bee collected so much windblown pollen but according to Michener (written sommunication) whose information follows below, this is normal for some species.

"There are many bees that regularly collect and use windblown pollen. I assume that this has nothing to do with pollination; the bees are simply taking advantage of a convenient food source. Bees of the genus *Andrena* frequently collect from *Quercus*. Bees of the family Halictidea (*Halictus*, *Lasioglossum*, *Nomia*) and also *Exomalopsis* in the Anthophoridae collect pollen from grasses very frequently. This is more common in tropical regions than in temperate areas but it happens here in Kansas and may well occur in Europe".

Bohart (written communication) mentions an *Anthophora* species in Utah, collecting pollen exclusively from *Quercus* species. He collected *Osmia lignaria* with pollen from Box Elder (*Acer negundo*), a wind-pollinated species unlike the European insect-pollinated *Acer* species. Bohart further mentions *Melissodes* taking pollen from *Chenopodium* and halictine bees collecting pollen from *Chenopodium*, *Ambrosia*, *Iva*, *Franseria*, *Amaranthus*, *Salsola*, and *Sarcobatus*.

Although no exact calculations on the number of pollen grains were made, a rough estimate will be given. One *Halictus*-nest contained at least 300,000 pollen grains, roughly estimated from the slides and the volume of the sample. Skrebtzova (Stanley & Linskens, 1974) mentions the hairs of

TABLE 3. POLLEN SPECTRA OF SOME DIGGER BEES AND BEE-NESTS

	I	II	III	IV	V	VI	VII	VIII	IX	X
Quercus robur-type							0.3		0.1	37.5
Picea										0.9
Aesculus							0.1			3.7
Corylus									0.1	0.9
Vitis								0.04		
Cerealia-type										0.9
Gramineae										0.9
Chenopodiaceae							0.2	0.08		
Artemisia vulgaris-type		0.2		0.7		0.2				
Plantago lanceolata		0.2	0.5							
Ranunculus scel.-type			0.2				0.1			
Capsella-type							0.1			
Lysimachia-type	8.1									
Gentianaceae	0.1									
Liguliflorae	0.3	84.8	66.0	65.4	9.0	58.8				2.8
Carduus-type		14.1	33.3	34.7	91.0	40.7		0.04		
Senecio-type	0.4	0.2								
Matricaria-type							99.2	99.8	99.7	61.4
Coronilla-type	12.1									
Lotus-type	79.0									
Astragalus-type		0.2								
Leguminosae indet.		0.2							0.1	
Linum						0.2				
Total pollen	1000	608	435	153	669	408	1037	2426	1000	1068

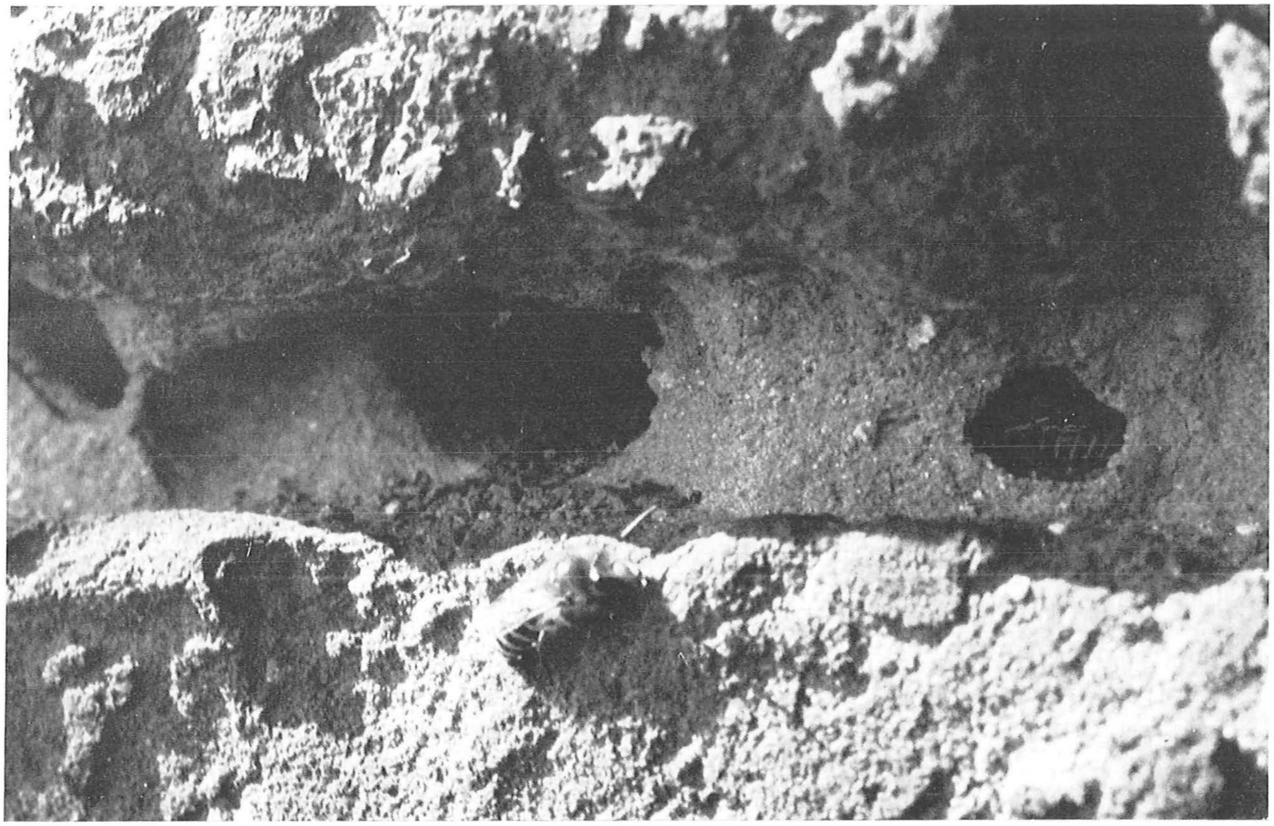
I: cf Megachile nest collected August 1973, Bossut, Yugoslavia
II, III, IV, V, VI; specimens of Colletes, collected August 1973, Gomolava, Yugoslavia
VII, VIII, IX: nests of Halictus, collected June (IX) and September 1974, Yde, the Netherlands
X: nest of cf. Osmia, collected 18th of August 1974, Yde, the Netherlands

one bee (*Apis*) to contain 250,000 to 6,000,000 pollen grains! According to Stanley and Linskens this is improbably high. For carrying 3 million *Prunus* grains they calculate a layer of 0.5 mm closely packed pollen on the body. Moreover such layers are only observed on the lower side of the abdomen of some Megachilae but not in the genus *Apis*.

In one square meter (fig. 4) I found at least 50 *Halictus*-nests, together yielding at least 15 million pollen grains.

This would mean about 1500 grains per cm^2, taking into account that this is only the production of one season. If such a wall would collapse, an excavation of the culture layer, later, would contain a lot of pollen not linked with the average vegetation, pollen corrosion not considered.

In connection with this contamination problem the following information from Hurd (written communication) is very interesting: "There are many species of solitary bees and even a number of 'social bees' which seem to thrive exceptionally well in man-made situations such as earthen walls (figs. 4, 5 and 6), earthen houses, all manner of path ways, walkways, dirt roads, and even cobblestone streets, sidewalks, and window boxes. In a sense these are the so-called 'weed species' of the bee world since they readily capitalize and urbanize with man sometimes in very large aggregations. I've observed, as have many others, great concentrations of certain species of bees (*Andrena*, *Halictus*, *Chalicodoma*, *Anthophora*, (figs. 6 and 7c) *Centris* etc.) nesting in the 'archaeological ruins' throughout the Americas. In some cases and especially in earthen works of many kinds it is evident that the bees have riddled these structures with their nesting tunnels and cells over a period of many, many years (perhaps hundreds of years



or even longer), so much so that accumulations of pollen residues are revealed when one excavates these situations. In such circumstances it is readily evident that the kind of contamination you (the present author) have written about is of considerable significance to archaeologists".

I quote from Sakagami and Michener (1962) who state that "Under natural conditions, exposed, firm ground can exist stably in large areas only in the desert, steppe or allied biomes under arid to semiarid conditions. The bee fauna in such ecological regions is usually rich. However, as scattered, discrete microhabitats, suitable conditions are often found in man-made environments such as paths, parks, athletic fields, and road and railway cuts".

Without doubt bee-nests confuse the real pollen precipitation, whether regional or local. When establishing the pollen sum of samples from prehistoric sites from areas with warm and dry summers, it is recommended to leave at least the Compositae and especially the Liguliflorae out of this sum.

Fig. 4. *Halictus* species nesting in an old farm-wall.

4.4 *Infiltration of younger material*

In a series of layers, all of them containing pollen, infiltration of younger material can only be established and proven for sure when the pollen concerned does not occur naturally.

This happens only on rare occasions, for instance exotic plants which are introduced at or after a fixed point of time, e.g. the discovery of America.

For such types, infiltration is quite clear. For native types (native in Europe), however a judgment as secondary is based more upon suspicion than on proof. This suspicion can be raised when, for instance, in a series of layers of more or less identical composition only the upper layers contain pollen.

Fig. 5. *Osmia* cf. *rufa* on an old farm-wall.

Fig. 6. *Anthophora pilipes* in front of its (artificially blocked) nest.

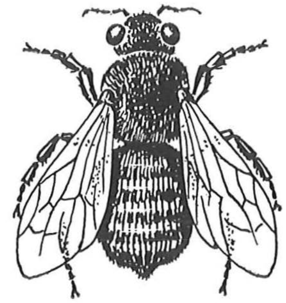


Fig. 7a. *Halictus* species
Fig. 7b. *Anthophora* species
Fig. 7c. *Chalycodoma muraria*

Calcareous, porous bone-breccia may serve as an example. Some samples from such breccia, collected mainly for palaeontological purposes, were investigated palynologically. It was noticed that pollen was only found in the upper part of a series. Although palaeontological dating suggested a considerable age, the pollen spectra resembled very much those of surface samples of degraded vegetation as found on the spot. The first sample (see Table 4) comes from Dragontovounari on the north-west coast of Cyprus. It was taken from a bone-breccia of dwarf *Hippopotamus* about 30-40 cm deep (Boekschoten & Sondaar, 1972). The high *Pistacia* pollen percentages point to a dominance of this shrub on the spot (*Pistacia* is under-represented in the pollen rain). Besides the high values for the weed *Mercurialis annua* are conspicuous. It is quite likely (although difficult to prove) that this maquis-like spectrum is not contemporaneous with the Pleistocene dwarf-hippo, but that recent pollen washes down into the bonebreccia. The grains disappear by corrosion but are followed by new infiltration.

Comparable samples originate from the Cueva de Son Muleta on Mallorca, excavated by W. Waldren. Samples from this site were investigated by Gottesfield and Martin (Geochronological Laboratory, University of Arizona) in 1966. In Table 4 a spectrum from a sample at 150 cm, counted by Gottesfield and Martin is compared with one from 100 cm analysed by myself. Gottesfield and Martin, emphasize that they had no reference material from the Mediterranean. Samples from a greater depth were found to be either sterile or very poor in pollen. Infiltration provides the upper layers with recent pollen. The relatively important share of *Pistacia* in spectrum I at 100 cm is conspicuous. These upper layers are contemporaneous with human habitation on the island. In the cave numerous bones and coproliths of the antelope *Myotragus* have been found. This animal is thought to have been destroyed by the early (neolithic?) inhabitants. For that reason the pollen grains of *Juglans* found at the same time (spectrum II, Table 4) must be due to infiltration, as this tree cannot have been present before Roman times.

Treatment of the *Myotragus* coproliths did not yield pollen. It is indeed doubtful whether pollen found in coproliths will teach us more about diets (report Gottesfield and Martin, 1966).

In connection with the spectra mentioned above the palynological study of a bone-breccia by Suc (1974) is of interest. However, the conditions of the site, sampling and exact depth are not given. The pollen spectrum is of a Mediterranean character, dated by Suc to the Lower Pleistocene. The pollen composition with types as *Olea*, *Juglans*, and *Castanea* could have been washed in to-day, but that does not explain the presence of grains of *Cedrus*.

The conclusion is that infiltration is difficult to prove and largely based upon the interpretation of the situation on the spot, experience with samples and a dose of suspicion.

4.5. *Corrosion*

All the pollen which ended in some way or another in layer A (fig. 2), whether it is old or young, is subject to corrosion.

In this field much work has been done by Havinga (1967, 1968, 1971). Havinga's investi-

TABLE 4. POLLEN SPECTRA OF SOME SAMPLES FROM BONE-BRECCIA

	I	II	III
Quercus robur-type	1.6	1.1	0.6
Pinus	1.6	1.1	11.6
Olea	1.6	–	0.3
Pistacia	13.7	–	42.3
Fraxinus	–	2.2	–
cf Tamarix	–	2.2	–
Juglans	–	2.2	–
Cupressaceae	–	–	10.6
Mercurialis annua	–	–	23.2
Polygala	0.8	–	–
Chenopodiaceae	0.8	–	–
Noaea-type	–	–	0.9
Plumbaginaceae	–	1.1	–
Artemisia	4.0	1.1	–
Centaurea solstitialis-type	0.8	–	–
Plantago lanceolata	6.4	–	2.5
Plantago species	–	5.6	1.9
Sanguisorba minor-type	0.8	–	0.3
Carduus-type	15.3	–	–
Jurinea-type	6.4	–	–
Liguliflorae	3.2	3.3	0.9
Matricaria-type	0.8	–	1.6
Umbelliferae	–	0.3	0.3
Tubuliflorae	4.0	8.8	0.3
Cerealia-type	1.6	2.2	0.3
Leguminosae	1.6	1.1	–
Potentilla-type	0.8	–	–
Liliaceae	–	2.2	0.6
Ranunculus cf. scel.	1.6	–	–
Cruciferae	0.8	5.6	–
Asphodelus	0.8	2.2	0.3
Caltha-type	0.8	–	–
Salicighia	1.1	–	–
Gramineae	31.4	56.6	1.3
Pollen sum	124	90	319
Cyperaceae	–	–	0.3
Typha	–	1.1	–
Dryopteris	2.4	–	0.3
Polypodium	1.6	–	–
Ophioglossaceae	1.6	–	
Indeterminata	6.4	1.1	11.9

I: 100 cm depth, Cueva de Son Muleta, Mallorca
II: 150 cm depth, Cueva de Son Muleta, Mallorca, anal. Gottesfield & Martin
III: Dragontovounari, N.W. Cyprus, bone breccia

gations showed that corrosion of pollen can play an important part and that Liguliflorae have one of the most resistant pollen types. Dimbleby (1974) draws the conclusion that pollen and spores ending up in soils have disappeared completely after two or three seasons, apart from some resistant types such as Polypodiaceae and Liguliflorae. This would count for soils with a Ph more thans 5.5.

The resistance of Ligulifloreous pollen, in combination with the easy identification of this type, even when it is corroded to a great extent, must contribute to its relative increase in spectra from settlements and caves.

4.6 *Activities of higher animals*

Leroi-Gourhan (1966) noticed the presence of sufficient pollen (a.o. high percentages Ligulifloreous pollen) at 200 m from the entrance of the Grotte de Prélétang. The same was found at about 30 m from the entrance of the Grotte de la Vache (Leroi-Gourhan, 1967). She thinks that in the first case bears carried the pollen in on their fur. Remnants of about a thousand bears were found in this cave. In the second example small rodents would have brought pollen in on the same way. This seems to be an acceptable possibility. It is reasonable to suppose that pollen of zoogamous plants sticks to the fur of animals easily and is carried far into caves.

To find out whether pollen sticks to the fur of small mammals and in what quantity I did some minor research. The accumulation of bones and fur of small mammals is very important in the nest-holes of owls (Schaefer, 1974). From a nest-hole of a Barn Owl (*Tyto alba*) in Yde, the Netherlands, a handful of pellets was collected. The pellets contained felt-like hair, small bones and skulls of the White-toothed Shrew (*Croccidura russula*), the Common Shrew (*Sorex araneus*), the Common Vole (*Microtus arvalis*), and the Wood Mouse (*Sylvaemus sylvaticus*). The absolute number of pollen found in the owl-nest sample is given in Table 5.

TABLE 5. POLLEN SPECTRUM FROM THE REMNANTS OF SMALL MAMMALS

pollen type	absol. nr.
Quercus robur-type	2
Corylus	1
Alnus	1
Chenopodiaceae	1
Cerealia-type	1
Gramineae	42
Delphinium-type	1

Pollen concentration in this sample is very low, the conservation good. Pollen types of wind-pollinating species are dominant and more research is necessary to explain the presence of insect-pollinating types deep in caves.

5. HIGH PERCENTAGES OF LIGULIFLOREOUS POLLEN IN LAKE SEDIMENTS

Occasionally high percentages of Liguliflorous pollen are found in samples from lake sediments (see also Suc, 1974). Sometimes these high values are restricted to some samples at the bottom or at the top of the sediment, sometimes high values are found before or after a hiatus in pollen preservation. The high values seem to be present often on levels were local conditions play a role. This is mostly close in front or close behind a hiatus where the pollen is corroded, possibly due to seasonal drought.

A small part of a pollen diagram of Limni Voivis (L. Karla, L. Volos), Thessaly, Greece, will be shown as an example (fig. 8). From time to time the water level of this lake has been lowered as the barrier towards the sea broke through. The sediment consists of grey clay with yellow patches (a sign of oxydation). The boring measured 447 cm. Figure 8 shows which part yielded pollen. The pollen curves of Liguliflorae and *Centaurea solstitialis*-type are given, calculated on the basis of a tree pollen sum. The sediment contained no pollen from 447-400 cm, 340-290 cm, and from 110-80 cm. Especially in front of and after these hiatuses, values for Compositae are high.

What may have caused such values? One can imagine that when the lake started to dry up at

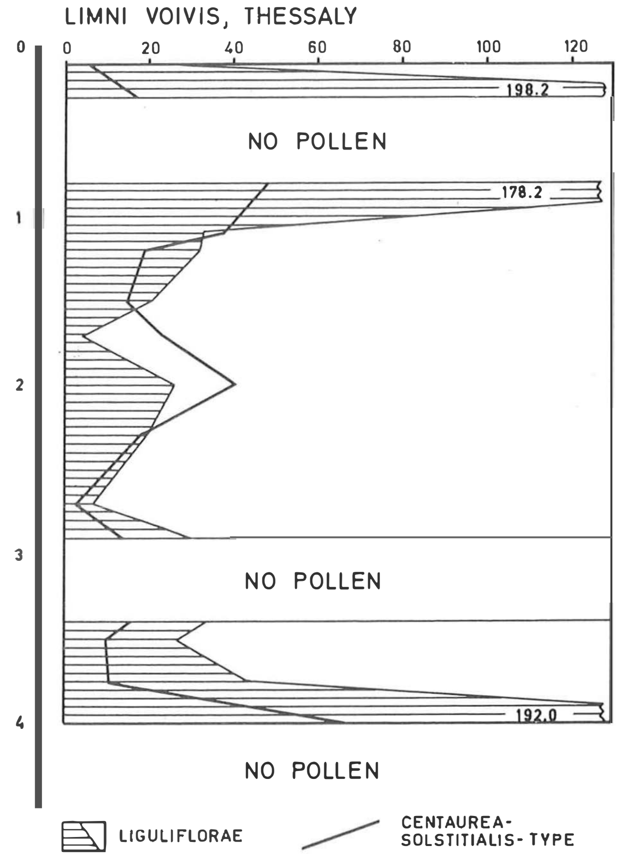


Fig. 8. Pollen curves of Liguliflorae and *Centaurea solstitialis*-type from a sediment of Limni Voivis, Greece.

the beginning of the summer, various annuals started to grow, delivering the pollen type found. The surface sample study has shown, however, that a vegetation with many Composits still does not show such high pollen percentages. Besides, that does not explain the total absence of pollen in the hiatuses. It is quite probable that the processes described by Havinga (1967, 1971) play a role here too. The pollen in the hiatuses completely disappeared under unfavourable conditions, shortly before and after these hiatuses the more resistant types are found, relatively over-represented.

This can also be illustrated from the curves of Liguliflorous and unidentified pollen grains (fig. 9) from a diagram of the upper reaches of the Barrada, west from Damascus (Syria) (unpubl.). There is a clear correlation between the Liguliflorous values and the amount of unidentifiable grains which represent the degree of corrosion there.

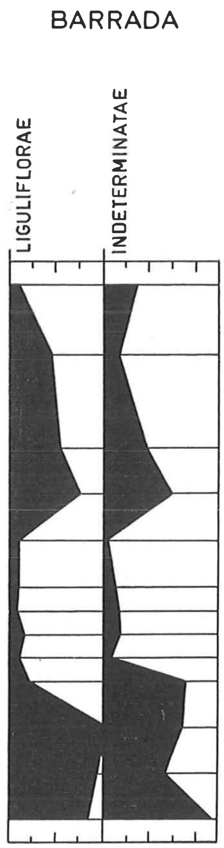


Fig. 9. Part of a pollen diagram from the Barrada valley (Syria) showing percentages of Ligulifloreous and unidentified grains.

6. SOME ASPECTS OF A FEW SAMPLES FROM TELL GOMOLAVA, YUGOSLAVIA

In regions with a reasonable amount of rain during the summer, the conditions for the preservation of pollen seem to be better than where a pronounced summer drought occurs.

In Western Europe, burial mounds of various periods appear to be suitable subjects for palynological investigations (Waterbolk, 1954; van Zeist, 1955, 1967). Also sandy soil profiles, eventually covered with drift sand, have been studied for this purpose, although one hase to interpret such spectra very carefully (Havinga, 1964, 1968). For the palaeobotanical research of the terps (dwelling mounds) of the coastal area of the Netherlands and northwestern Germany the emphasis is placed on the study of subfossil seeds (van Zeist, 1974). Still, pollen analysis of such prehistoric settlements is very possible. Samples of the old surface, first habitation layer, inundation layer, sods and ploughed soil from the excavation of the terp of Elisenhof, Tönningen, Germany, yielded 66 pollen types in satisfactory numbers (S. Bottema, unpubl.).

The rich samples of the cave of Baulmes, Switzerland (Leroi-Gourhan & Girard, 1971) also indicate that in areas with a moderate climate pollen preservation can be good.

In the next part, spectra from a tell in an area with reasonable precipitation during the summer months will be discussed.

Gomolava is a tell near Hrtkovci, Srem, Vojvodina, Yugoslavia. Habitation starts in the late Vinča period (see Table 6). Thereafter the tell is deserted for some time and a soil profile is developed on top of the Vinča layers. On this level aeneolithic people settle down, followed by various other cultures.

Samples were taken by Prof. Dr. W. van Zeist and the present author. For that purpose a profile from 1969 was studied to find a clear stratigraphy. At a suitable spot the profile was set back one meter. We assumed that corrosion and contamination would at least be less important there.

Samples were taken at 20 cm intervals, avoiding house-floors, fireplaces, and other constructions. Where the soil profiles were clearly visible sampling was adapted to the situation.

TABLE 6. SAMPLE NUMBERS, DEPTHS AND CULTURE PERIODS OF TELL GOMOLAVA

sample nr.	depth	culture period
1	80 cm	La Tène
2	140 cm	Hallstatt
3	220 cm	Late Aeneolithic
4	260 cm	Aeneolithic humus
5	280 cm	Aeneolithic humus
6	455 cm	Humus layer (old surface)
7	465 cm	Humus layer (old surface)

In Table 7 the pollen spectra of seven samples are given. They are a selection of the complete series. All pollen types are included in the pollen sum, apart from those of local water and marsh plants.

I am aware of the (too) low pollen sums, a

TABLE 7. POLLEN SPECTRA FROM TELL GOMOLAVA

Gomolava	1 80 cm	2 140 cm	3 220 cm	4 260 cm	5 280 cm	6 455 cm	7 465 cm
Quercus robur-type	–	8.9	1.2	1.4	2.6	3.7	13.3
Pinus	13.3	8.9	28.3	48.3	11.7	18.4	23.4
Abies	2.2	–	5.9	2.8	1.3	0.7	3.1
Picea	2.2	2.2	10.6	5.0	1.3	5.9	0.8
Corylus	2.2	6.7	–	0.7	2.6	0.7	1.6
Carpinus orientalis/Ostrya	–	–	2.4	–	–	0.7	0.8
Alnus	2.2	–	2.4	0.7	1.3	–	–
Quercus coccifera-type	–	–	–	–	–	–	5.5
Pistacia	–	–	–	–	–	–	2.3
Betula	–	4.4	–	2.1	–		–
Tilia	–	2.2	–	1.4	–	0.7	0.8
Fraxinus excelsior	–	–	–	–	–	0.7	–
AP	22.2	35.5	50.7	62.4	20.8	31.6	52.3
Chenopodiaceae	6.7	–	2.4	0.7	3.9	–	–
Artemisia	2.2	4.4	–	0.7	–	–	3.1
Centaurea solstitialis-type	8.9	8.9	5.9	1.4	3.9	2.2	3.9
Centaurea scabiosa-type	–	–	–	–	1.3	–	–
Plantago lanceolata	–	2.2	4.7	5.0	6.5	0.7	1.6
Plantago spec.	–	–	1.2	–	–	0.7	–
Sanguisorba minor-type	–	–	–	–	–	–	2.3
Matricaria-type	–	–	–	0.7	–	1.5	2.3
Jurinea-type	2.2	–	–	–	–	–	–
Carduus-type	–	6.7	1.2	2.8	11.7	10.3	–
Tubuliflorae	11.1	2.2	2.4	18.4	16.9	10.3	3.1
Liguliflorae	11.1	20.0	1.2	–	5.2	2.2	6.2
Umbelliferae	–	–	–	0.7	–	–	–
Cerealia-type	4.4	6.7	7.1	1.4	18.2	29.4	12.5
Zea mais	8.9	–	–	–	–	–	–
Teucrium	2.2	–	–	–	–	–	–
Leguminosae	–	–	5.9	–	–	–	–
Malvaceae	–	–	–	–	–	0.7	–
Cruciferae	–	2.2	–	–	–	–	0.8
Caryophyllaceae	2.2	–	1.2	1.4	2.6	1.5	–
Scabiosa columbaria-type	6.7	2.2	4.7	–	2.6	1.5	1.6
Euphorbiaceae	–	–	–	–	–	0.7	–
Rosaceae	–	–	–	–	–	–	1.6
Potentilla-type	–	–	–	–	–	–	0.8
Gramineae	13.3	6.7	11.8	4.3	7.8	6.6	7.8
Pollen sum	45	45	85	141	77	136	128
Polygonum aviculare-type	15.6	11.1	5.9	1.4	11.7	–	–

Gomolava	1 80 cm	2 140 cm	3 220 cm	4 260 cm	5 280 cm	6 455 cm	7 465 cm
Cyperaceae	–	2.2	2.4	–	–	–	0.8
Myriophyllum verticillatum-type	–	–	–	–	–	–	0.8
Sparganium-type	–	–	–	0.7	–	–	2.3
Valeriana	–	–	–	–	–	–	0.8
Ophioglossaceae	–	–	–	–	1.3	0.7	1.6
Dryopteris	2.2	–	1.2	0.7	1.3	–	2.8
Pteridium	–	–	–	–	–	0.7	–
Pediastrum kawraiskyi	–	–	–	–	–	–	4.7
Indeterminata	4.4	13.3	8.3	5.7	6.5	3.7	10.9

handicap occurring more often in such investigations. In view of the experience with Compositae these types could also have been left out of the pollen sum, but here they form no part of the discussion.

The preservation is generally rather good, but pollen concentration in the samples varied. The greatest concentration was found in the two soil profiles, spectra 4 and 7. Although the pollen sums are low, some conclusions can be drawn.

The natural vegetation would have been a deciduous forest. In this connection I refer to the "silvae Bulgarorum" between Beograd and Niš, crossed by Walter of Poissy during the First Crusade, 1096-1097 (Turrill, 1929). *Quercus* species and *Carpinus betulus* would have been important constituents of the forest as they are today in local forest remnants.

In the spectra *Quercus robur*-type is present with relatively low values. *Pinus*, *Picea*, and *Abies* pollen are quite probably not derived from the local vegetation, because conifers do not grow in the lowlands nowadays. At present coniferous forest is found further south in the Bosnian mountains. Possible transport in river clay from the Sava cannot be excluded. The coniferous pollen values in spectrum 7, which represents the old surface underneath the tell, are, however, already high. Spectrum 7 is situated above the highest level of the river and no clay was seen deposited on the loess. The origin of the coniferous pollen remains vague.

One clear source of error, as mentioned in Chapter 4.5., could be traced. In the La Tène layers (ca. 500 BC - 0) four pollen grains of *Zea mais* were found. On top of this layer another 80 cm of material is found, the upper part of mediaeval times. The growing of maize could not have started before the 18th century (Huber, 1962). These grains, that could be recognized as due to contamination, have bridged 80 cm of tell and about 2000 years! In the case of types that cannot be recognized as such, one can only guess about possible infiltration.

Another possibility for learning something about the vegetation is the identification of charcoal. Van Zeist made a preliminary investigation on the charcoal of Gomolava (A preliminary report on the botany of Gomolava, 1973, intern report). It is interesting to compare the pollen spectra with the results of the charcoal study.

Van Zeist found *Quercus* dominating the charcoal remains, followed by *Ulmus*, *Fraxinus*, and *Populus*. *Acer* and *Tilia* were found in most of the periods in small quantities only.

We may assume that prehistoric men selected wood for several purposes and that charcoal is not a direct reflection of the forest. Still it draws the attention that rather much elmwood is present whereas not a single pollen grain of this tree is found.

Although in this case samples have been taken with great care, instead of interpreting the spectra for a reconstruction of vegetation and climate around the site, a discussion on sources of error in the pollen spectra is started!

Of course there remain facts that can be mentioned. But nobody will be surprised if in a tell, where farmers lived, various weed-types and high percentages for Cerealia pollen occur.

There remains the unexplained presence of some specimens of *Pediastrum kawraiskyi* (Chlorophyceae) in the oldest sample.

7. CONCLUSION

The use of palynological information from caves, rock-shelters, and prehistoric settlements for the reconstruction of vegetation and climate in the past is a matter requiring great caution, and cannot be done without corrections.

In the first place, pollen types of zoogamous plants, especially when present in great numbers, have to be judged critically. Pollen of Liguliflorae and some types of Tubuliflorae are by preference to be excluded from the pollen sum.

When sampling a prehistoric site, great care has to be exercised; the profile has to be cut back and a clear stratigraphy has to be looked out for.

One has to consider the possibility of infiltration of younger material, contamination with types selected by burrowing bees, transport of building material containing pollen, and (selective) corrosion.

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