CAVE POLLEN TAPHONOMY IN KURDISH IRAQ

MARTA FIACCONI

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Abstract

This thesis aims to understand the mechanisms involved in pollen transport and deposition in cave environments and the influence of different factors on the composition of the pollen assemblage, with special reference to the problem of the Neanderthal ‘Flower burial’ at Shanidar Cave, Kurdish Iraq. Limited systematic taphonomic work has been done in cave environments, with most of the studies on an *ad hoc* basis. However, the number of interconnected factors acting on pollen transport, deposition and accumulation in this kind of environments implies that models used for open-air sites are inadequate and demonstrates the need for further taphonomic studies.

Surface samples from six caves located in the Zagros Mountains of Kurdish Iraq were collected along front-back transects and outside for comparison in order to evaluate the distribution of anemophilous and entomophilous taxa in relation to the sample location. Additional surface samples were collected from Shanidar Cave along a side to side and perimeter transects to better evaluate the pollen distribution. Water, airfall and animal dung samples were also collected to investigate the influence of those factors in pollen transport. Finally, stratigraphic samples collected during the excavation at the site were analysed for pollen and for particle size distribution.

Results show that simple sac-like caves with little or no influence of factors such as water, humans and animals are characterised by broadly predictable patterns of pollen distribution with a positive correlation between anemophilous pollen and vicinity to the cave entrance and entomophilous pollen and distance from the cave entrance.

Caves with active biotic vectors and/or more complex geomorphology show instead more irregular patterns. Cave SLS203 presents an inverse anemophilous/entomophilous distribution that is likely to be related to its geomorphological complexity (a second entrance at the back of the cave influencing the air circulation) and to the presence of animals. Shanidar Cave presents a very irregular distribution which is likely to reflect a combination of factors such as the mixing of surface sediments caused by the tourists visiting the site, the pollen transported by animals and that moved by the wind. Other factors, such as water input and cave entrance flora, seem not to play an important role in

Kurdish Iraq, while they appear to strongly influence pollen distribution in caves elsewhere (e.g. Coles, 1988; Simpson, 2006).

The stratigraphic samples were sterile or contained few pollen grains, probably because the aeolian nature of the sediments, deposited during stadials, with low pollen deposition and high sediment influx.

Finally, clumps of pollen of both anemophilous and entomophilous taxa have been found for different taxa in all the caves. Leroi-Gourhan (1975) had suggested that similar clumps found in the vicinity of Shanidar IV remains were evidence for burial with flowers but their presence on the surface demonstrates that they can occur naturally and that other explanations should be considered. Moreover, the high amount of Lactuceae and the presence of older pollen grains in her samples suggest a strong taphonomic imprint not necessarily resulting from anthropogenic activity.

La mente non è un vaso da riempire

ma un fuoco da accendere.

Plutarco

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1. Introduction

1.1 Introduction

Palynology - the study of pollen and spores - has been used since its first development in the early years of the 20th Century to reconstruct past vegetation and climate (Lowe & Walker, 2014). In arid and semi-arid areas, conventional sources of pollen such as lakes, bogs and mires are often rare or absent, implying difficult collection of samples for pollen analysis and resulting in a lack of information about the past environments of those regions. In the last few decades, caves have been widely used to recover pollen in these problematic areas in order to understand the local and regional vegetational changes (e.g. Gale et al., 1993; Carrión et al., 1999; Hunt et al., 2011; de Porras et al., 2011; Edwards et al., 2015).

A number of experimental studies have dealt with modern cave pollen taphonomy showing that in caves with simple morphology and a limited influence of external factors - such as drip water, cave-entrance flora and human and animal presence - there are some general patterns in pollen distribution (van Campo & Leroi-Gourhan, 1956; Burney & Burney, 1993; Coles & Gilbertson, 1994; Prieto & Carrión, 1999; Camacho et al., 2000; Navarro et al., 2001; Navarro et al., 2002; Hunt and Rushworth, 2005; de Porras et al., 2011). These are:

- a decrease of anemophilous and an increase of entomophilous taxa with distance from the cave mouth;
- a better preservation of pollen in dry areas;
- a good representation of the local vegetation;
- a general agreement between cave and nearby open-air assemblages but with under-representation of arboreal pollen and over-representation of fern spores in the cave assemblages;
- a higher pollen concentration in caves with human and animal presence.

However, in more complex caves, the number of interconnecting factors acting on pollen transport, deposition and accumulation implies that the models used for open-air environments are inadequate and that the interpretation of the data can be problematic (e.g. Coles & Gilbertson, 1994; Van Campo & Leroi-Gourhan, 1956;

Simpson & Hunt, 2009; Hunt & Rushworth, 2005; Fiacconi & Hunt, 2017, see Appendix 4).

1.2 Research design

Project rationale

This research is part of a five-year programme of excavation at Shanidar Cave, in Kurdish Iraq, which aims to establish a new understanding of the archaeology and the findings of one of the world's most important prehistoric sites. The relevance of Shanidar Cave is related to the discovery of a number of Neanderthal skeletons in the 1950s and 1960s (Solecki, 1963) and the associated pollen analysis that led to the idea of the earliest example of a funerary ritual (Leroi-Gourhan, 1975; Solecki, 1975, 1977) – the famous Shanidar 'Flower Burial'. This interpretation was later questioned by many authors (Chase & Dibble, 1986; Gargett et al., 1989; Sommer, 1999) but the political situation of the country prevented further investigations at the site and the debate remains open.

Research aim and objectives

The initial aim of this research was (i) the understanding of the provenance and the stratigraphic coherence of the pollen recovered from the cave in order to reconstruct the Late Quaternary vegetation history of the Zagros Mountains, (ii) to resolve the debate about the Shanidar 'Flower Burial' and (iii) to address the fundamental issues of pollen taphonomy in caves. However, difficulties related to the unstable political situation of the country delayed the start of the excavation; therefore, the collection of stratigraphic samples was limited and the archaeological work is still ongoing. These circumstances moved the focus of the research towards the last point and set the aim to the understanding of the mechanisms involved in pollen transport and deposition in this kind of environment and of the influence of the factors mentioned above on the composition of the pollen assemblage.

In order to achieve the aim, the main objectives are:

1. to take surface samples from Shanidar Cave and other caves in the Zagros Mountains area for pollen analysis;
2. to sample the different potential pathways by which pollen might enter the caves;

3. to take surface samples from outside the caves to compare the material from the caves and test the representativeness of the cave pollen assemblages;
4. to analyse the stratigraphic samples available from the cave;
5. to re-evaluate taphonomically the work of Leroi-Gourhan as it relates to the Shanidar ‘Flower Burial’.

1.3 Thesis outline

The following chapters present the background, methodology, findings and discussion of this research project. Chapter 2, 3 and 4 provide the background of this PhD project reviewing the literature available for pollen taphonomy in open-air and in cave environments, for the palynological work done in the Near East area and for previous excavations and findings at Shanidar Cave. Chapter 5 describes the environmental settings of this research and the location and characteristics of the caves under investigation. Chapter 6 explains the field and laboratory methodology used to collect and prepare the samples. Chapter 7 presents the results of the pollen and particle size analysis. Chapter 8 discusses the findings in relation to the issues outlined in the literature review and Chapter 9 summarises the main conclusions, highlights the limitations and provides suggestions for further research.

2. Pollen taphonomy

This chapter presents the theory behind the prediction and interpretation of pollen dispersal and plant-pollen relationship in open-air environments with a description of the models adopted, from the first correction factors to the development of modern complex computer simulations. Then, an overview of the principles, potentials and problems of cave palynology with particular attention to the taphonomy is provided. The main pollen transport, accumulation and post-depositional processes are discussed, the literature available on modern pollen taphonomy is reviewed and a summary of the main palaeoenvironmental studies undertaken in caves in the Mediterranean area is provided.

2.1 Introduction

The word taphonomy, from the Greek *taphos* and *nomos* – laws of burial – first coined by Efremov (1940), refers to the study of the processes involved in the formation of fossil assemblages, from the death of the organism to its fossilization. As other organic remains, pollen and spores undergo a series of steps that lead them from the biosphere into the lithosphere and pollen taphonomy deals with the processes governing the production of this kind of sub-fossil assemblages (Coles et al., 1989). One of the main applications of palynology is the reconstruction of the past vegetation and environment using the information contained in the fossil pollen assemblages, based on the assumption that the pollen rain over a given area is the reflection of the vegetation growing there (Birks & Birks, 1980). However, factors such as differential pollen production among species, transport and dispersal mechanisms, deposition velocities and differential preservation affect the pollen assemblage and the correspondence between the pollen and the related vegetation. Therefore, soon after the development of palynology, researchers have focussed on understanding the relationship between these factors and created models of pollen dispersal and pollen-vegetation relationship in order to infer past vegetation compositions from the fossil pollen data.

2.2 Pollen taphonomy in open air-environments

The first element to consider in a fossil pollen assemblage is the source of the pollen. Tauber (1965) created a model that accounts for the different sources transporting pollen in a small lake or mire within a forest vegetation and suggested that the total pollen consists of three different components: the trunk space component, which is the pollen produced by shrubs and herbs and transported at sub-canopy level; the canopy component, that includes the pollen produced within the canopy and transported by the air above the tree level; the rain component, which refers to the pollen in the atmosphere transported down to the ground by the rain drops. Moore et al. (1991) added other two components to the model, especially crucial in sites such as mires, which are a local or gravity component (pollen from plants growing in the immediate vicinity of the site) and a secondary or inwashed component (pollen transported by drainage water) (Figure 2.1).

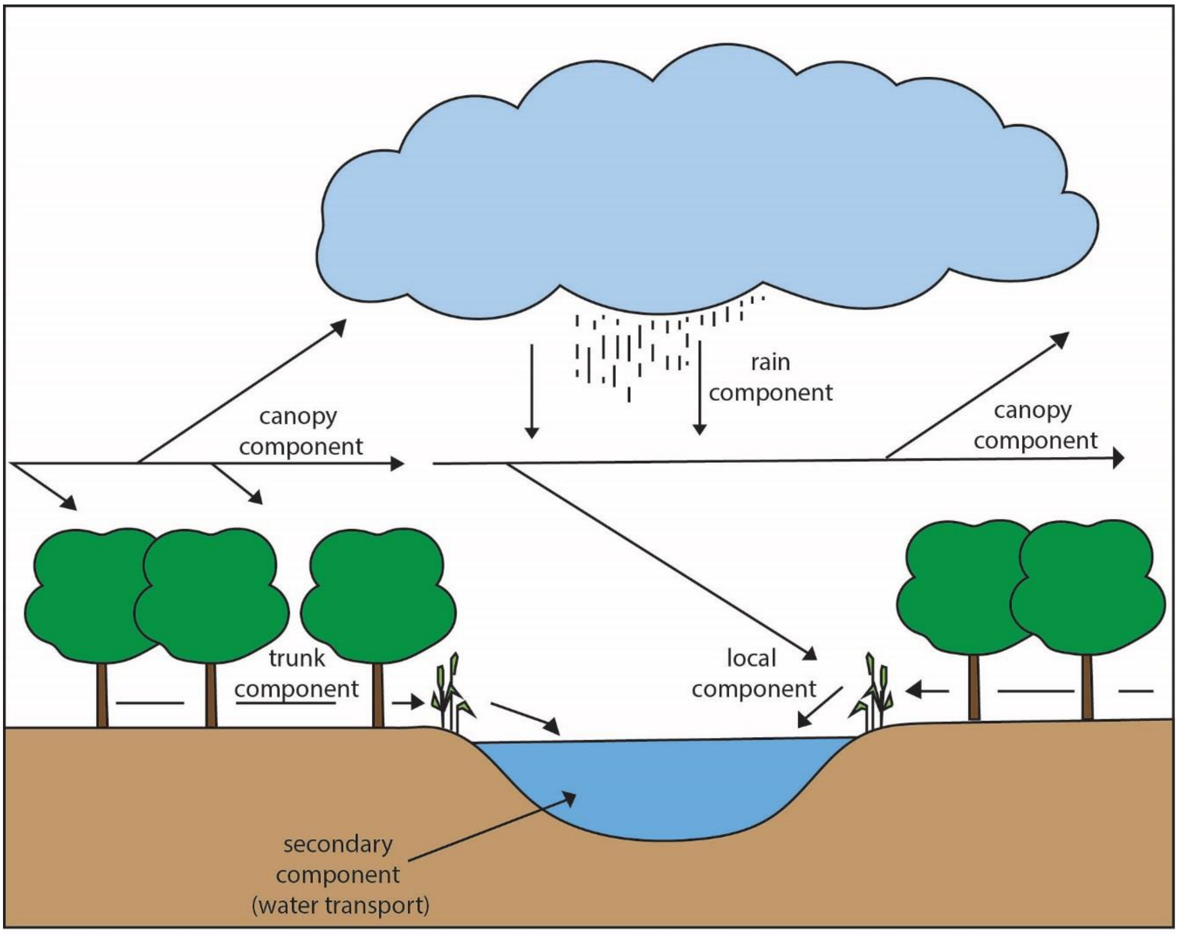


Figure 2.1 Sources of pollen in a site within a forest environment based on Tauber (1965) and modified from Moore et al. (1991).

The size of the site is another element influencing the pollen composition. Jacobson and Bradshaw (1981) correlated the diameter of the site with the local, extra-local and regional component of the pollen within the total pollen deposited showing how small sites are dominated by pollen coming from the local vegetation while bigger sites collect pollen coming from a wider area (Figure 2.2). The first attempt to correlate the pollen percentage recorded in a pollen diagram with the actual vegetation percentage was represented by Davis' R-values (1963), with high values relating to over-representation in the pollen record and vice versa (Lowe & Walker, 2014). However, this index has its limitations, depending on the source of pollen, the vegetation structure, the topography of the area (Moore et al., 1991) and not taking into account the background pollen (the pollen coming from outside the area under investigation) (Gaillard et al., 2008).

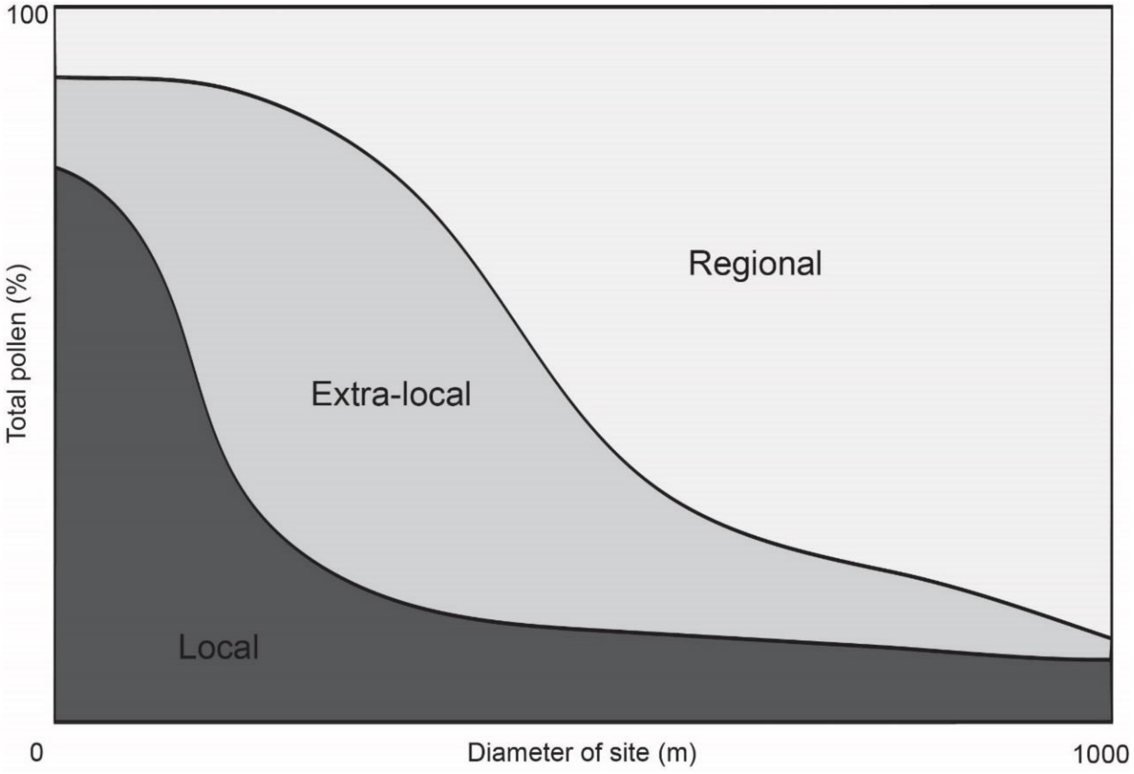


Figure 2.2 Relationship between diameter of the site and the source of pollen (modified from Jacobson & Bradshaw, 1981).

To overcome these limitations, Andersen (1970) suggested the use of a linear regression curve where the background pollen is represented by the y axis intercept (Seppä, 2006). This model, however, implies a linear relationship between pollen and vegetation, whereas the Fagerlind effect (Fagerlind, 1952) presupposes an expectation of non-linearity when the relationship is expressed in percentages instead of absolute numbers.

The combination of the features of both models led to the creation of the extended R-value method (ERV) where the pollen input is considered as a percentage and the background component is also taken into account (Parsons & Prentice, 1981; Prentice & Parsons, 1983). In addition, different ways of introducing the distance of the pollen source into the equation have been proposed in order to acknowledge that plants located closer to the site will contribute to the pollen more than plants located further (Webb et al., 1981; Prentice, 1985; Prentice & Webb, 1986; Schwarz, 1989; Sugita, 1993; Calcote, 1995; Jackson & Kearsley, 1998). The resulting Prentice-Sugita model of pollen dispersal and deposition (Prentice, 1988; Sugita, 1993; 1994) considers the pollen found in a site as the result of the plant productivity, the plant abundance and a pollen deposition function which is based on Sutton’s equation (Seppä, 2006).

To improve the model and to account for pollen dispersal, Sugita proposed two additional models – the Finite Line Source Model (FLS model, Sugita et al., 1997) and the Ring Source model (RS model, Sugita et al., 1999) - where the distance of the plant source is described as a line and as concentric rings respectively. An important implication of the Prentice-Sugita model is related to the concept of the ‘relevant source area of pollen’ (RSAP), defined as the vegetation within a certain distance from the sampling point which is most sensitively recorded in the pollen assemblage (Bunting & Hjelle, 2010) and calculated using the maximum likelihood method (Broström et al., 2005). This means that small sites (with radius <50m) will record local vegetation while bigger sites (with radius>250 m) will better represent regional conditions. Nevertheless, some of the assumptions on which the model is based rarely occur in real situations (e.g. the circularity of the basin or the even direction of the pollen dispersal) and it does not take into account the stream-borne pollen which is often a major source of pollen in lakes (Seppä, 2006).

Computer models, such as POLLSCAPE (Sugita, 1994) and HUMPOL (Bunting & Middleton, 2005) have also been developed to simulate pollen dispersal and deposition in heterogeneous landscapes based on the Prentice-Sugita model and, although some limitations, they provided to be successful in simple and closed forest environments. More recently, Sugita created an algorithm for the reconstruction of the landscape (LRA, Figure 2.3) which includes models for both the local (LOVE – Local Vegetation Estimates) and regional (REVEALS – Regional Estimates of Vegetation Abundance from Large Sites) components. LOVE determines the local vegetation using fossil pollen from small sites (<100ha) based on pollen counts from target sites, their RSAP, the pollen productivity estimates and the regional vegetation composition (obtained using the REVEALS model) (Sugita, 2007b) while REVEALS uses pollen from large sites (>100ha) to estimate regional vegetation with small standard errors (Sugita, 2007a).

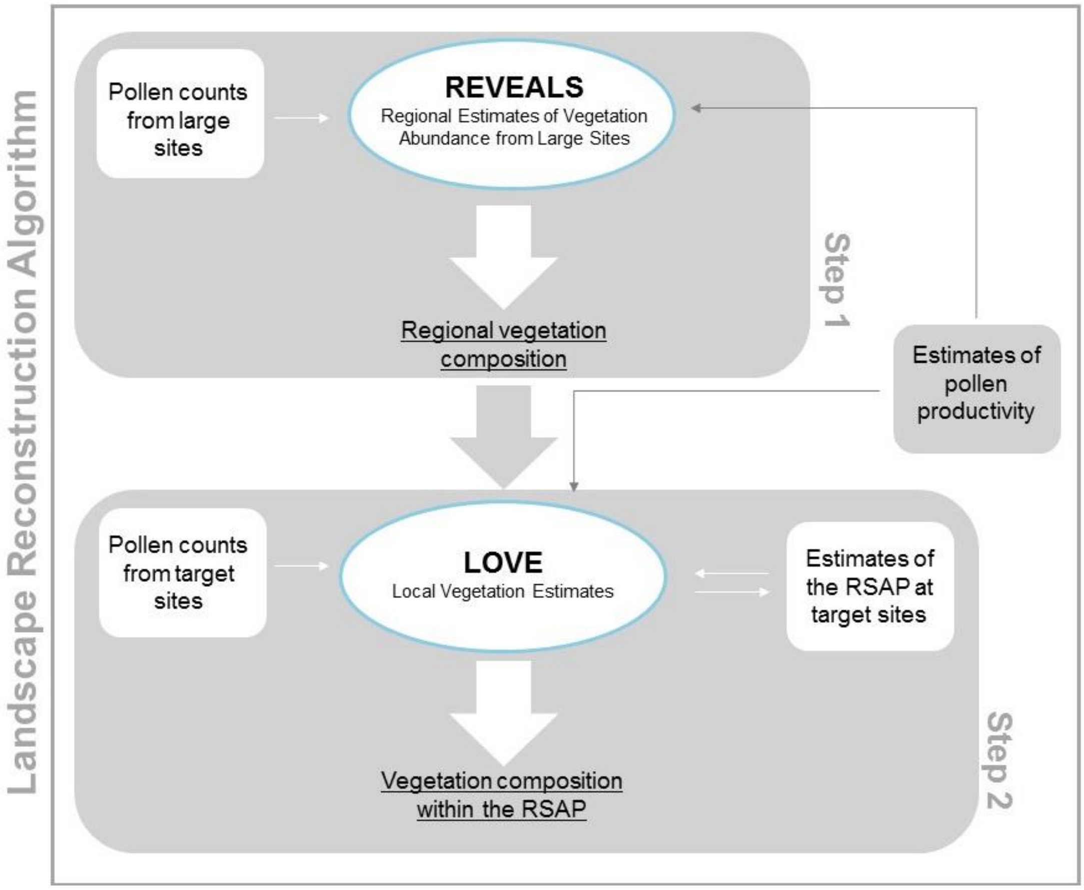


Figure 2.3 The LRA model structure (modified from Sugita, 2007b).

All the models presented above are valid in a forested environment, while less work has been done on non-arboreal landscapes. Bunting (2003) presented estimates of RSAP for individual taxa and assemblages in open landscapes in Scotland demonstrating the possibility of local vegetation reconstruction in these types of environments; she also reported that samples from mires are dominated by pollen from the vegetation growing within few meters from the sampling point and that some anthropogenic taxa are present in the pollen assemblage even when they are not part of the local vegetation, with clear implications for the palaeoecological interpretation. A similar study by Schofield et al. (2007) in a treeless landscape in Greenland found a good representation of the vegetation growing within 1 m from the sampling point.

2.3 Pollen taphonomy in cave environments

As discussed above, most of the studies undertaken on pollen transport concerns open-air environments and, in caves with particular characteristics such as free air and/or water passages, results obtained through these studies can be used effectively. In all the other cases, however, specific aspects related to pollen transport inside caves must be considered.

The formation of fossil assemblages involves a series of events that are production, dispersal, transport, deposition and post-depositional processes (Figure 2.4, Coles *et al*., 1989). In addition, for each of those steps there are a series of interconnected factors that complicate the situation and create problems in the interpretation of the pollen assemblages.

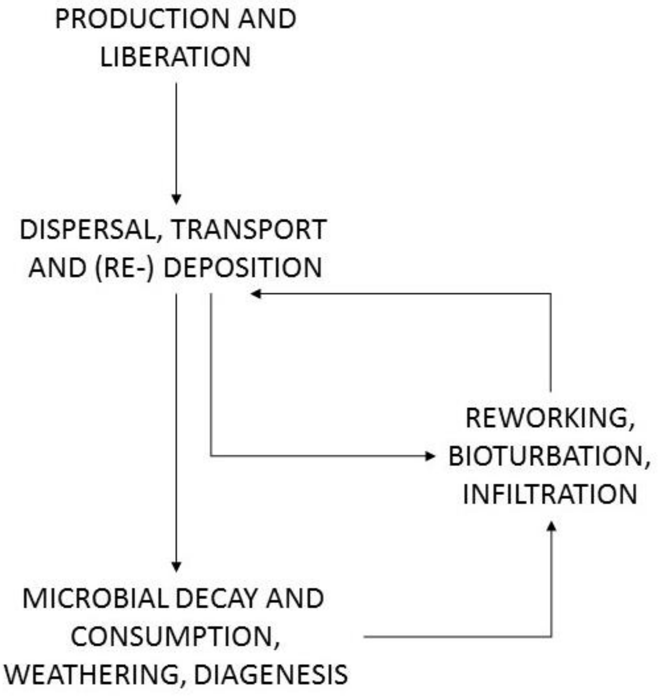


Figure 2.4 Summary of processes involved in the formation of fossil assemblages (modified from Coles et al., 1989).

2.3.1 Pollen transport

The main vectors that incorporate pollen in cave deposits are wind, water and humans and animals.

Airborne transport

When the wind is the main element transporting pollen grains in the cave system, a distinction between caves with single and multiple entrances is necessary. In simple sac-like caves the air circulation is likely to be linear and it changes depending on time and season: in summer, during the day, the rock is cooler than the outside environment, so cold air from outside moves into the cave at roof height and drains out at ground level. On the contrary, during summer nights and in winter the rock is usually warmer than the outside environment so the air circulation follows an opposite route, entering the cave at ground level, getting warmer by contact with the rock and leaving the cave at roof level.

In caves with multiple entrances, when these are grouped and interconnected, the system acts as it does in simple caves but when entrances are at different altitudes there might be a chimney effect. In both cases the distance that pollen can reach inside the cave - related to the velocity of the air flow - has been calculated to be 10 m in simple sac-like caves and further in multiple-entranced caves with concentration decreasing with distance from the entrance (Van Campo & Leroi-Gourhan, 1956).

The entrance flora can be another factor influencing the air flow: ferns usually grow abundantly near cave entrances and can have a strong influence on the pollen spectra by acting as a filter for the incoming air and/or by influencing the composition of the palynological assemblages when releasing their spores. An example of this process can be found in Coles & Gilbertson (1994) in their study of Creswell Crags (England) where they recorded a higher percentage of fern spores and a lower percentage of arboreal pollen in the samples from the cave compared to the assemblages from the nearby Crags Lake, supporting the idea of a strong influence of the entrance flora on the cave pollen composition. In general, the airborne pollen appears to be representative of the vegetation within 500 m of the cave entrance and up to 40% of the taxa recorded in the cave grow within 100 m from the site (Coles, 1988).

Water-borne transport

Transport by water occurs through streams entering the cave system or through percolating ground-water. In general, pollen transported by rivers reflects the vegetation of the hydrological catchment area of the river (Birks & Birks, 1980) although there may be taphonomic bias (Hunt, 1994), while the pollen reaching the cave through percolating water reflects the local vegetation above the cave. Dripping water can contain much pollen, such as at the Haua Fteah in Libya where the dripwater pollen composition was similar to local airfall pollen assemblages (Simpson, 2016) or may contain no pollen at all, such as at Creswell Crags (Coles et al., 1989).

Transport by biotic vectors

Transport by animals (vertebrates and insects) and humans is the final mechanism involved in pollen and spore movement. Transport through animals can occur in different ways: directly on the exterior of the animal, indirectly on the exterior on the animal inside soil or sediment, within the gut, through material used by the animal as food or bedding and by organisms that act as bioturbators in the cave (Coles et al., 1989; Hunt & Rushworth, 2005). Examples of the influence that wild and domestic animals can have on the pollen spectra are evident at Niah Cave (Borneo), where bats and birds bring mangrove and riverine pollen into the cave producing enormous influx figures when comparing nest and airfall areas (Hunt & Rushworth, 2005) or at Haua Fteah (Libya) where fumier deposits are dominated by pollen taxa that reflect sheep, goats and cattle grazing several km from the cave (Hunt, unpublished).

Humans can also influence the pollen composition of cave sediments. In particular, it has been noticed that in occupation areas there is an abundance of herbs and ferns that are related to material introduced as food or bedding by people visiting or living in the cave (Van Campo & Leroi-Gourhan, 1956). At the Great Cave of Niah, Hunt et al. (2007, 2012) found clumps of immature pollen that likely came from fructifications introduced by humans rather than from the air. At the Wadi Bottamsa Cave, in Libya, algae of standing water were found in the fill of the dry cave floor together with the eggs of the human gut parasite *Trichurus* suggested a use of the cave as a latrine (Hunt et al., 2011).

2.3.2 Depositional factors

In addition to the transport mechanism, the energy and speed of deposition during the formation of the assemblage can also affect its composition and integrity and have effects on the chronology. High sedimentation rates and high process energy are associated with a high chance of a chronologically mixed assemblage; on the contrary, a high sedimentation rate associated with a low energy process is likely to produce defined horizons and the best chronological resolution (Figure 2.5, Hunt et al., 2015).

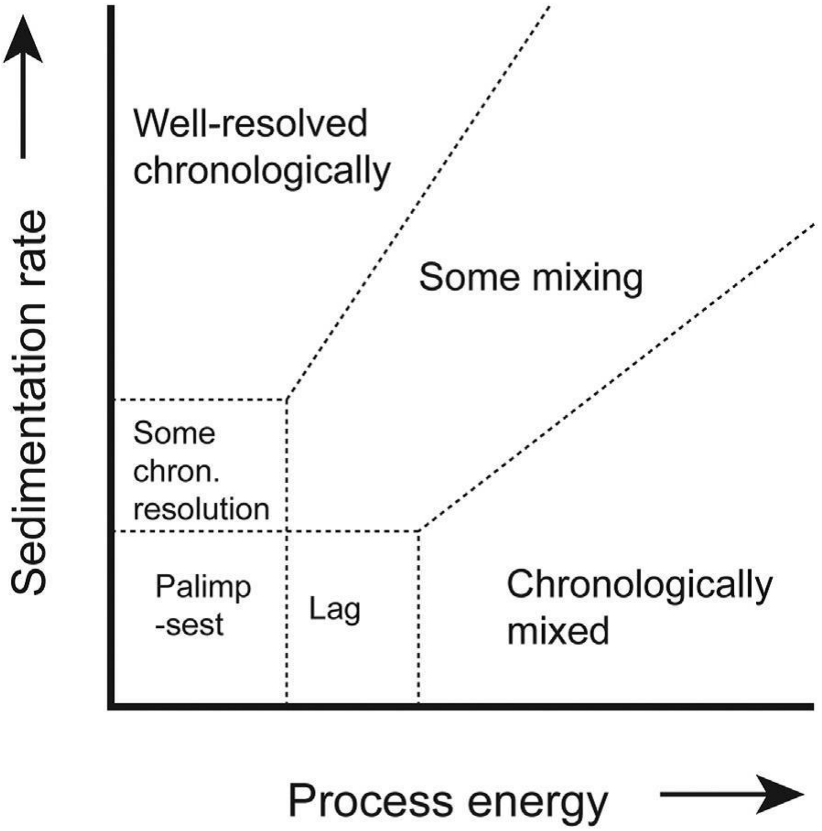


Figure 2.5 Conceptual model of the relationship between sedimentation rate, process energy and chronological integrity of archaeological assemblages (Hunt et al., 2015).

2.3.3 Post-depositional processes

After deposition in the cave environment, other processes can affect pollen grains and cause redeposition and/or destruction of the record. There are four main different mechanisms that result in the presence of younger or older pollen in a depositional layer: (i) complete removal and redeposition; (ii) partial removal and complete deposition of the removed fraction; (iii) complete removal and (iv) partial redeposition; partial removal and partial redeposition (Campbell, 1999). The principal vectors that can relocate pollen grains are wind and water and, depending on the characteristics of the grains, they control the pollen assemblage. However, biological activity remains one of the most important factors in pollen redistribution (Bottema, 1975a; Davidson et al., 1999; Hunt & Rushworth 2005).

Preservational factors

Another problem is related to preservation and differential destruction of the grains, related both to the grain composition and to the depositional environment. The amount of sporopollenin in the exine is the first factor influencing the grain resistance to oxidation and microbial attack (McGarry & Caseldine, 2004) but the physical and chemical parameters of the environment where the pollen is preserved play also an important role. Havinga (1964) demonstrated that an oxidised pollen grain is more easily affected by microbial attack and, according to Faegri and Iversen (1975), conditions of high pH do not always support pollen preservation (oxidation, the principal mechanism of pollen destruction, is mediated in part by pH, particularly in soils). However, all taxa are subjected to oxidation and even a low concentration of the oxidant and a short time of exposure produce a decrease in pollen concentration (Lebreton et al., 2010). Grain deterioration can occur *in situ* but also in transit: the collisions between pollen grains and clasts in rivers can provoke destruction and wet-dry cycles can cause mechanical damage to pollen grains (Campbell & Campbell, 1994).

2.3.4 Studies of modern pollen taphonomy

Cave pollen assemblages have been widely used to reconstruct past vegetation and environments, mainly when the cave contains important archaeological assemblages. Thus, palynological analysis has become part of the interdisciplinary study of the site in arid areas where lakes and bogs are not available. In fact, caves can preserve pollen better than open air sites because there is less chance of oxidation (Weinstein-Evron, 1994) and therefore, when the conditions are favourable, they provide invaluable sources of palaeoecological data. However, considering the number of interconnecting factors influencing pollen transport, accumulation and preservation in cave environments, it is essential to understand the taphonomic processes that led to the formation of the assemblage in order to use the information to reconstruct the past environmental changes. There have been few pioneer studies looking at those processes, but it was only in the last two decades that the majority of work has been done. However, despite improvements, an understanding of many processes is still incomplete.

Different approaches have been used to study the modern pollen deposition in this kind of environment, such as 1) paired studies comparing cave assemblages with nearby open-air sites, 2) single caves studies and 3) studies comparing caves in the same region that differ in morphology and/or other characteristics. The ideal condition is to compare cave assemblages with nearby open-air sites in order to understand and correct possible bias in the cave records, such as over- or under-representation of some of the taxa or the predominance of the local signal, but this is a rare circumstance.

1) Navarro et al. (2001) analysed six caves in south-eastern Spain comparing cave floor sediments, speleothems, moss polsters and animal dung with external samples taken from moss polsters and surface sediments. Cave samples appeared to be more reliable than the pollen rain outside the cave in representing the local vegetation, even with some over- and under-representations. Dry samples showed the best results in terms of spatial variability, pollen concentration and representativeness. A decrease of pollen concentration and an increase of zoophilous taxa with the distance from the cave mouth were also recorded.

A further example is the two-year pollen trapping experiment by Burney and Burney (1993) in three caves in New York State, where results from pollen traps, cave sediments, lake sediments and moss polsters were compared. In all the three caves, wind-pollinated taxa showed similar percentages both inside and outside, even if some of the taxa were under-represented. The influx study registered lower values inside the caves, as expected, and a decrease in the influx rate with the distance from the cave mouth, suggesting aerial transport as the major source of pollen in the caves. In general, caves with large entrances seemed to favourite air circulation and therefore pollen transport and sample location appeared to be a main factor in the representativeness of the pollen spectra.

A third example is the work of Coles and Gilbertson (1994), mentioned above, which found that the airfall-pollen collected over a year in four caves at Creswell Crags (England) reflected the vegetation growing near the cave entrance, the gorge and the surrounding area. The comparison with the samples from the nearby Creswell Crags Lake showed a general correspondence but some differences, such as an under-representation of arboreal taxa in the cave samples or the presence in only one of the records of some of the taxa. In addition, some of the plants growing within the caves or close to their entrances were absent from the airfall pollen possibly because their low pollen productivity, even if other taphonomical processes might have acted. Finally, fern spores appeared to be over-represented in the cave pollen record with values between 20% and 38% of the total pollen, even if the number of fern plants within the caves was modest. The suggested explanation was the time of spore liberation, which is higher at night when there are also movements of cold air inside the caves at ground level that could transport the spores.

2) Other studies have looked at single caves of archaeological importance. Prieto and Carrión (1999) analysed surface samples from Cueva de Jose, a single-entranced cave located in Murcia. The results showed a generally good preservation of the grains compared with samples taken outside and the assemblage being representative of the regional flora. Wind-pollinated taxa were more abundant in the middle of the cave while insect-pollinated taxa peaked near the entrance, contrary to what is usually found in caves. Therefore, animal transport must have played a major role in the pollen input, as demonstrated by the amount of goat and boar excrement found in the cave, as well as water transport, as suggested by the results of samples from water infiltration that showed the closest similarity to the outside samples.

A tropical environment was investigated by Hunt and Rushworth (2005) at the Great Cave of Niah, in Malaysian Borneo. Here the two main biotic vectors transporting pollen were bats and swiflets, with fruit and insectivore species having different nesting areas. The pollen influx study showed the highest pollen deposition near the nesting zone and the lowest in the rear of the entrance area. The pollen composition near the cave entrance was similar to that outside the cave, suggesting the predominance of air transport, while zoophilous taxa were prevalent from the middle of the cave. The study showed that the importance of animals as pollen vectors is higher in tropical areas compared to temperate zones and that pollen distribution is also strictly related to animals' foraging territories, nesting areas and diet.

Simpson and Hunt (2009) and Simpson (2016) investigated the pollen taphonomy at the Haua Fteah, Libya, analysing the influence of air-fall and vertebrate transport in the composition of the cave pollen assemblage. The results pointed out that the influence of both sources was evident in the pollen record creating bias in the pollen composition to be taken into account in the interpretation of the results. However, this also implies that it is possible to study the local or regional input by selecting a particular sampling area in the cave.

3) Finally, a third approach consists of comparing two or more caves that differ in morphology or other characteristics in order to study the effects of these parameters in the pollen record. One of the first attempts in this direction was undertaken by Van Campo and Leroi-Gourhan (1956) who placed sticky slides as pollen collectors within caves which had different geomorphology in central France. They noticed a decline in the numbers of airfall pollen with distance from the mouth of sac-like caves. In caves with through-drafts, instead, pollen was carried considerable distances from the entrance. Where human activity was frequent, pollen deposition was higher compared to less frequented caves.

Weinstein-Evron (1984) compared modern pollen samples from Abu Usba and Upper Open caves, located on the north- and south-facing slopes of Nahal Oren, Mount Carmel, in order to study the influence of the location of the slope in the composition of the pollen assemblage. Results showed a very different composition of the two cave pollen spectra, each reflecting the local vegetation growing on the relative slope and recording even slight variation in the direction of the cave entrances. However, despite the different taxonomic composition, the two spectra did not differ in their AP values; because arboreal/non arboreal pollen percentages are often used in the comparison of pollen diagrams, this result must be taken into account when using pollen data to reconstruct palaeoenvironments.

Caves in the Iberian Peninsula have been extensively studied mostly because the region lacks in swamps and peats and because entomophilous taxa, which make up the most of the local vegetation, are better recorded in caves than in lakes (Carrión et al., 2003). Navarro Camacho et al. (2000) analysed Moro I and Moro II in the Sierra Mariola Mountains, two caves with two entrances and three chambers and one entrance and two chambers respectively. Surface samples from both caves supported the presence of different types of pollen input, such as wind, insects and animal dung. Both caves showed a similar pollen assemblage with anemophilous taxa more abundant near the entrance and zoophilous taxa near the back of the cave but with some differences, such as the presence of a mouth-rear gradient for the numbers of degraded pollen grains in Moro I but not in Moro II. This suggests that even if the caves have similar location and they belong to the same karstic system, they can be characterised by different mechanisms that produce differences in the pollen assemblages. In general, there was an under-representation of anemophilous taxa - with the exception of Poaceae - and an over-representation of entomophilous taxa when comparing cave samples with the external pollen rain. Considering the type of samples, dry floor sediments seemed to be the best in terms of pollen preservation and concentration while samples from the middle of the cave floor were the most representative of the outside vegetation compared to those near the cave walls.

Two caves from arid south-eastern Spain were analysed by Navarro et al. (2002) to understand the impact of climate and cave morphology in the pollen taphonomy. The data showed that pollen grain preservation was good in both caves, anemophilous taxa were more abundant outside the cave (even if entomophilous species were predominant in the external vegetation) while zoophilous taxa were more common inside. The number of degraded pollen increased in wet areas demonstrating again the positive impact of aridity on pollen preservation and pollen concentration decreased with distance from the cave entrance. The morphology of the caves seemed to play a key role in pollen transport and deposition as the cave with a small entrance and a long and narrow shape showed lower pollen concentration and higher degradation.

Finally, De Porras et al. (2011) studied two caves with different orientation, location and morphology in the Patagonian steppe of Argentina to understand pollen transport and taphonomy. The two main pollen transport and depositional mechanisms in action appeared to be air and biotic, with sheep acting as primary vectors. The presence of fungal taxa *Sporormiella* was used as an indication of biotic transport due to coprophilous association. The samples collected from the ravines and the plateaux outside the cave were used for comparison. The cave pollen assemblage reflected only the local vegetation, while the dwarf shrub communities growing in the plateaux were under-represented. In this case, the differences between the two diagrams did not seem to be related to cave orientation, cave topographic position and plants growing at the cave entrances; therefore, it was likely to reflect post-depositional processes acting in the caves, such as differential preservation or the presence of a entrance-rear gradient, even if pollen preservation and concentration was good in both caves. The difference between anemophilous and entomophilous taxa in relation to the distance from the cave mouth was not as strong as in other caves. However, the percentages of *Sporormiella* suggested that biotic transport was strong in both caves and increased toward the back, so animal behaviour and diet might have had some influence in the pollen assemblage composition.

2.3.5 Other sources of pollen in cave environments: speleothems and organic deposits

Pollen concentration is one of the most problematic issues in the use of cave sediments for the reconstruction of past vegetation (Gale & Hunt, 1985). However, caves are often characterized by the presence of particular sources of pollen such as organic deposits (middens, dung and coprolites) and speleothems that have been demonstrated to have good potential for the recovery of well-preserved material.

Speleothems

Speleothems (stalagmites, stalactites and flowstones) are reprecipitated carbonates common in limestone regions that can provide long palaeoenvironmental records, contain stable isotopes which are useful for palaeoclimatic reconstructions and can be dated by U-series dating (Lowe & Walker, 2014). In addition, they can be a useful tool in cave palynology because they can contain well preserved pollen that is representative of the local vegetation (McGarry & Caseldine, 2004). Pioneer work on speleothem palynology was carried out by Bastin (1978, 1990) which demonstrated how the vegetational changes recorded from speleothems in Belgium correlated with the vegetational changes recorded from peats and lakes in the region, suggesting the potential of this kind of material especially in calcareous regions (Bastin et al., 1982; Bastin & Gewelt, 1986).

However, the use of speleothems presents some limitations, such as a poor temporal resolution caused by their slow growth, that might prevent the record of short or rapid environmental changes and cases of sterility (Lauritzen et al., 1990; Brook et al., 1990), where the absence of pollen can be related to: a dense vegetation outside the cave which prevents the pollen in reaching the surface; the filtering activity of clay particles in the soil above the cave; the distance of the speleothem from the cave mouth in relation to the distance decay of pollen concentration; the absence of humans or animals transporting pollen in the vicinity of the speleothems.

Despite the problems, several studies (e.g. Burney & Burney, 1993; Burney et al., 1994; Caseldine et al., 2008; Martinez-Pillado et al., 2014) comparing pollen recovered from speleothems with pollen from other sources (moss polsters, bogs and lakes) suggested that there is a good correspondence between them and often a good preservation and concentration of the grains, implying that speleothem pollen is representative of the vegetation outside the cave and that speleothem palynology is a valuable tool for the recovery of datable pollen records.

Coprolites

Coprolites are commonly present in caves and they can represent a source of pollen with good concentration and biodiversity which is representative of the local and regional flora (Carrión et al., 2002). Among the different types of coprolites studied, hyena coprolites are one of the most analysed, as it has been demonstrated that they provide a rather impartial picture of the regional vegetation (Djamali et al., 2011). Several studies undertaken in Spain give an overview of the potential of their use. Carrión et al*.* (2001) analysed the pollen content of *Crocuta crocuta* coprolites collected from Las Ventanas Cave (Granada), comparing the record with the one already available for the region. They found well preserved pollen with high taxonomic diversity and it was possible to exclude post-depositional contamination, concluding that the hyena diet has no influence on the pollen record. In fact, in Las Ventanas, the most likely source of pollen recorded in coprolites is the stomach content of hyenas' prey (large herbivores) and, considering that these mammals eat mostly grasses, the pollen from coprolites reflects the regional vegetation. Other possible sources are however the pollen which has stuck to nasal membranes of the hyenas and swallowed with mucus and the pollen which was on the coats of the animals eaten by them. In addition, Carrión (2002) demonstrated that conventional pollen records are influenced by long-distance transport and tend to under-represent insect-pollinated plants so coprolites can provide useful information, especially when used in association with other pollen records, in particular in arid environments.

Another example of successful application of pollen analysis on hyena coprolites is the study by Carrión et al. (2007) who recovered *Crocuta crocuta* coprolites from a rockshelter and a karstic cavern in central Spain that allowed the reconstruction of the late Middle Pleistocene and the early Upper Pleistocene vegetation in the region. As in the previous case, pollen preservation and concentration were good in most of the samples. Pollen analysis of the content revealed some differences within the same site that could be related to the presence of a patchy environment, as suggested by previous studies (Carrión et al., 2001; Scott et al., 2003). From these studies it can be argued that the pollen record in hyena coprolites gives a regional view of the vegetation as these animals cover long distances searching for food (González-Sampériz et al. 2003).

In geographic areas where conventional sources of pollen are scarce, such as the Zagros Mountains, the analysis of hyena coprolites offers an important tool to add detailed information about the vegetational changes that characterised the region during time. A recent study by Djamali et al. (2011) in the Wezmeh Cave represents the first use of coprolite analysis in Iran and provides a further evidence of its potential. Despite the fact that three out of seven samples were sterile and that it was not possible to establish chronostratigraphical pollen zonation due to problems with the stratigraphic location of the samples, the picture that emerged from the pollen content was of a landscape dominated by steppe vegetation during the last glacial age and the Holocene.

Dung of other species has also been also used in cave palynology. The rationale for the use of bat guano for palaeoenvironmental reconstructions can be found in Maher (2006); he reported that the pollen composition in bat guano samples was similar to the one found in the pollen rain of the area where the animals were feeding and that can be compared to the pollen record from nearby lakes and bogs. Geantă et al*.* (2012) analysed bat guano samples from Măgurici Cave in Transylvania (Romania) to reconstruct the vegetation in the area during the last 800 years with radiocarbon dating of the samples.

The importance of animal input in cave pollen assemblages in tropical areas has been highlighted by Hunt & Rushworth (2005) in their analysis of bat and bird droppings from the Great Cave of Niah in Malaysian Borneo. Their results showed marked differences in pollen influx and composition between the areas near the cave entrance, where the airfall pollen is dominant, and the back of the cave under the animals’ roosting area. In addition, the foraging habits of the different species appeared to be recorded in the pollen record which can lead to over-representation of some taxa and the record of plants growing further from the sampling site. Despite the problems, the growing number of studies using animal coprolites demonstrates the invaluable contribution of this source of palynological information to obtain a detailed track of the vegetational changes happening in the study area (e.g. Scott et al., 2006; Yll et al., 2006; Carrión et al., 2006; Scott & Woodborne, 2007; Brook et al., 2010).

Animal middens

Another source of pollen within the organic deposits is represented by packrat and hyrax middens. Packrats (*Neotoma*) are small rodents with twenty one species living in different habitats from Canada to Nicaragua (Betancourt et al., 1990). These animals collect vegetal material in an area up to 50 m from their dens, which is then cemented together by urine and preserved as a midden. Packrat middens are interesting because their content of plant macrofossils and pollen grains and the possibility of dating using the radiocarbon method. In particular environments, such as dry caves, they can be preserved for thousands of years (Thompson & Anderson, 2000). However, the problem in the use of packrat middens in palaeovegetational reconstruction is represented by the provenience of the material used to build the den: in fact the pollen can reflect both the local and regional scale with driving mechanisms still poorly understood. In addition, there are also problems related to the taphonomical processes leading to their formation and to post-depositional episodes such as erosion, rockfalls and collapse into crevices which produce relocation of the middens in the stratigraphy (Wells, 1976).

To avoid these complications, some authors have focussed their attention on middens of other species, such as hyraxes (*Procavia capensis).* Comparisons between the pollen content found in those middens with that found in nearby open-air sequences demonstrated that the animals’ diet does not have a big impact on the pollen composition and, therefore, the middens can provide a good representation of the surrounding vegetation (Carrión *et al.* 1999a). Even if macrobotanical remains are rare in hyrax middens as they are not collectors like other species, the pollen is usually abundant and well preserved thanks to the conservation in the hyracium, the solidified concentrated urine that accumulate in dry environments (Scott and Bousman, 1990; Scott, 1994; Scott, 1996).

2.3.6 The use of cave palynology for palaeoenvironmental reconstruction

Because of the relatively low number of studies dealing with the modern taphonomical processes acting in caves, the application of cave palynology to palaeoenvironmental reconstructions still presents problems. Cases of caves that are sterile of pollen, have very low pollen concentration or a poor pollen preservation are common. There are also cases where, even with a sufficient number of grains, the uncertainty about the preservation of the original stratigraphy implies concerns about the temporal coherence of the assemblage.

An example of unsuccessful application of cave palynology can be found in Carrión et al. (1995) in the analysis of a Mousterian and Upper Palaeolithic sequence from Perneras Cave in Murcia. Because of the nature of the sediments - detritic deposits over a stalagmitic floor – absolute dating was impossible, implying limitation in the palaeoenvironmental reconstruction. The abundance of poorly-preserved Lactuceae grains also suggested differential preservation and some evidence of bioturbation. Samples from calcium carbonate layers, however, appeared to be the best for pollen analysis and allowed a general reconstruction of the environment. Carrión and Scott (1999) studied a travertine from Sterkfontein Cave, in South Africa. The results showed low pollen concentration values and the presence of cytoplasm in some of pollen grains, suggesting contamination from the cave or the laboratory with grains of different ages getting incorporated in the sediments and not being removed during the preparation procedures. Another example of the difficulties represented by cave assemblages comes from Groner (2016) who reported the results from a high alpine karst cave in Switzerland. Most of the pollen was damaged, crushed or showed a very thin wall with indeterminable grains more abundant than those identifiable. The author suggested that the reason for the extremely low pollen concentration was that ice represented the only transport mechanism acting in the cave system and was unable to move a great quantity of grains. In addition, the assemblage showed a mixture of grains coming from different ages suggesting reworking of material. Carrión et al. (2009) published a review paper on the importance of negative results in palynological studies of Quaternary sites in Spain: of 221 cases of pollen sterility, 22% were caves and 11% rockshelters, representing the majority of the case of failure, together with open-air archaeological sites (Figure 2.6).

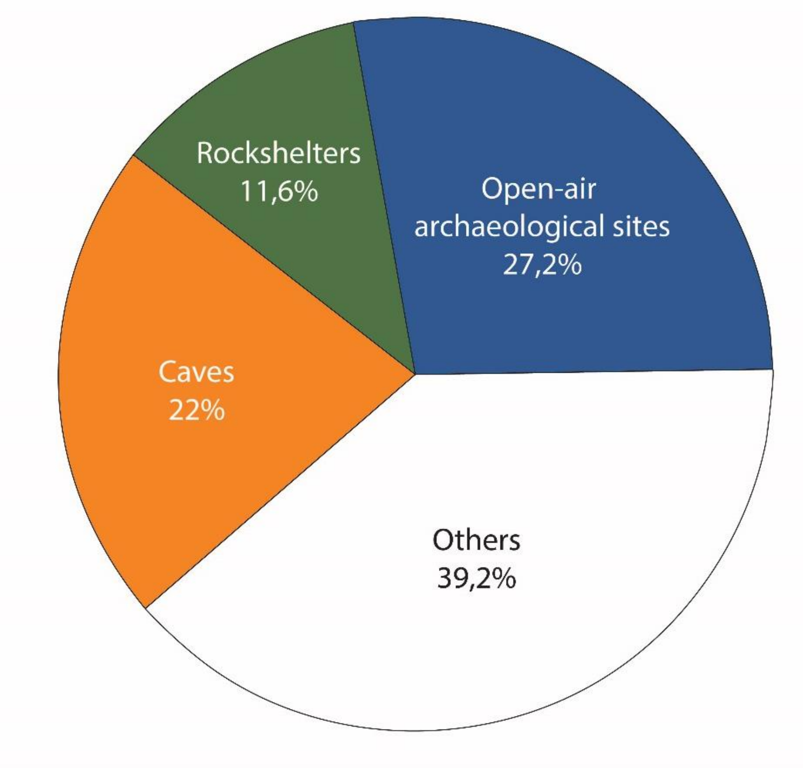


Figure 2.6 Percentages of cases of palynological sterility in Spain per type of environment (modified from Carrión et al., 2009).

Nevertheless, there are cases when a scarce or poorly detailed palynological record can still be useful if integrated with data coming from other sources. Renaut and Bamford (2006) presented results from Sibudu Cave (South Africa) that contained organic materials but pollen only in few occasions. They interpreted the lack of preservation as the main cause for low pollen concentration, probably due to fires (as suggested by the presence of ashes). However, they were able to draw a picture of the vegetational changes happening in the area by matching the pollen with the results from seeds and charcoal.

Despite the problems, numerous authors have succeeded and the number of studies relying on cave palynology has grown during the last twenty years, especially thanks to the improvements made in the understanding of the taphonomical processes acting in this kind of deposits (e.g. Deacon, 1979; Head, 1985; Worthy & Mildenhall, 1989; Scott, 1993; Hunt & Rushworth, 2005b; Yakovlev et al., 2006; Hunt et al., 2015; Danukalova et al., 2008; de Porras et al., 2009; Bar-Yosef et al., 2011; Doláková, 2014; Li et al., 2014; Buosi et al., 2015; Scott, & Thackeray, 2015). Because of the geographical location of the area studied in this PhD and the Shanidar Cave chronological framework - dating back to the Mousterian period – this part of the literature review will focus on examples from Pleistocene cave sites in the Mediterranean area.

Spain

As already mentioned, the Iberian Peninsula is particularly rich in palynological studies in caves because of its environmental and vegetational characteristics. Carihuela Cave, one of the main archaeological sites in Andalusia, contains some of the youngest evidence for Neanderthals in Europe and has been studied by several authors (Carrión, 1992; Carrión et al., 1998; Fernández et al., 2007) with environmental reconstructions available for the Pleistocene and the Holocene. The cave pollen assemblage seems to be representative of the external vegetation, as supported by the good correlation between the litho- and the biostratigraphy, even if some of the results, such as the variation of anemophilous and entomophilous taxa in relation to the distance from the entrance or the differences in the dominant pollen types cannot be explained. However, the geomorphological complexity of the cave, characterised by several entrances, might have played a major role in determining the air circulation patterns and, therefore, the pollen composition. The most recent study of the cave (Fernández et al. 2007) offered the occasion for some taphonomical considerations. The highest values of indeterminate pollen recorded in the pollen diagram were associated with peaks of Asteraceae and a low pollen concentration, suggesting differential preservation. However, the fact that some of the Asteraceae peaks corresponded to high pollen concentrations and that periods where a low pollen concentration corresponded also to low Asteraceae percentages suggested other possible explanations. Unfortunately, the lack of knowledge about the post-depositional processes acting in caves prevents a conclusive interpretation of the data and allows only speculation. In general, some factors seem to be related to a successful pollen analysis in caves, such as the presence of large entrances that enhance air circulation, calcium carbonate layers and generally dry sediments that help pollen preservation and the presence of artefacts or human remains that allow the comparison with the pollen assemblage.

Palynological data from another archaeological site in the region, Cova Beneito, were produced by Carrión (1992a) and Carrión and Munuera (1997), tracking the transition between the Middle and the Upper Palaeolithic and providing important information about Neanderthals and modern humans in the Mediterranean area. In general, the correspondence between concentration and percentage pollen diagrams suggested a reliable representation of the vegetation; however, the authors highlighted how data coming from pollen analysis should be used to reconstruct general trends more than specific events related to single peaks of the diagram, considering the number of factors that can influence the pollen composition. In particular, some of the doubts were related to *Pinus* and Poaceae curves with changes that could have been explained as representative of changes in the vegetation but also as an over-representation caused by the location of those plants in the vicinity of the cave as well as an artefact caused by the calculation method.

Carrión et al. (1999) published a summary of successful cases of cave palynology in Spain. What emerged from these studies is that there are a series of elements that enhance the possibility of success when analysing pollen from caves, such as a diversity of around 30 taxa per sample; a concentration of 10000 grains/g^{-1} and a pollen count of more than 200 grains/sample, excluding Asteraceae; a percentage of indeterminate pollen of less than 20%; the collection of the samples from central areas of the cave; the ecological coherence of the taxa recorded; a multidisciplinary approach in order to validate the data.

Iriarte-Chiapusso et al. (2015) studied the burial site at El Miron Cave (Spain) dated back to the Lower Magdalenian. As most of the samples collected from the western area of the cave showed very poor pollen preservation, they tested the integrity of the sequence by comparing the sampling column with another sequence taken in a different area of the cave. The funerary context showed a pollen composition completely different from the rest of the cave with an unusual amount of Chenopodiaceae pollen, sometimes in groups of 6 grains. They supported the hypothesis of a floral offering to the burial because of the scarcity of this pollen type in other spectra from the same period in the region and the presence of these grains in clumps that excludes the wind as transport vector. In addition to the pollen, microvertebrate remains were used to validate the vegetational reconstruction, highlighting the importance of a multidisciplinary approach to correct possible bias introduced by the analysis of a single proxy.

A successful example of a the multidisciplinary approach in the study of a cave environment can be found in López-García et al. (2012) where different proxies from Teixoneres Cave were used to reconstruct the Late Pleistocene environment in the north-eastern part of the Iberian Peninsula. In particular, level II and III of the cave showed association with Mousterian industries and Neanderthal occupation and pollen, small vertebrates, amphibians and dental wear were used to draw a climatic and environmental picture of the area during that time. In general, all records showed the presence of an open forest landscape, but pollen and small vertebrates allowed differentiation between humid and temperate climatic conditions in the two levels, showing the importance of the comparison of different proxies in order to improve the detail of the reconstruction.

A similar strategy involving faunal, charcoal and pollen analyses was used at Escuilleu cave in Cantabria to study the relationship between Neanderthals and their environment (Uzquiano et al., 2012). Results from pollen analysis allowed the identification of three main vegetational phases: an open landscape from 53 to 51 ka BP, an intermediate phase from 50 to 39 ka BP, where the information is scarce due to very poor pollen preservation and a phase characterised by moist conditions (suggested by the amount of *Pinus* and mesophilous taxa) from 39 to 34.3 ka BP. The charcoal analysis showed similarities with the pollen record suggesting the presence of an open landscape between 53 and 39 ka BP with taxa constantly present throughout and used as fuel (e.g. *Pinus sylvestris*). In addition, results from the faunal analysis provided important information about hunting strategies and site function, suggesting the presence of periods where most of the resources used by the inhabitants of the area were local and others when further zones were explored.

Zilhão et al. (2016) reported a multi-proxy analysis of the south-eastern site of Cueva Antón where stratigraphic, dating, pollen, charcoal, molluscs, lagomorphs, large mammals and archaeological analyses have been used for a comprehensive reconstruction of the palaeoenvironment and the human occupation of the area during MIS 3 and MIS 5a. On the one hand, pollen and charcoal records allowed the reconstruction of the environment in the proximity of the cave suggesting that the beginning of the MIS 5a was characterised by higher rainfall (as shown by the presence of deciduous oak), the second half of MIS 5a showed a colder climate (suggested by the absence of *Pinus halapensis* and the presence of *Pinus sylvestris/nigra)* and the end of the MIS 5a was arid with a prevalence of *Juniperus* and scarce trees. On the other hand, the archaeological and bone records allowed the reconstruction of the human occupation of the site, which appeared to be sporadic with short-term visits as suggested by the absence of archaeology in most of the stratigraphic units and a low concentration of artefacts in the layers where they were present, as well as the large amount of rabbit bones accumulated by the eagle-owls, indicating an environment unfavourable for terrestrial animals and, therefore, for humans.

Italy

Although cave palynology is not unusual in the Italian Peninsula, there are relatively few examples where palynological analysis have been used in conjunction with palaeontological and/or other types of studies in order to improve the detail of information that can be obtained from highly complex sites. Covoli di Velo, a karstic cave located near Verona (Veneto), was studied by Bona et al. (2006). Its collection of more than 2000 remains of cave bears makes this cave extremely important from a palaeontological point of view. The study paired the results from the faunal assemblages with those from pollen samples collected at different depths to reconstruct the past vegetation at the site. As often in caves, the concentration of pollen was low and dominated by entomophilous taxa, probably brought inside by the bears on their fur or through their coprolites, but other vectors appeared to be acting as well, such as air, water and humans.

A similar study using palaeontological, archaeological and palynological data was undertaken on samples collected from Grotta Grande of Scario (Salerno, Campania) by Ronchitelli et al. (2011). The cave has two chambers connected by a corridor and opens directly to the sea, which inundated the cave on several occasions in the past. During the Middle Palaeolithic the cave was occupied by humans, as testified by the lithic assemblage. The thirty samples collected for pollen analysis, dating back to MIS 5e, showed very low concentration but good preservation and a richness of taxa and, together with the data coming from mammals, allowed the reconstruction of the vegetation in the region.

France

Multidisciplinary studies characterised the approach used in France to reconstruct palaeoenvironments from caves. Two caves in Savoy, analysed by Girard et al. (1981), provided enough information to reconstruct a detailed history of the vegetation in the region and to identify the human occupation of the cave starting from the Late Glacial.

Thery-Parisot et al. (2008) published the results of plant remains, charcoal and pollen analysis from the Late Pleistocene deposits of Coudoulous II Cave in Tour-de-Faure (Lot). The palaeoenvironmental reconstruction based on the pollen analysis was in accordance with the results obtained from the macro-and micro-faunal and the geological analysis. However, vertical movements of organic material recorded in the stratigraphy suggested the possibility of post-depositional processes, such as cryoturbation.

Other Mediterranean caves studies

Two studies from cave fills in northern Libya allowed the reconstruction of the Late Holocene environment in the region. Gale et al. (1993) undertook geochemical, mineral magnetic, pollen, plant macrofossils, phytoclast and mollusc analysis from cave sediments in Tripolitania. The pollen record was dominated by herbaceous taxa but showed changes in the composition with alternate periods of Chenopodiaceae and Asteraceae predominance. The most likely source of pollen appeared to be floodwater and animals, since faecal pellets were found in abundance in the cave, but there was also record of long-distance airfall transport as suggested by the presence of *Pinus*, *Alnus*, *Cedrus* and *Fagus*. The species of molluscs and vertebrates found were in accordance with the type of environment described by the pollen record as they were represented by taxa living in open and exposed environments.

Hunt et al. (2011) studied the geology, archaeology, palynology and molluscs from a small cave fill located in the eastern edge of Wadi Bottamsa (Cyrenaica). The bottom layers (9-8) of the stratigraphy probably formed before the 5th century AD in the Roman period and showed a patchy environment with scrub and valley floor woodland, even if the reconstruction must be considered carefully because of the low the pollen concentration. Layers 7-6 described an environment characterised by a tall maquis and some juniper forest with probable cereal cultivation nearby the site. Layer 5, corresponding to the Little Ice Age in Europe, marked a change in the vegetation with evidence for a decline in biodiversity and a climatically-disrupted flora. Finally, layers 4 to 1 suggested a return of juniper woodland and a highly diverse maquis, similar to the modern environment.

Cave palynology studies from other Mediterranean countries are rare, usually because of the climate that causes low pollen concentrations. An exception is the multidisciplinary study of Tabun Cave, in Mount Carmel, Israel, which reconstructed the Late Pleistocene environmental, archaeological and occupational history of the region (Jelinek et al., 1973). The samples collected correspond to the beginning of the first maximum of the Würm Pluvial and to the following interstadial period. Results showed a high amount of arboreal pollen, especially *Quercus*, with *Pinus* also present, that corroborate the attribution of the sequence to pluvial climatic conditions.

2.4 Conclusions

Pollen taphonomy deals with the processes governing the production of fossil pollen assemblages, from the production of the pollen to its deposition and to post-depositional processes influencing the final composition of the assemblage. In order to understand the influence of differential pollen production among species, transport and dispersal mechanisms, deposition velocities and differential preservation, models of pollen transport and pollen-plant relationship have been created. However, the creation of models implies the simplification of the actual situations and the definition of assumptions that are often violated in the real world (Gaillard et al., 2008).

In addition, the taphonomical processes affecting transport, deposition and accumulation of pollen in caves are still poorly understood because the mathematical models created for open-air sites are often inappropriate for these environments. Few studies analysed the deposition mechanisms acting in caves. What emerged from those studies is that in caves with simple morphology there are some general trends, such as that the pollen composition inside the cave is similar to the pollen rain outside the cave, that anemophilous taxa are more abundant near the cave entrance and entomophilous taxa near the rear and that pollen concentration decreases with distance from the cave mouth. However, in cases with complex cave system, animal and human presence or water input the pollen composition is likely to reflect those factors in ways that are specific to the cave system under study.

The next chapter focusses on pollen analysis in the Near East area, the geographical setting of this research project.

3. Pollen studies in the northern Near East

This chapter outlines the palynological background of this research by summarising the research available for the northern Near East from the early 1970s pioneering works to the present day. The little work available on modern pollen studies analysing the relationship between pollen and vegetation in the area is reported and the palaeoenvironmental reconstructions available for Turkey, Iran Syria and Iraq are summarised.

3.1 Introduction

The history of vegetation in Europe during the last glacial-interglacial cycle has been the subject of extensive work. The availability of long, high-resolution continental records, and especially the combination of pollen data with deep-sea stable isotope analyses, allowed a detailed reconstruction of the climatic and environmental changes characterising Europe during that time (Pickarski et al., 2015). On the contrary, the history of vegetation and climate change in the Near East has been the subject of relatively few studies because of the lack of availability of long continental records. Recently, the number of late-glacial and Holocene pollen records has increased with extensive research from Lake Urmia and, in particular, Lake Van that have significantly contributed to the knowledge about the environmental history of this geographic area. Lake, river and/or soil sequences are available from Turkey, Iran and Syria, while Iraq has been the subject of very little research (Figure 3.1).

3.2 Modern pollen studies

The study of modern pollen assemblages represents a prerequisite for the correct interpretation of past pollen assemblages, their significance and implications (Wright et al., 1967). Even if modern studies have not been systematic in the area, some papers are available and provide important information about the ecological significance of the most common plant groups growing in the Near East.

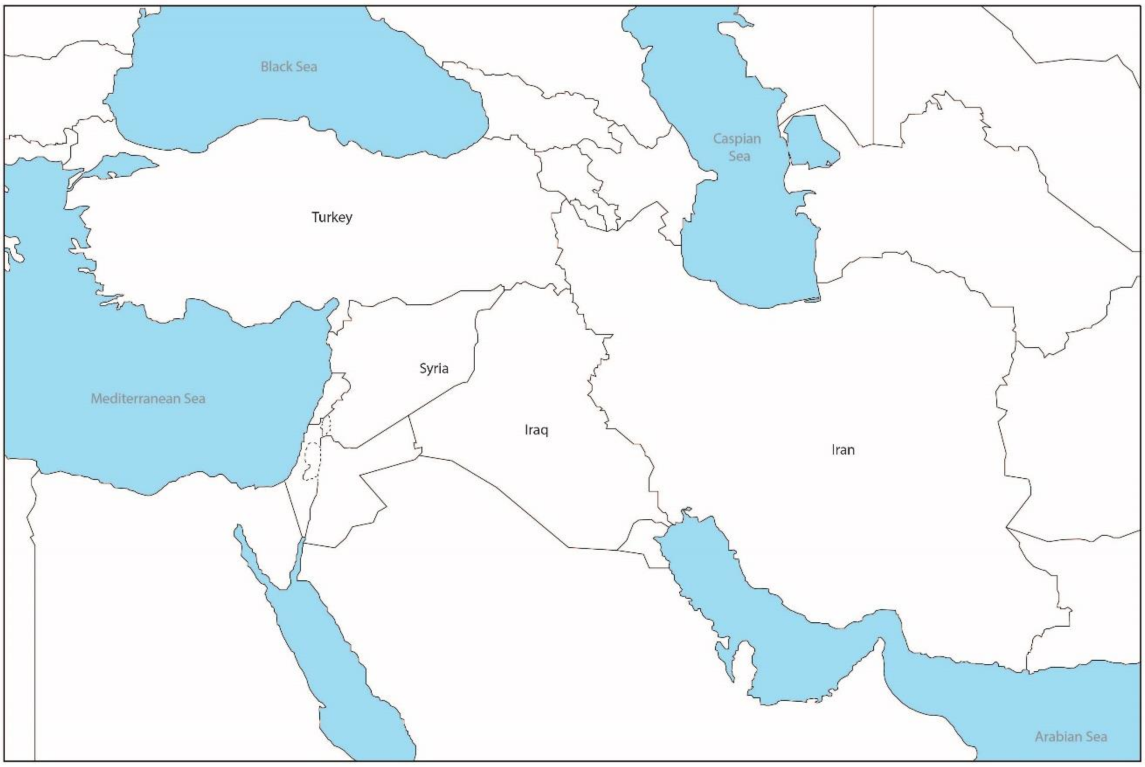


Figure 3.1 Map of the northern Near East countries where palynological studies have been undertaken.

Bottema and Barkoudah (1979) showed that pollen rain was representative of forest, steppe and desert habitats in a pioneering study in Syria. El-Moslimany (1990) considered the dryland areas that include the Arabian Peninsula, western Iran, the Iranian plateau and part of the Levant, addressing the ecological significance of the main plants representing the local pollen rain. She reported that different species dominated the landscape depending on the amount of annual precipitation. Arid areas were characterised by *Calligonum* and *Cyperus* which are able to survive periods of drought; areas with rainfall around 50-150 mm/yr were characterised by an abundance of Chenopodiaceae, *Plantago* and insect-pollinated herbs; semi-arid areas (150-300 mm/yr) were dominated by *Artemisia* and show more arboreal and grass pollen; finally, when precipitation exceeds 400 mm/yr tree pollen increased significantly. The author also indicated the Chenopodiaceae/*Artemisia* ratio as an indicator for moisture. However, despite some strong correlations, the presence or absence of those plants in past pollen assemblages cannot be directly related to the amount of precipitation and to the climate because, especially in semi-arid regions, intensive grazing and collection of scrub for firewood led to vegetation assemblages that would not have occurred naturally in the area.

Similar conclusions about the amount of rainfall and vegetation types are reported in Davies and Fall (2001) in their analysis of the connection between pollen spectra and vegetation along an altitudinal transect in Jordan. They recognised five different vegetation zones – *Quercus calliprinos* woodland, *Artemisia herba-alba* shrub steppe, shrub steppe with *Juniperus phoenica*, *Hammada salicornia* desert and *Haloxylon persicum* desert scrub - which could also be identified in the pollen spectra, demonstrating a good relationship between the two. Again, the Chenopodiaceae/*Artemisia* ratio is reported to be representative of the amount of precipitation but it can also be used to distinguish between steppe (higher *Artemisia* values) and desert (higher Chenopodiaceae values). Wind- and water-transport appeared to have an influence on the pollen concentration as *Quercus* pollen can be found close to its source while *Olea*, *Pinus* and *Pistacia* can travel long distances and, therefore, are representative of the regional vegetation. Finally, it is worthwhile to mention the absence in the pollen diagram of some entomophilous taxa abundant in the local vegetation with implications for past pollen assemblages interpretation.

The Golestan National Park, in north-eastern Iran, offered the possibility to study the relationship between modern pollen rain and vegetation in a transitional area between the Euro-Siberian and Irano-Turanian phytogeographic regions (Djamali et al., 2009). Results from analyses undertaken on vegetation and surface samples showed that in those transitional vegetation areas the correlation between vegetation and pollen percentages is less simple than in homogeneous habitats because of the contemporary presence of plants characteristic of different phytogeographical regions. There were several under-representations in the pollen rain in comparison with the local vegetation, such as *Zelkova carpinifolia* and *Parrotia persica*, probably because of their poor pollen dispersal; rosaceous trees and shrubs (e.g. *Crataegus*, *Prunus*, *Pyrus*) and *Acer* and *Fraxinus* also showed very low pollen percentages, possibly because their entomophilous pollination; other insect-pollinated taxa, such as *Berberis*, were completely absent from the surface pollen samples even when present in the vegetation. Despite those cases, the authors were able to differentiate the different vegetation communities by the fluctuations of their shrub species pollen values.

A further insight into pollen-vegetation relationships in the Near-East is provided by Ramezani et al. (2013) who analysed an altitudinal transect in the Hyrcanian forest of northern Iran. Results showed some under-representations of anemophilous taxa and over-representations of entomophilous taxa in the pollen data, even if the main vegetation zones were well represented by the pollen assemblages; however, it must be considered that the pollen percentage of a given taxon is related not only to its pollen production and dispersion but also to those of the other taxa that form the pollen sum (Janssen, 1966). In particular, Rosaceae (e.g. *Sorbus*, *Crataegus*, *Pyrus*), *Buxus*, *Diospyros*, *Tilia*, ferns, Poaceae and Cyperaceae were all present in small amounts in the pollen data even when they formed the majority of the vegetation. On the contrary, *Artemisia*, Chenopodiaceae, Amaranthaceae and *Juglans* were present in the pollen samples even when the plants were completely absent in the area. In addition, long-distance transport was responsible for the presence of some of the taxa (e.g. *Pinus, Ephedra*, *Plantago*, *Artemisia*, etc.).

These studies, collectively, demonstrate that pollen rain reflects vegetation in this broad region. No pollen rain studies have yet been made for Iraq, however.

3.3 Palaeoenvironmental studies

The following paragraphs summarise the main palynological work undertaken in the area. For early works, uncalibrated ^{14}C dates have been calibrated using Calib 7.1 (Stuiver et al., 2005) in order to facilitate comparisons between the information available for the different regions.

3.3.1 Turkey

Figure 3.2 Locations of palynological work undertaken in Turkey.

Locations of palynological work undertaken in Turkey are shown in Figure 3.2. Several pioneer studies reconstructed the Late Quaternary vegetation in the region (Van Zeist & Woldring, 1978; Van Zeist & Bottema, 1991; Bottema, 1995) with longer and detailed pollen sequences becoming available only recently (Litt et al., 2009; Litt et al., 2011, 2012; Kaplan, 2013; Litt et al., 2014; Pickarski et al., 2015; Beug & Bottema, 2015). Vegetational reconstructions have been mainly focussed on Lake Van (Litt et al., 2009; Litt et al., 2011; Litt et al., 2012; Kaplan, 2013; Pickarski et al., 2015), located in the eastern part of the region, because of its sensitivity to climatic changes due to geographic position (Wick et al., 2003). The longest sequence available so far was published by Litt et al. in 2014, based on the chronology established by Stockhecke et al. (2014), spanning the last 600 k years. The pollen diagram can be divided into 11 pollen superzones and relates to the last 15 MIS, with a general pattern of steppe and desert-steppe vegetation during glacials and oak-steppe forest during interglacials; *Artemisia*, Chenopodiaceae, *Ephedra* and Poaceae are the main components of the first vegetation type while *Quercus*, *Pistacia* and *Juniperus* are the main components of the second.

A more detailed description and a better resolution of the Holocene can be found in Wick et al. (2003) where a 13000 year long record from the south-western part of Lake Van is analysed using pollen, stable-isotopes, geochemistry and charcoal analysis. Results picture an arid Late Glacial characterised by steppe vegetation that became semi-desertic during the Younger Dryas because of the decrease in the lake water levels. The beginning of the Holocene registered a marked change in humidity that produced an increase in NAP values with the predominance of grass-steppe and *Pistacia*; fires were frequent and the dry weather caused a delay in the expansion of *Quercus* of ca 3000 years compared to other records of the area. From around 8200 cal. BP the record shows an increase in moisture that led to an expansion of the oak forest, which reached its maximum between 6200 and 4000 cal. BP. After 4000 cal. BP the aridity returned and the climate changed toward a situation similar to present day.

Data for south-west Turkey came from the study of Gölhisar Lake. Eastwood et al. (2007) presented stable isotope data and compared them with a pollen record from the same sediments already available (Eastwood et al., 1999). The comparison between the two datasets showed similarities and differences, with the Early Holocene characterised by a good correspondence of moisture availability recorded by both pollen and isotopes and the Late Holocene record showing a difference between the two proxies that reflected a period of increasing human impact (the Beyşehir Occupation - BO - Phase, 3500-1300 cal. BP).

The relationship between human impact and vegetational change in the same area was investigated in detail by Eastwood et al. (1998) through the comparison of pollen analysis and archaeological evidence. Results indicated a change towards more humid conditions from about 3500-1375 cal. BP, corresponding to the BO Phase, as suggested by the expansion of the forest in areas previously covered by steppe vegetation. The end of the phase was then characterised by an increase in arboreal pollen and a decrease in cultivated trees and other anthropogenic indicators.

Two lakes from central Turkey, Nar Lake and Eski Acigöl, provided a 13.8 ka long multi-proxy record for the region that allowed the study of how regional and local factors affect the palaeoenvironment (Roberts et al., 2016). The isotope analysis allowed the identification of wet and dry phases, supported by pollen, diatoms and XRF elemental analysis. The latest part of the record, corresponding to the Late Glacial, was characterised by deep-water conditions of the lakes and an open-steppe environment with a low tree coverage. The following period, corresponding to the Younger Dryas, recorded lower lake water conditions and relative aridity with vegetation consisting mainly of *Artemisia* and Chenopodiaceae. A clear passage from arid to wet conditions marked the Pleistocene-Holocene transition. The beginning of the Holocene was characterised by a wetter climate with drier phases around 9.3 and 8.2 ka, followed by a return to wetter conditions with oak forest reaching high values. Again, two extremely dry phases characterised the area from around 4.3 ka with wetter conditions at the end of the record.

Finally, a Late Glacial and Holocene record is available from Lake Yeniçağa, in the north part of the region (Beug & Bottema, 2015). The oldest data available dated back to about 14500 cal. BP and showed the presence of thermophilous species such as *Quercus cerris*-type and *Abies,* an increase in *Juniperus* and *Betula* as well as an open vegetation characterised by *Artemisia* and Chenopodiaceae. Around 12000 cal. BP there was an increase in AP and Poaceae, after which open habitat species decreased and then maintained low values. The period between 7927 and 7622 cal. BP (6920 ± 70 uncal. bp) was distinguished by *Pinus* dominance and presence of *Quercus cerris*-type, *Abies*, *Fagus*, *Carpinus betulus*, *Corylus* and *Juniperus*, as well as human indicators such as *Cerealia*-type and *Plantago lanceolata*. Finally, the period between 5574 and 4587 cal. BP (4430 ± 160 uncal. bp) saw the decline of *Abies* and *Fagu*s with *Pinus* fluctuations, depending on periods of settlements and human impact.

3.3.2 Iran

Locations of palynological work undertaken in Iran are shown in Figure 3.3. Lake Urmia, the biggest lake in Iran and one of the world's largest hypersaline lakes, offered the possibility for investigation at different time scales. A pioneer study undertaken by Bottema (1986) spanned the Late Pleistocene and Holocene and a longer pollen record, covering a period of ca. 200 ka, was published by Djamali et al. (2008). The results describe the penultimate interglacial period (MIS7) as characterised by a steppe-forest environment with *Quercus*, *Juniperus* and *Pistacia,* then replaced by an *Artemisia* and grass steppe during the penultimate glacial phase; then an increase in aridity with *Artemisia* steppe as main vegetation type marked the end of that phase. The Last interglacial (MIS5) was then characterised by an expansion of the forest with moderate winters and rainy springs and summers that favoured the presence of *Zelkova carpinifolia*. The following glacial period (MIS4-2) saw a return of *Artemisia* and grass steppe that developed into an oak forest during the late-glacial and Holocene.

A closer look to recent times can be found in Talebi et al. (2016) through the analysis of two short cores from the same lake which describe the Late Holocene climate and vegetation changes in the Urmia region. The record starts at 2555 cal. BP when the vegetation was desert steppe-like with *Artemisia* dominance and a secondary presence of Asteroideae, Chicorioideae, Caryophyllaceae, Brassicaceae and *Ephedra* until 1474 cal. BP, when an increase in rainfall, lake water levels and humidity promoted the increase in AP and the expansion of *Quercus*. The situation changed between 1088 and 813 cal. BP, in correspondence with the Medieval Climatic Anomaly, when *Artemisia* increased and *Quercus* decreased. The most recent part of the record, which relates to the Little Ice Age, registered an increase of NAP and the decline of *Quercus*. Some of the taxa recorded, such as *Vitis*, *Ricinus communis*, *Juglans* and *Olea,* allowed also the identification of human presence through arboricultural practices.

Figure 3.3 Locations of palynological work undertaken in Iran.

Lake Zeribar, located in the Iranian section of the Zagros Mountains, was studied by Van Zeist & Bottema (1977) and El-Moslimani (1987), but recent stable-isotope analysis allowed the integration of the pollen data available with $\delta^{18}O$ values (Stevens et al., 2001), diatoms, plant macrofossils and molluscs (Wasylikowa et al., 2006) for a detailed palaeoclimatic reconstruction. Between 25700 and 21100 cal. BP the climate was cold and dry and the vegetation typical of semi-desert conditions. Lake water levels were unstable between 18400 and 15400 cal. BP, as suggested by the diatom record and by the presence of *Chenopodium rubrum, with a* vegetation dominated by *Artemisia* and Chenopodiaceae. A temporary change occurred between 15400 and 12600 cal. BP when *Artemisia* decreased and tree pollen increased due to the expansion of *Pistacia*. The climate reached its driest moment during the Younger Dryas, as suggested by the temporary expansion of Chenopodiaceae and an increase in salinity. The end of the period was marked by a slight increase in moisture and temperature with the presence of trees and the arrival of *Plantago*; however, the relevant amount of *Pistacia* indicates that the climate was still drier than in the later part of the Holocene. From around 6.5 ka BP isotope and pollen values revealed a much moister climate with higher precipitation that allowed the spread of *Quercus*. During the latest part of the Holocene the climate shifted towards the current conditions with higher lake levels and the establishment of the Zagros oak forest but with dry episodes such as the one occurring between 4 and 3.5 ka BP.

A detailed reconstruction of the last 5700 years is recorded at Lake Maharlou, located in south-western Iran (Djamali et al., 2009). The oldest part of the record shows a dry climate with *Artemisia*, Chenopodiaceae and Apiaceae, followed by a period of increase in AP values with *Pistacia*, *Quercus* and *Juglans* until 5100 cal. BP, when a dry period occurred and the *Pistacia-Amygdalus* scrub declined. At the same time *Platanus*, *Vitis* and *Olea* appeared for the first time, suggesting a more intense human presence in the area, even if long-distance transport cannot be excluded due to the very low pollen percentages. Bewteen 4000 and 2800 cal. BP *Pistacia* increased significantly as well as cultivated trees, suggesting a climatic improvement. From 2800 cal. BP the conditions changed with *Pistacia* declining sharply and *Artemisia* and Chenopodiaceae increasing again.

From western Iran came also the Wezmeh Cave record, where hyena coprolites informed about the Late Pleistocene-Holocene vegetation at a local scale and complemented data from lakes because of the incorporation of insect- and self-pollinated taxa, often under-represented in lake-core sediments (Djamali et al., 2011). However, as already explained, the uncertainty regarding the stratigraphic position of the samples impeded the chronological location of the pollen zones.

Finally, two records are available from the northern part of the region, the first one providing a multi-proxy analysis from the Qazvin alluvial plain (Schmidt et al., 2011) and the second presenting palynological data from the SE corner of the Caspian Sea (Leroy et al., 2013). Results describe the beginning of the Holocene in the area as characterised by the predominance of Amaranthaceae, Chenopodiaceae, *Artemisia* and Poaceae, while tree pollen (mostly *Quercus*) was low, indicating a semi-desertic environment. The climate improved from around 9400 cal. BP when arboreal pollen increased with *Quercus*, *C. betulus* and *P. persica*. The samples corresponding to the 7500-3510 cal. BP interval were sterile, probably because of periods of unfavourable conditions, such as shallow water and/or fluctuations between aquatic and dry phases. *Artemisia* steppe dominated the landscape from 3510 to 1455 cal. BP, with *Alnus* along the coast and a high amount of *Cerealia* which, together with *Plantago* and *Juglans*, suggest strong human presence. The following period, until ca. 460 cal. BP, saw an increase in Amaranthaceae and Chenopodiaceae and a decrease in Poaceae, *Cerealia* and AP, suggesting aridification or an intense human pressure. Finally, the most recent part of the record is characterised by an increase in *Quercus*, *Pinus* and *Acer* due to afforestation.

3.3.3 Syria

Figure 3.4 Locations of palynological work undertaken in Syria.

Locations of palynological work undertaken in Syria are shown in Figure 3.4. The Syrian record was studied by Nickewski and van Zeist (1970) through a 11 m core from a drainage canal in the Ghab Valley. Three radiocarbon dates obtained from shells dated the oldest sample back to 47000 years BP (which is at the limits of the radiocarbon technique and potentially unreliable, especially given the probability of hard water error). These dates were used to estimate the ages of the other sections of the pollen diagram, divided in nine sub-zones on the basis of the AP/NAP ratio. The oldest part of the record shows a Chenopodiaceae steppe vegetation with a climate colder and dryer than today followed by an increase in tree coverage with *Quercus*, *Juniperus*, *Pistacia* and *Ostrya*-type. From around 47000 years BP, the climate changed towards moist and colder conditions with mountains covered by a pine and juniper forest. The following period showed again a predominance of forest vegetation with *Cedrus*, *Juniperus* and *Ostrya*-type as common trees and a climate similar to the present but characterised by lower temperatures. Around 45000 years BP, pollen suggests an increase in dryness with the expansion of the steppe at low elevations and a mixed-oak forest at higher elevations. At 40000 years BP trees expanded again forming a vegetation similar to present day. Between 35000 and 25000 years BP, mountains appear to be almost treeless with the predominance of steppe and open forest above the steppe zone. After a rise in AP values, caused mostly by an increase in *Quercus* around 25000 BP, the steppe reached its maximum with a dry and cold climate. From around 10000 years BP *Quercus* and other trees gradually substituted the steppe and the vegetation reached a composition similar to the present day.

A reappraisal of the Late Glacial and Holocene in the Ghab Valley area can be found in Yasuda et al. (2000) where results of palynological analysis undertaken on a 6 m long lacustrine sediment core are presented. The Late Glacial was dominated by *Artemisia*-Chenopodiaceae steppe, then followed by increasing values of *Quercus* and *Cedrus* suggesting improvements in the climatic conditions. The beginning of the Holocene until ca. 10100 cal BP was characterised by *Quercus* forest on the mountain slopes and *Cedrus libani* at higher elevations. Around 13000 cal BP the appearance of Poaceae pollen, together with *Plantago lanceolata*, suggests a possible start of plant cultivation. Deciduous oak forest declined from around 10100 cal BP probably as consequence of a forest clearance by Neolithic people. Moreover, the contemporary appearance of *Olea* and the increase in cultivated Poaceae in the pollen record suggested that the clearance was probably related to cultivation. The deforestation reached higher elevations from about 8400 cal BP with the decrease in *Pinus* and *Cedrus* pollen, a corresponding increase in *Olea* that reached its maximum and the presence of evergreen *Quercus* indicating the development of a maquis. Another evident forest clearance by Early Bronze Age people occurred around 5600 cal. BP, again followed by high values of *Olea* pollen. Finally, from 900 cal BP a secondary pine forest expanded on the mountain slopes reaching the present day levels.

Another opportunity for a vegetational reconstruction covering the postglacial period is offered by the Barada River record (Bottema, 1975a). The pollen diagram is divided into zone Y and Z with the first dated back to the Wurm-Glacial age - according to a comparison with Leroi-Gourhan pollen diagram (Kaiser et al., 1973) from a site 4 km south of the Barada coring place - and the beginning of the second to about 350 years ago (with dates based on the appearance of *Zea mays*). Zone Y describes an open landscape characterised by deciduous *Quercus*, *Pistacia* and *Cedrus* as well as grasses. Sub-zone Y2 shows a relative increase in AP values corresponding to a regeneration of the forest, also suggested by the decrease in plants indicating farming activities such as *Cerealia*-type and *Centaurea solstitialis*-type. The vegetation during zone Z appears to be strongly influenced by human activity with a decrease in AP values and an increase in weed and crop plants.

A longer and more recent study of the Damascus region vegetation is provided by Deckers et al. (2009) who reconstructed the vegetation history from the Late Pleistocene and Early Holocene. Baaz rockshelter was excavated between 1999 and 2004 with seven archaeological horizons established going from 34000 BP to the end of the fifth millennium BC. Charcoal, fruits and seeds, phytoliths and pollen analyses have been undertaken in order to reconstruct the vegetation in the area. The lowest stratum is characterised by high percentages of *Pinus* and more than half of the pollen coming from trees and shrubs. Stratum VI contains high amounts of *Pinus* but other trees are rare, while higher amounts of herbs suggest an increase in aridity. Strata V and VI contain very little pollen so vegetational inferences are problematic but this scarcity might be related to the drought that occurred around 25000 BP. Stratum IV (23-21000 BP) shows an abundance of herbs (up to 90%) and the presence of a steppe vegetation. The upper strata are characterised by a high percentage of NAP with predominance of Asteraceae, Chenopodiaceae, Polygonaceae and Caryophyllaceae.

3.3.4 Iraq

Figure 3.5 Locations of palynological work undertaken in Iraq.

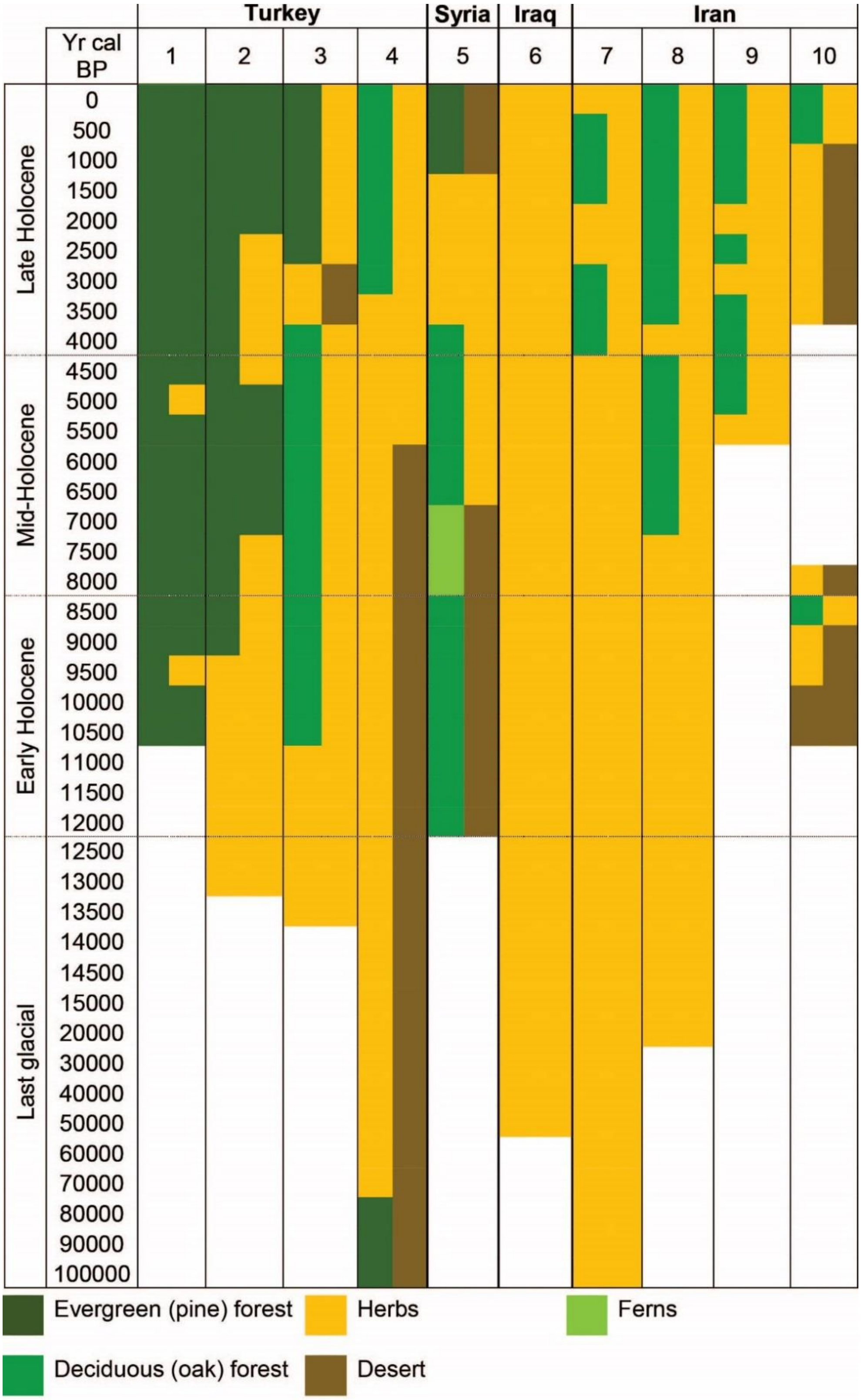
Palynological studies from Iraq are rare. The first attempt to reconstruct the vegetation in the area was made by Arlette Leroi-Gourhan during the analysis of the Shanidar Cave deposits (Figure 3.5 - Solecki and Leroi-Gourhan, 1961; Leroi-Gourhan 1998). The samples cover the period going from the Middle Palaeolithic to present. The oldest sample was collected at a stratigraphic depth of 9.65 m and shows steppe conditions with Lactuceae reaching 40%. The sample from 8.60 m was collected from a stalagmitic crust indicating wet conditions and contained pollen of *Quercus*, *Ulmus*, *Pinus*, *Juglans* and *Alnus,* probably growing on the mountain slopes and *Phoenix dactylifera* growing in the valley with some dry grass flora also present. The 7.5 m sample was collected from the soil below the skeleton of Shanidar II when the climate was probably colder, as suggested by the presence of few *Abies* grains. Two samples from around 4.30 m, corresponding to 46000 years BP, contain *Pinus*, *Juniperus*, *Quercus*, *Castanea* and *Phoenix dactylifera* pollen. The first sample from the Upper Palaeolithic was collected at 4 m (35000 BP) and represents the first proper dry climate of the record with a typical steppe flora of Asteraceae and Labiatae. Around 28700 BP a return of wet conditions with a new increase in forest plants (*Alnus* and *Fraxinus*) and the predominance of Poaceae was recorded. The bottom of the Mesolithic layer includes, together with pollen from the flora of that period (*Cupressus, Pinus* and *Castanea)*, older grains probably from the Tertiary, suggesting an intrusion of older sediments caused by water infiltration. After that time the climate became drier.

A modern literature on palynological studies of this region is almost absent. The only published work is represented by few papers (Al-Ameri et al., 2011; Al-Ameri et al., 2011a; Ali 2014) mostly based on previous works and/or presenting an unclear chronology.

3.4 Conclusions

Contrary to Europe, where detailed long continental sequences are available, there are relatively few palaeoecological records available for the Near East. Most records come from lake sequences and allow the reconstruction of the late Quaternary climatic and vegetational history of the area. The main climatic and vegetational changes that occurred in the area are summarized in Table 3.1. The general trend showed by several of the pollen records in the area is of a transition from Late Pleistocene steppe to forest-steppe vegetation and then to Holocene open forest environments, with *Artemisia* and Chenopodiaceae predominance during the steppe phase, *Quercus*, *Juniperus* and *Pistacia* as main element of the forest-steppe vegetation and *Quercus* as the main elements of the forest. Despite the agreement between records coming from different regions, the timing of the vegetational successions appears to be different in the Lake Van record, with a delay of ca. 3000 years in the appearance of the oak forest.

Table 3.1 Summary of climatic and vegetational changes in the Near East. Locations: 1. Gölhisar Golu (Eastwood et al., 1999); 2. Lake Yenicaga (Beug & Bottema, 2015); 3. Nar Lake (Roberts et al., 2016); 4. Lake Van (Wick et al., 2003; Litt et al., 2014); 5. Ghab Valley (Yasuda et al., 2000); 6. Shanidar Cave (Leroi-Gourhan, 1998); 7. Lake Urmia (Djamali et al., 2008; Talebi et al., 2016); 8. Lake Zeribar (Wasylikowa et al., 2006); 9. Lake Maharlou (Djamali et al., 2009); 10. Caspian Sea (Leroy et al., 2013).



Van Zeist and Bottema (1982, 1985) suggested a difference in the wind direction with a consequent difference in moisture and in the direction of the mountain ridges as possible explanation, while Bottema (1986) proposed an error in the Van record dates. Wick et al. (2003), however, reported aridity as the main limitation for tree growing and explained the delay as a response to dry springs and summers during the Early Holocene.

This chapter summarised modern and palaeoenvironmental studies available for the norther Near East, analysing the climatic and vegetational changes that occurred in the wider geographic area of Shanidar Cave and the other study sites. Palynological data outside Syria, Turkey and Iran are, however, very scarce and additional research is needed in order to provide new palaeoecological information and improve environmental reconstruction in this area of the world. The next chapter describes the importance of Shanidar Cave reporting the previous archaeological work undertaken at the site, its findings and the implications.

4. Shanidar Cave

This chapter describes previous investigations at Shanidar cave undertaken from 1950s to 1960s by the American archaeologist Ralph Solecki and his team. A summary of the excavations and their findings is provided, with particular attention to the cave stratigraphy and the Neanderthal skeletons recovered from the Mousterian level. The palynological investigation of the site and the debate about the pollen related to Shanidar IV are reviewed and a report of the new excavations undertaken as part of this project is reported.

4.1 Introduction

The Near East has always been an area of particular interest for archaeology and prehistory because it represents the connection between Europe, Asia and Africa and the area of the first domestication of plants and animals. Before the discovery of Shanidar Cave, other archaeological expeditions had surveyed Iraq in search of traces of the first populations in the country (e.g. 1928, Dorothy Garrod in Southern Kurdistan; 1949, Carleton Coon at the caves of Hazar Merd; 1950, Wright and Howe at four sites in North-eastern Iraq). In 1950, Ralph Solecki was invited by George Cameron, from University of Michigan, to take part in his expedition to Iraq with the aim of studying the steles at Topzawa and Kaleshin in the Zagros Mountains. During this trip, they surveyed several caves, such as Shkata Kotek in Rowanduz and other caves near a little village called Mawort, but none of them appeared to be of any archaeological significance. When they finally heard about Shanidar from the District Governor, they decided to have a look at this cave located near the Greater Zab River which was still inhabited by local Kurds.

4.2 History of excavations, cave stratigraphy and findings

During his first visit to the cave, Solecki noticed signs of recent human presence and cattle and sheep dung on the cave floor. In October 1951, he started his work in the cave and excavated a test trench recovering a large amount of crude pottery. This represented the starting point for organising the first season of proper excavations at the site. At the end of the first season, the stratigraphy of the cave was divided into four layers defined by the archaeology and named A to D from the top to the bottom (Figure 4.1).

Layer A, corresponding to modern, historic and Neolithic periods, consisted of multi-coloured and dry ash beds and soil dark in colour - probably due to the organic staining caused by the livestock being kept in the cave.

Layer B, later subdivided into layer B1 – Proto Neolithic - and B2 – Mesolithic, appeared less stained and lighter in texture.

Layer C was easily distinguished by the soil texture and the artefact content and separated from layer D by a large limestone rock fall. The archaeology related to the Upper Palaeolithic, an industry he called Baradostian.

Layer D represented the majority of the cave fill, going down up to 45 feet in depth and containing artefacts attributed to the Middle Palaeolithic or Mousterian.

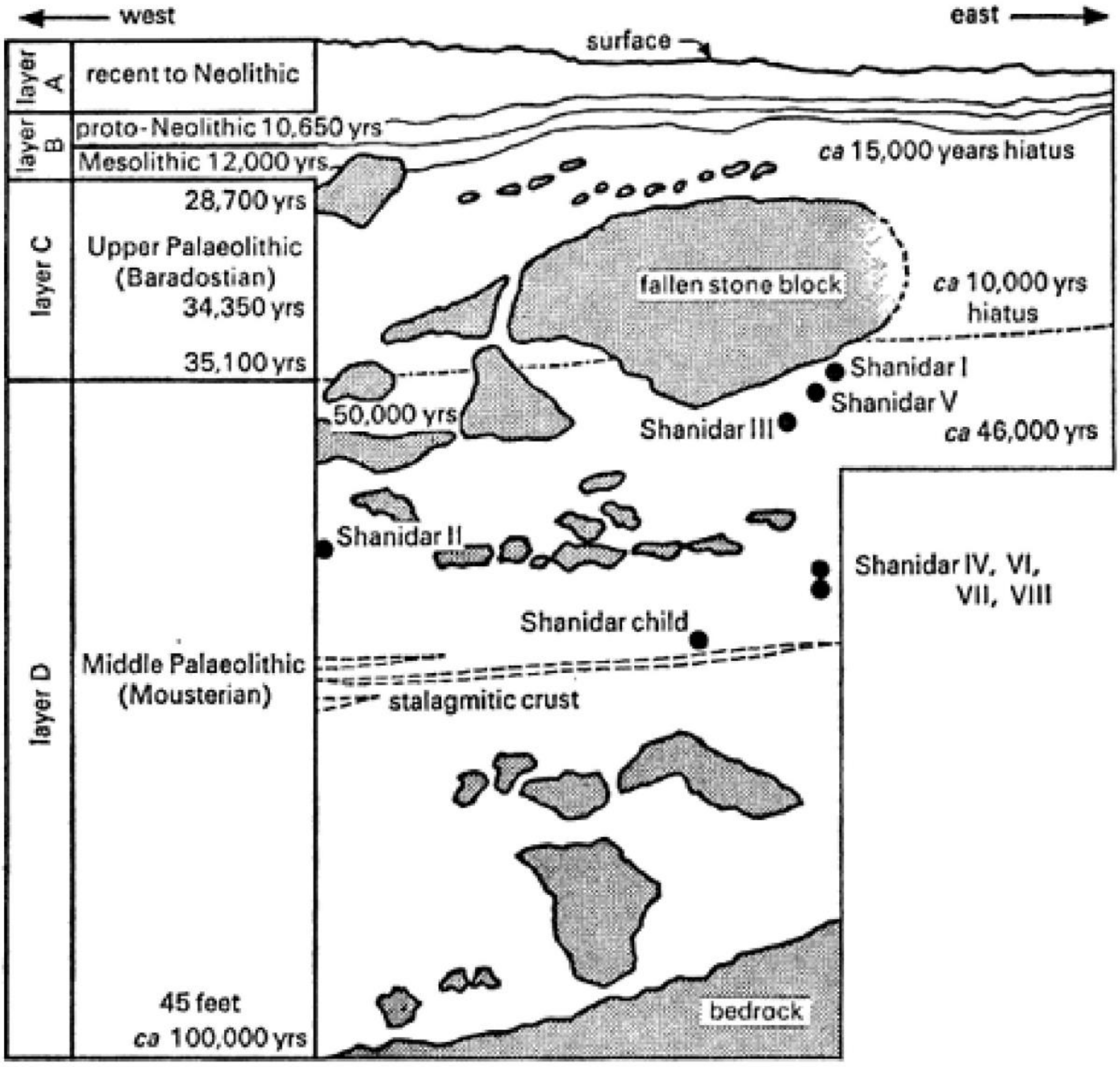


Figure 4.1 Cross section of the Shanidar Cave excavation (Solecki, 1971).

The second season of excavation started in 1953 and was notable because of the discovery of the first Neanderthal skeleton, an infant in the Mousterian layer. The third season (October 1956 to June 1957) was the most prolific in terms of findings: Solecki and his team recovered another three Neanderthal skeletons (Shanidar I, II and III) and studied the nearby Neolithic site of Zawi Chemi Shanidar. Solecki also noticed the presence of at least four major rockfalls that were probably the cause of death of some of the Neanderthals. The fourth and last season, in 1960, led to the discovery of Shanidar II and Shanidar IV-VII together with another child (Shanidar VIII) and a proto-Neolithic cemetery with 28 skeletons in Layer B1. After this season, the Kurdish rebellion that started in 1961 impeded the continuation of the research (Solecki, 1971).

The four seasons of excavations led to the recovery of artefacts from each layer that allowed their separation on the basis of the stylistic features of the findings. Layer B1 included bone and ground stone artefacts such as mortars and hand rubbers that suggested some sort of food preparation by the inhabitants of the cave. Moreover, the presence of luxury items (e.g. pendants and inscribed slates) indicated a quiet and secure lifestyle (Figure 4.2a). Layer B2 differentiated from the upper layer because of the presence of geometric type microliths and the absence of ground stones (Figure 4.2b) that indicated to Solecki an advanced industry and an orientation toward hunting. Layer C was characterised by a blade-tool type industry (Figure 4.2c) suggesting sophisticated techniques of wood-working. Finally, Layer D contained unifacial flakes, points, scrapers and knives (Figure 4.2d) (Solecki, 1963). Layers B1 and D also contained skeletal remains. The proto-Neolithic layer included a cemetery found in the right rear area of the cave and consisting of thirty-five individuals (Solecki et al., 2004). In the Middle Palaeolithic layer nine Neanderthal skeletons were found which are described in detail by Stewart (1977) and Trinkaus (2014) and summarized in Table 4.1. In addition to Solecki's findings, Cowgill et al. (2007) identified the rests from another infant consisting of the distal tibia, fibula, one metatarsal and two tarsals that were recovered from the lowest part of the Mousterian level and assigned to Shanidar X.

The Shanidar findings have been the object of an extensive literature especially looking at bones, wounds and diseases (e.g. Trinkaus, 1982; Trinkaus & Zimmerman, 1982; Trinkaus & Thompson, 1987; Crubézy and Trinkaus, 1992; Ogilvie et al., 1998; Franciscus & Churchill, 2002; Cowgill et al., 2007; Churchill et al., 2009) and the cave faunal content (Perkins, 1964; Evins, 1982), that helped the reconstruction of the social, cultural and behavioural dimension of the Shanidar Neanderthals. An interesting insight into their dietary regimes and, therefore, their social development comes from the microfossils found in dental calculus of one of the skeletons. Three teeth from Shanidar III have been studied and the calculus produced starch grains and phytoliths including grass seeds, legumes and dates. Several of them showed clear signs of preparation and cooking, suggesting that Neanderthals were able to prepare these foods in order to increase their edibility and they were also capable of complex gathering behaviours with different harvest seasons (Henry et al., 2010).

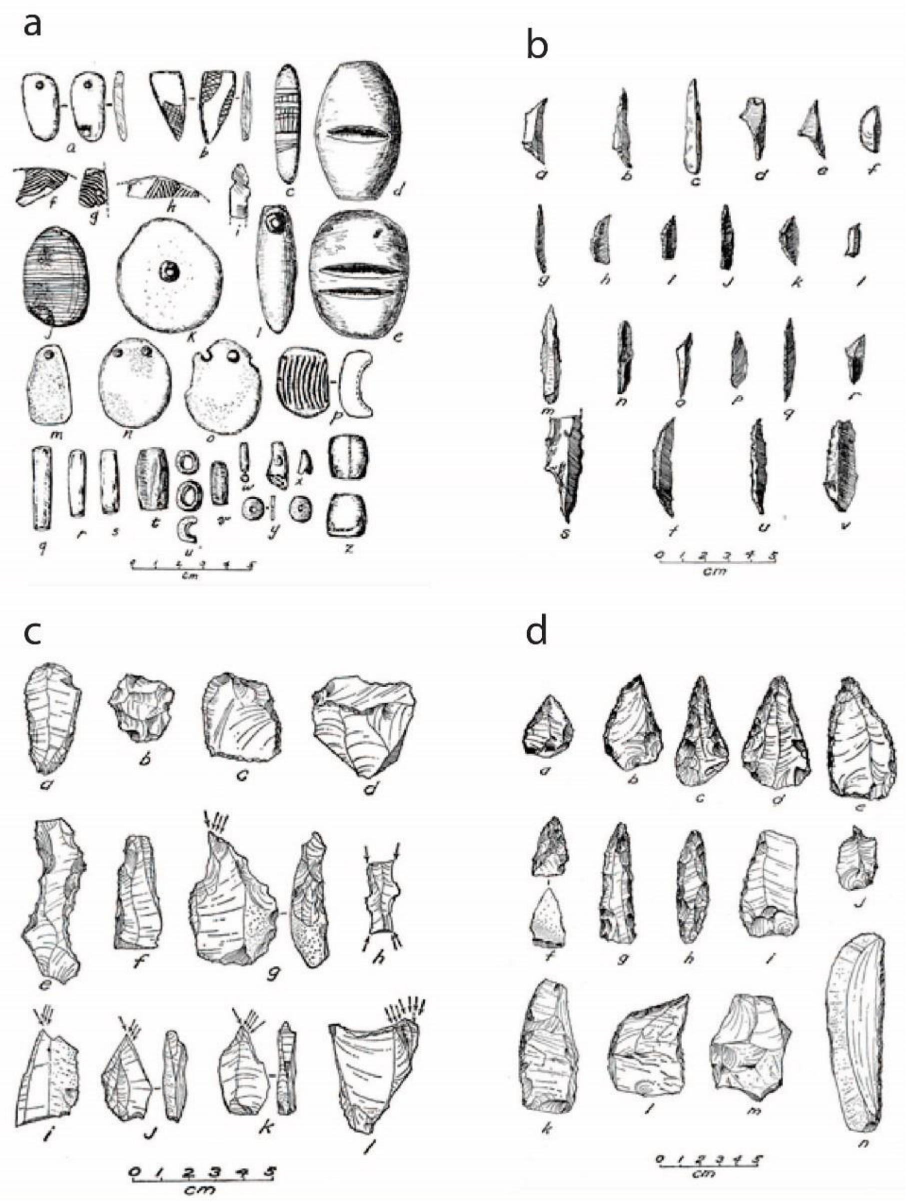


Figure 4.2 Examples of artefacts from layer B1 (a), B2 (b), C (c) and D (d) (Solecki, 1963).

Table 4.1 Summary of the skeletal remains from the Mousterian level at Shanidar Cave

Individual	Depth below datum (m)	Age and sex	Burial position	Other info
Shanidar I	4.34	Adult, male	Lying on his back on his right side, legs extended, arms across his chest. Found between large rocks and under a layer of smaller rocks.	Injuries to his frontal and left orbit and to his right side before death. Probably killed by a rockfall and then buried.
Shanidar II	7.25	Adult, male	Unknown	A rockfall during or after his death changed the bones position.
Shanidar III	5.40	Adult, male	Lying on his right side between rocks.	
Shanidar IV	7.49	Adult, male	Lying on his left side, legs partially flexed and arms across the body.	Bones found together with the ones of other two adults (Shanidar 6 and 8) and an infant (Shanidar 9).
Shanidar V	4.48	Adult	Lying between rocks, legs in a semi-flexed position	Probably killed by a rockfall
Shanidar VI	7.49	Adult, female	Found in a semi-flexed position lying on the left side	Found together with Shanidar 4
Shanidar VII	7.87	Infant	Lying on his right side in a flexed position	The oldest of the individuals
Shanidar VIII	7.49	Adult		Found together with Shanidar 4 and 6. Incomplete.
Shanidar IX	7.49	Infant	Unknown	Only cervical and thoracic vertebrae recovered together with Shanidar 4, 6 and 8.

4.3 Pollen analysis and the 'Shanidar Flower Burial'

Palynological analysis at Shanidar Cave was undertaken by the French palynologist Arlette Leroi-Gourhan and published for the first time by Solecki and Leroi-Gourhan in 1961 with the relative pollen diagram by Leroi-Gourhan in 1998 (Figure 4.4). There had been an earlier attempt at pollen analysis on the cave samples by Erdtman who found the samples to be sterile. Leroi-Gourhan's analysis, instead, was successful and the 23 soil samples studied produced a pollen diagram that spanned from the Middle Palaeolithic to recent. The oldest sample was collected at 8.6 m from a stalagmitic crust indicating a wet period. The main taxa found were *Phoenix dactylifera* - probably growing in the valleys, *Quercus*, *Pinus*, *Castanea* and *Ulmus* growing at higher altitudes and Lactuceae, Chenopodiaceae and Labiatae characterising the grassland. A second sample from the same layer was collected at 7.5 m just below Shanidar II and indicated a colder climate characterised by forested mountain slopes and grassland. The upper part of the layer was studied through the collection of two samples at 4.35 and 4.25 m that showed *Phoenix dactylifera* and *Cupressus* growing in the valley and *Pinus*, *Quercus*, *Juniperus* and *Castanea* on the mountains. Layer C is separated from the previous layer by a hiatus. Two samples were collected from this layer, one from the bottom and the other from the top showing, respectively, a very dry climate characterised by herbaceous plants and a return to wetter climatic conditions with tree pollen. Another gap separated the Upper Palaeolithic from the Mesolithic where Leroi-Gourhan found tree pollen grains mixed with older pollen, suggesting mixing of the sediments probably due to flooding. Finally, the proto-Neolithic period marked a return to dry conditions.

In the same paper Leroi-Gourhan also discussed the finding related to two of the samples – No. 313 and No. 314 - collected from the sediment around Shanidar IV that showed a pollen content completely different from the others in terms of richness and type of grains. This skeleton belongs to an adult male that was found lying on his left side, covered by stone blocks and interpreted as a burial (Figure 4.3). Solecki estimated the date of death at approximately 60000 years ago based on sediment accumulation rate. The remains of Shanidar IV were found together with the ones of three other individuals - two females and a child (Shanidar VI, VII and VIII) (Solecki, 1975). The two samples showed an unusually high number of pollen grains with seven of the twenty-eight species identified found in clumps of 2 to 100 grains and different species grouped together, sometimes keeping the shape of the anther of the flowers (Leroi-Gourhan, 1975). Those species, and in particular *Senecio*, *Ephedra*, *Achillea*, *Centaurea*, *Althaea* and *Muscari,* all have flowers that, even if small, are bright in colour so that they can be considered attractive and are also known for their medical properties. These findings led Solecki and Leroi-Gourhan to the conclusion that complete flowers had been purposely introduced into the cave and deposited with the burial as part of a funerary ritual. The only exception is represented by *Ephedra,* which has very small and unattractive flowers, but whose branches could have been used as bedding for the dead (Leroi-Gourhan, 1968). Later phytopharmacological analysis of the species discovered in the burial confirmed that each has strong stimulating and psychotropic properties (Lietava, 1992). The soil from around the samples also appeared to be different from elsewhere and rich in burned and unburned vegetal remains. Moreover, it was much more disturbed, darker in colour and looser than the soil elsewhere. Solecki suggested that the reason for this was the burial fill but another explanation could have been found in the bones of small animals around the skeletons and the animal hole just 5 cm far from Shanidar IV, suggesting that small mammals, probably rodents, were predating the human remains (Solecki, 1977).

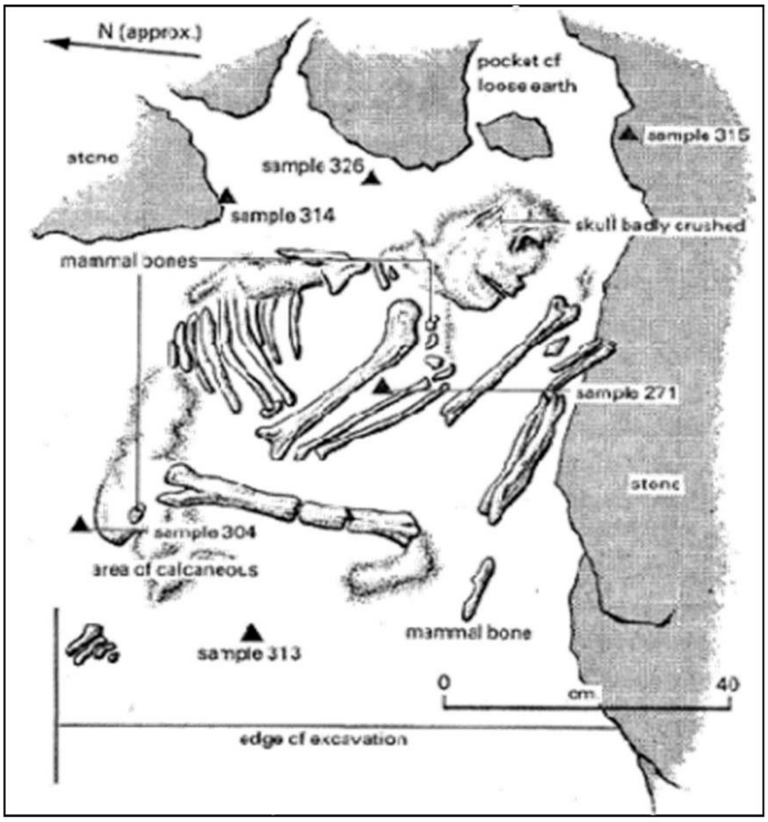


Figure 4.3 Shanidar IV and the location of the pollen samples (Leroi-Gourhan, 1999).

Figure 4.4 Pollen diagram from Shanidar Cave produced by Leroi-Gourhan (1998).

These findings, together with the fact that Shanidar III was severely injured and unable to look after himself so he needed help from the other members of the community to survive, supported the idea that the Neanderthals had more complex social organisation than previously thought. In addition, the specific selection and collection of the plants placed in the burial supported the idea that some kind of language had already developed and was being used (Leroi-Gourhan, 2000).

After the publication of Solecki and Leroi-Gourhan's results, several authors questioned their interpretation. Doubts about Leroi-Gourhan's '*indisputable human provenience*' of the pollen came from Chase and Dibble (1986) who suggested rodents or a later intrusion as more plausible causes for the presence of clumped grains. Gargett et al. (1989) published an interesting review on Neanderthal burials where he re-examined and questioned several discoveries described as intentional burials and underlined how often, especially in the past, most of the attention was given to the skeletal remains themselves without an accurate record, description and analysis of the stratigraphic and taphonomical context where they have been found. Gargett et al. criticised Solecki's inference of an intentional burial for Shanidar I who stated that the man was probably killed by a rockfall but then buried by the others who survived. Gargett criticised Solecki's statement about the contemporaneity of the Shanidar IV, VI, VIII and IX burials because there were no clear evidence and the remains were separated by 19 cm of sediment. Finally, they also suggested that the most probable agents that brought the flowers into the cave were the wind - because of the size of the cave entrance that facilitates air circulation - or rodents. The American zooarchaeologist Sommer (1999) also supported the animal origin of the pollen. In his paper, he pointed out how Solecki himself mentioned the presence of animal burrows around the bones. The analysis of the cave bone remains undertaken by Perkins (1964) found the majority of rodents recovered to be *Meriones* sp. and, in particular, *Meriones persicus*, a species living in the Zagros Mountains area and in the Iranian Plateau. These animals can store vegetal material, seeds and plants in their burrows and the related species *Meriones crassus* is reported to store complete flowers, included the members of the Compositae family found in Shanidar. To date this debate has not concluded and the true origin of the pollen remains unknown.

4.4 New investigations at the site

In 2014 a new program of excavations at Shanidar Cave started under the supervision of Prof. Graeme Barker from Cambridge University, with the aim of establishing a new high-resolution chronology of the cave and re-investigating the context and content of the Neanderthal burials. Two seasons of excavations were undertaken in 2015 during which Solecki's old trench was extended, exposing 10 m of sediments. The study of the Upper Palaeolithic layer led to the recovery of three ash and charcoal-filled scoops and burnt animal bones probably used as fuel, suggesting that the cave was used sporadically by small groups of individuals. The initial analysis of the Middle Palaeolithic assemblage revealed the presence of new bones near the point where Shanidar V was originally discovered, that might belong to the same individual or be part of a different one. There were no signs of a grave cut or lithics in the whole exposed section (Reynolds et al., 2015).

Further excavations are still ongoing. Preliminary results of palynological analysis on the cave surface soil has been reported in Fiacconi and Hunt (2015) (Appendix 3). The samples contained all the taxa recorded from Leroi-Gourhan in the samples from around Shanidar IV and often Asteraceae pollen was found in groups of 2 to 5 grains, suggesting that clumps can occur naturally and that explanations other than a flower burial are likely. A more detailed analysis of these results and a discussion of their implication is presented in the Discussion section of this thesis.

4.5 Conclusions

Previous archaeological investigations at Shanidar Cave were undertaken when taphonomy was still not considered as a fundamental step in the excavation process, involving often poorly-based interpretation of the information recovered from the findings. Solecki used the osteological and palynological data provided by the skeletal remains and the soil samples to support his idea that Neanderthals were more socially and morally developed than previously believed. However, as suggested by other authors, there might have been other plausible interpretations for the findings that involved taphonomical processes acting in cave systems such as mixing of sediments, air circulation patterns or animal activity.

This section provided a summary of the main archaeological and palaeoecological information available for Shanidar Cave and an overview of the palynological work undertaken on the stratigraphic samples collected from the cave, as well as the main issues and criticisms related to its interpretation. The next chapter introduces the geological, climatic and vegetation characteristic of the study area and describes the main features of the caves where the samples have been collected.

5. Environmental settings and study sites

This chapter introduces the geology, climate and vegetation of the area under investigation and describes the main features of the sampling sites. However, the political situation in Iraq has impeded modern research in the area during the last fifty years and, therefore, the environmental information available and provided here is scarce and based on a few old publications.

5.1 Geology

The territory of Iraq can be divided, geologically, into three regions (Figure 5.1):

- the west and south area, represented by the Iraqi portion of the Arabian Shield, with limestones and shales of Cretaceous, Eocene, Miocene and Pliocene ages;
- the north and north-east area, occupied by the foothills of the Zagros Ranges, with mountain ranges and hills dated back to the late Tertiary, formed by pressure and creating a series of parallel anticlines and synclines. Some of these movements are probably active at present day even if at a very slow pace. Most of the country consists of Cretaceous and Eocene limestones and shales, with some Palaeozoic strata exposed.
- the Mesopotamian plain area that lies between the other two regions. It is a filled basin with geologically recent upper deposits with river and marine alluvium, sand, silt and clay (Guest and Al-Rawi, 1966; Leturmy and Robin, 2010).

Evidence for glaciation in Iraq can be found in Wright (1962) who described stream terraces in the area close to Shanidar Cave, probably of fluvio-glacial origin. He hypothesised that these glacial features were related to the last glacial phase of the Pleistocene (the Würm in the Alpine sequence).

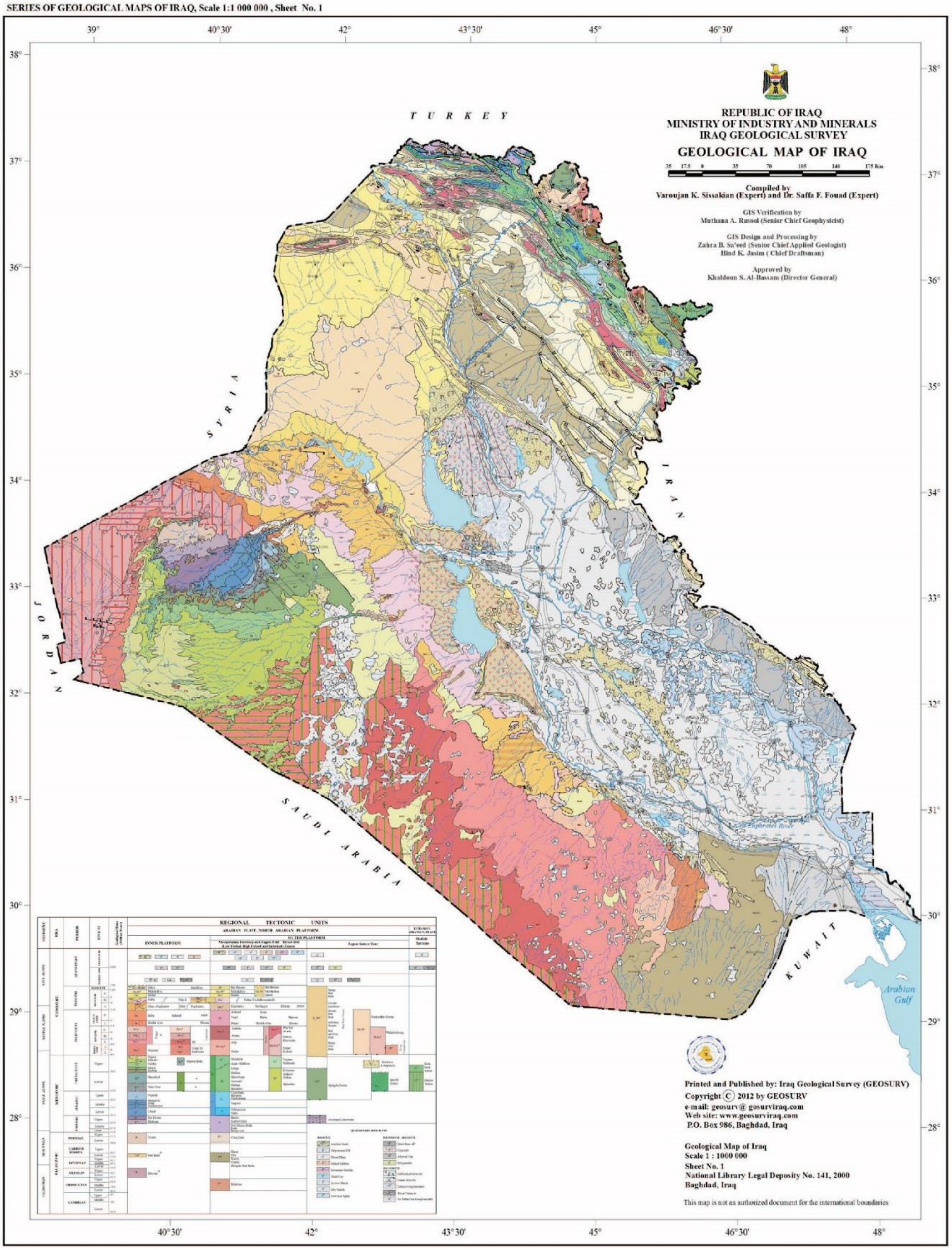


Figure 5.1 Geological Map of Iraq (Sissakian & Fouad, 2015).

5.2 Climate

The climate of Iraq is semi-arid and can be described as continental/sub-tropical. Its main characteristics are large differences in temperature between day and night and between winter and summer; low atmospheric humidity; general scarce rainfall with an annual average around 150 mm in Lower Iraq and around 300 mm on the Upper Plains, that goes up to 600 to over 1200 mm in the forest zone of the Zagros in the northwest. Lower Iraq is characterised by two separated seasons: the hot rainless summer spanning from May to October and the short cool winter from December to February. The coldest month of the year is January with temperatures ranging from 2 to 15 ˚C while the hottest months are July and August with a daily minimum and maximum temperature range from 24 to 43 ˚C (Guest and Al-Rawi, 1966).

5.3 Vegetation

Guest and Al-Rawi (1966) provide a detailed description of the vegetational features of Iraq and divide the vegetation in the following phytogeographical elements:

1. Mediterranean (204 species);
2. Irano-Turanian (968 species);
3. Saharo-Sindian (118 species);
4. Eurosiberian-Boreoamerican (23 species);
5. bi- and pluri-regional groups (600 species).

The studied area is located within the Irano-Turanian phytogeographic region and, more specifically, within the Irano-Anatolian sub-region, which includes the mountainous areas of inner Anatolia and Armenia, the Iranian mountain plateaux and the greater part of Transcaspia (Figure 5.2). The Irano-Anatolian sub-region is characterised by a highly diversified territory with mountains reaching an elevation of over 4000 m, plains and vast valleys. Generally, the majority of this region has annual precipitation of not more than 300 mm, even if in the mountain areas the rainfall may approach 1500 mm. In terms of vegetational zones, the studied area is located in the mountain-forest region, with altitudinal limits between 500 and 3000 m (with the forest zone between 500 and 1800 m and the alpine zone between 2750-3000 m). The main arboreal element of the forest is *Quercus* (*Quercetum aegilopidis*, *Quercetum aegilopidis-infectoriae* and *Quercetum infectoriae-libani*), while in some small areas near Mosul *Pinus halepensis* var. *brutia* is predominant. In undisturbed areas the tree cover is high, resulting in a closed forest that becomes an open forest in more densely populated places, such as near villages, where trees are slashed (their side branches are removed) to provide winter fodder for goats. Steppe vegetation can completely replace forest in those areas were the trees have been over-exploited and in dry areas.

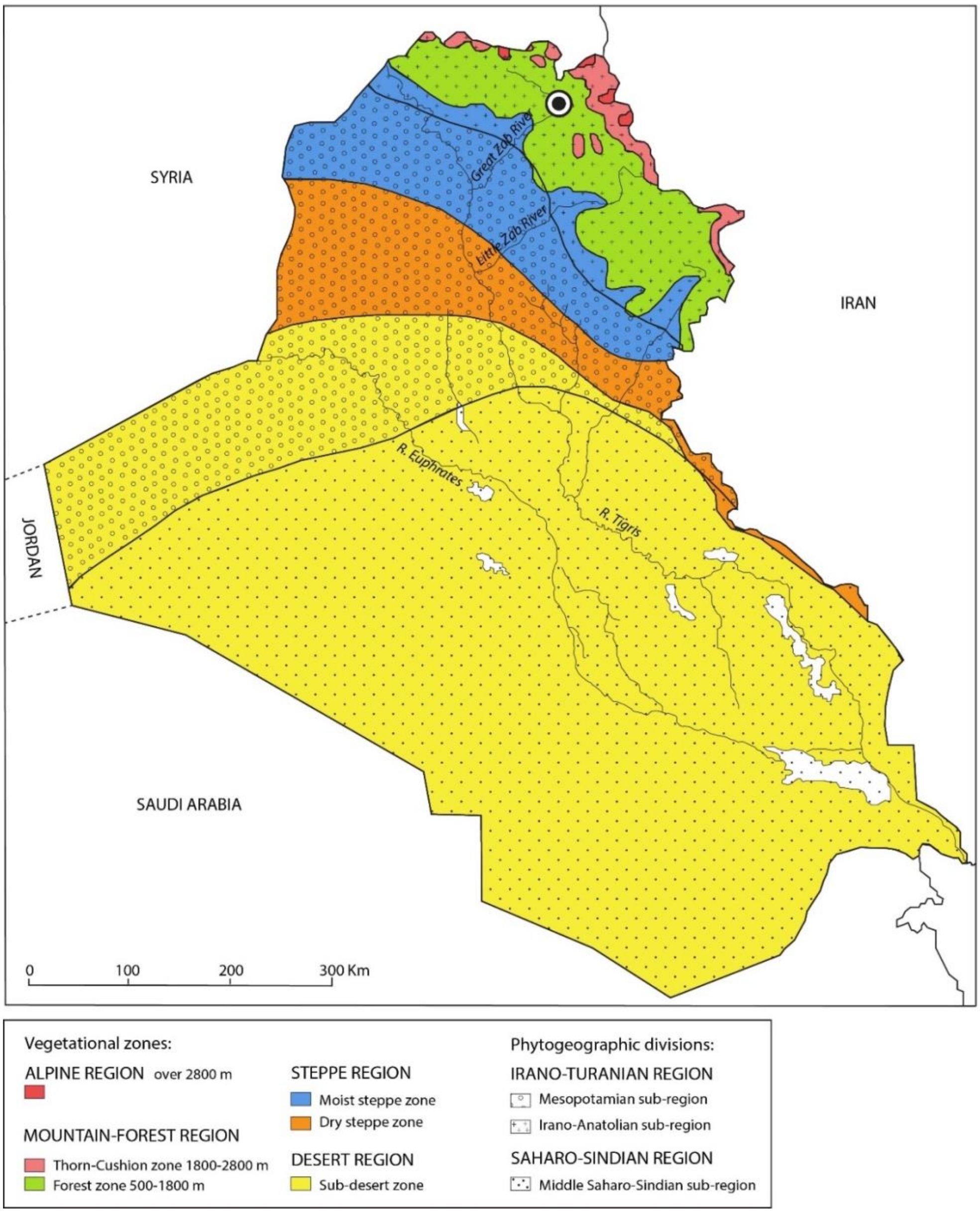


Figure 5.2 Phytogeographic division and vegetation zones of Iraq with the study area identified by the circle (Fiacconi & Hunt, 2017. Modified from Guest & Al-Rawi, 1966).

Around Shanidar the vegetation consists of a managed mixed montane grassland-woodland characterised by steppe of grassland and herbs with generally sporadic trees, which are slashed (pruned) near settlements while the branches are dried and used as winter fodder. The main local trees are deciduous *Quercus* and *Juniperus*, with *Acer*, *Juglans* and *Fraxinus* at middle elevations and *Pistacia* and *Olea* in drier areas. Herbs are quite diversified with *Poaceae*, wild cereals, *Anemone*, *Ranunculus* and Asteraceae visually prominent during the spring (Fiacconi & Hunt, 2015) (Figures 5.3, 5.4, 5.5).

Figure 5.3 The view of Shanidar Cave from the valley of the Greater Zab. The vegetation around is herb-rich grassland with occasional trees.

Figure 5.5 View of the area around Shanidar Cave showing herb-rich grassland with wild cereals and sparse trees.

Figure 5.4 Example of herb types adjacent to Shanidar Cave with prominent Anemone and Asteraceae.

5.4 Study sites

This paragraph describes the main geomorphological features of the sampling sites (Figure 5.7), in north Iraq. The location of the six caves is shown in Figure 5.6 and indicated by the star symbols.

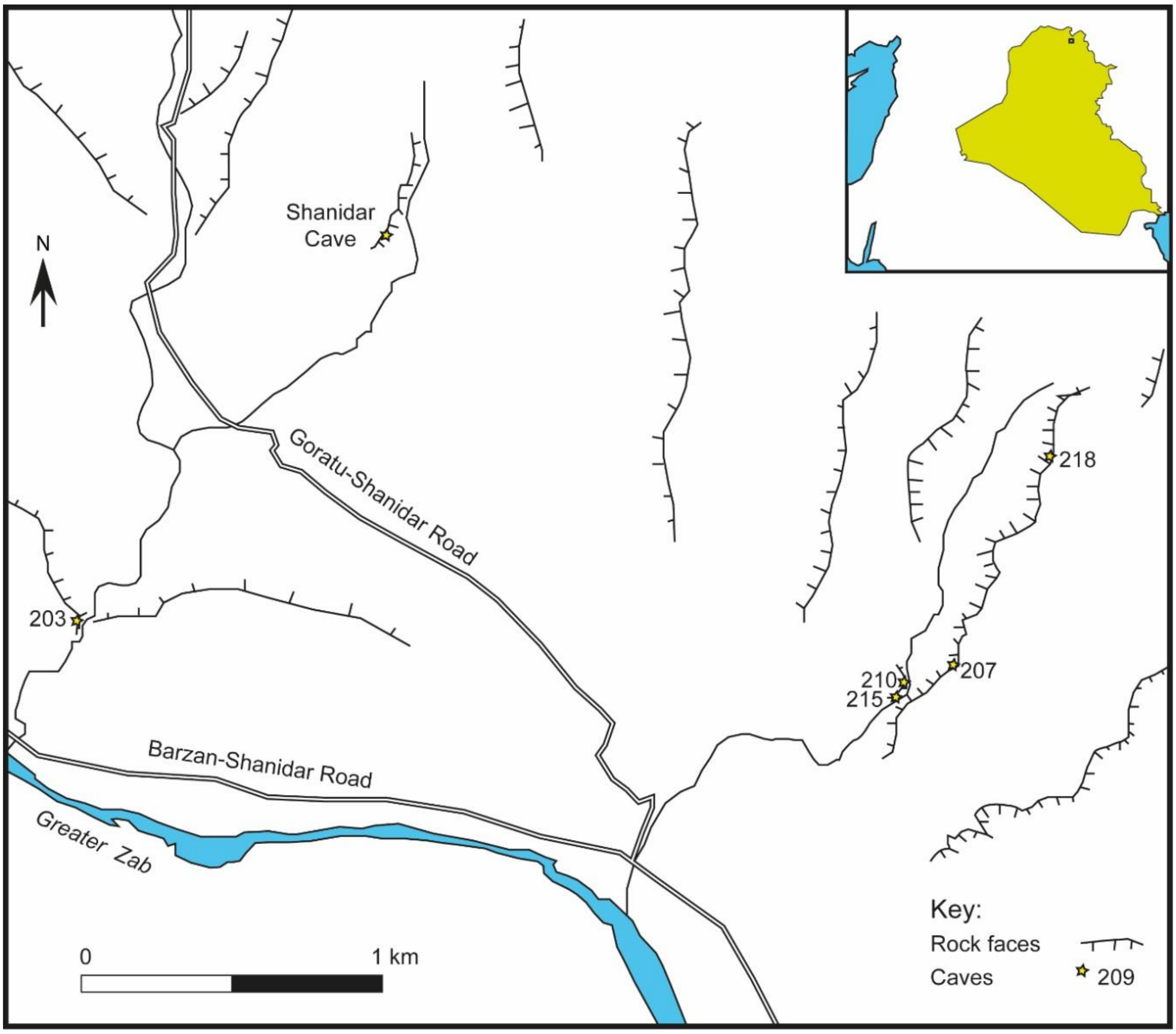


Figure 5.6 Location of studied caves north of Shanidar Village, Kurdish Iraq.

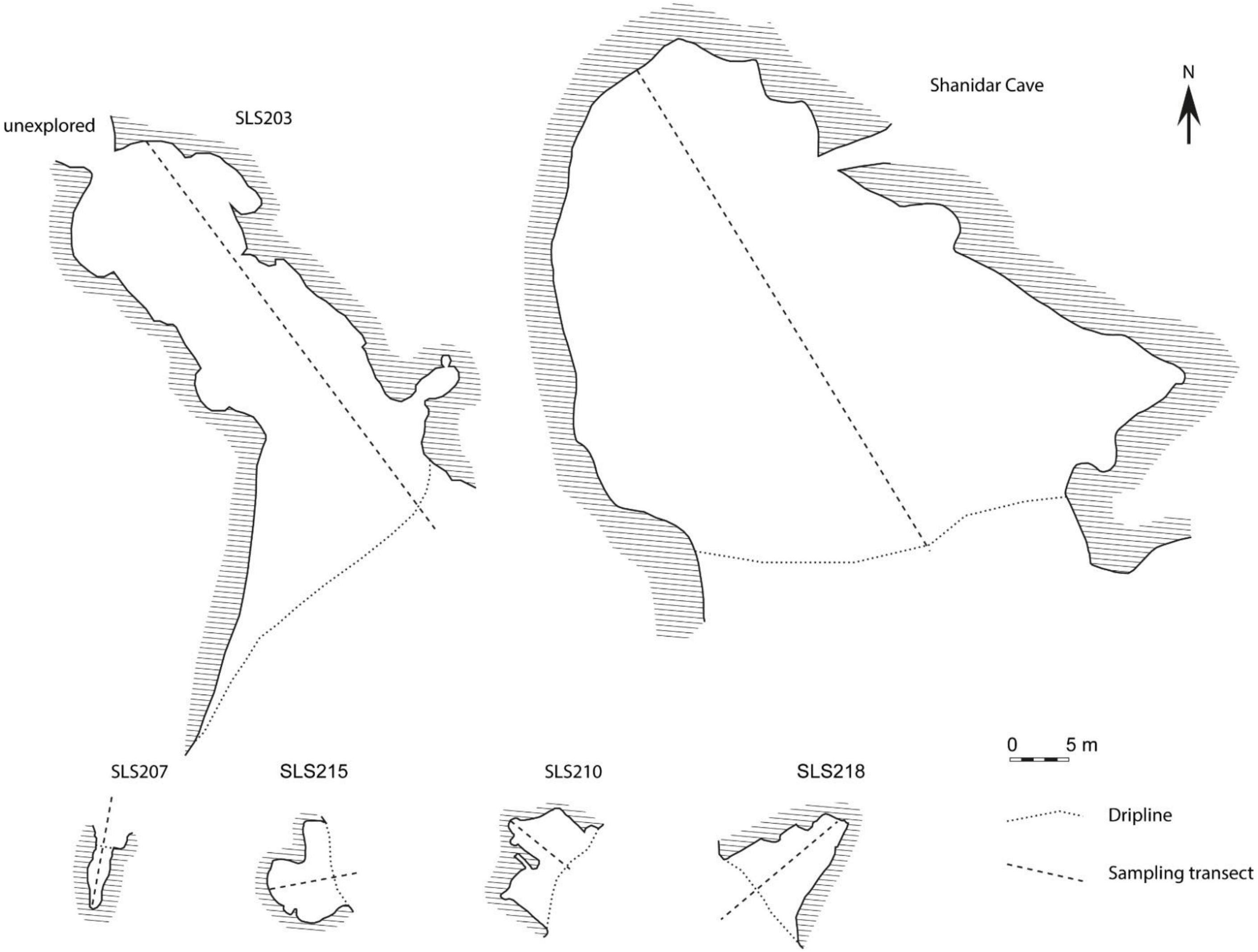


Figure 5.7 Cave plans with sampling transect.

Shanidar Cave, 36˚50’ 0.1” N, 44˚ 13’ 11.8” E, 747 m asl (Figure 5.8)

Shanidar Cave is of phreatic origin and shows well-developed half-domes and other phreatic features. The main chamber is connected to a small second chamber to the rear right that is infilled with sediment and has no archaeological significance. There are some vadose features, particularly in the network of narrow vadose canyons which open on the right side of the main chamber. The cave floor is covered by silty organic sands which were formed by the disintegration of the cave roof, aeolian dust and animal dung. The cave was inhabited until recently by tribal Kurds who used it during winters as a shelter for them and their animals; nowadays Shanidar is a popular local tourist destination and it is visited by up to several thousand people every day in the spring and summer.

Figure 5.8 Shanidar Cave.

SLS203, 36˚ 42’ 22.3” N, 44˚ 12’ 29.6” E, 581 m asl (Figures 5.9, 5.10)

SLS203 is a sub-tubular cave with half-domes characteristic of formation in a phreatic system which does not show vadose features. There is one chamber and two entrances, with the cave floor that measures 36 m in length and up to 12 m in width. The second entrance at the back of the cave opens on to a cliff face and is partially blocked by a drystone wall. A strong draft coming through the northern entrance to the cave was noticed during the work in the cave. The floor is covered by silty-organic sands and abundant sheep and cattle dung. Occasionally, the cave is used by local shepherds to keep their animals overnight.

Figure 5.9 Entrance of SLS203, known locally as Caf Sidar. Photo: C Hunt.

Figure 5.10 Rear of SLS203, showing goat-pen structure. Photo: C Hunt.

SLS207, 36^0 49’ 12.8” N, 44˚ 14’ 22.1” E, 559 m asl (Figure 5.11)

SLS207 is developed along a gull, where cambering is dragging the bedrock to the west of the cave outward and downward into the valley which runs parallel to and to the west of the chamber. The cave does not present phreatic or vadose features. The cave, facing north, is characterised by one chamber and a single entrance and measures 13 m in length, 7 m in width at the front and 2 m at the back. The cave floor is made of inorganic sandy silts probably of aeolian origin with some material derived from granular disintegration of the cave walls and roof.

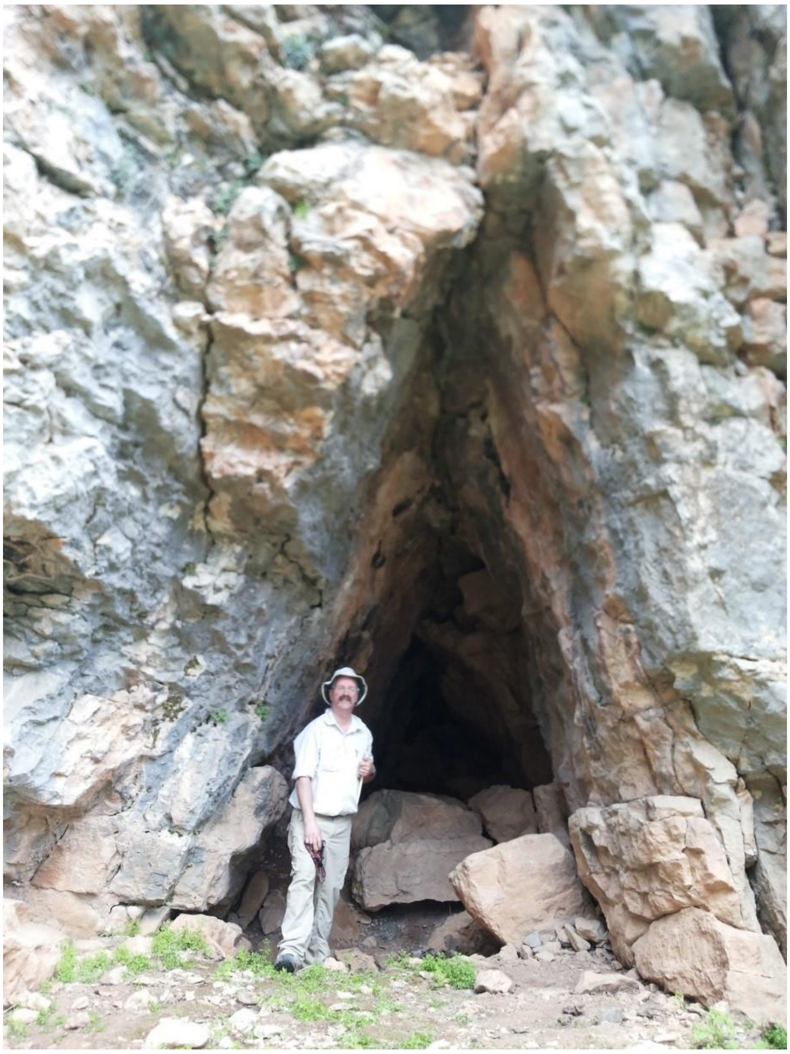


Figure 5.11 Entrance to SLS207.

SLS210, 36˚ 49’ 10.1” N, 44˚14’ 15.6” E, 623 m asl (Figure 5.12)

SLS210 is a complex phreatic remnant, 6 m long and 8 m wide with one entrance and one chamber. The floor deposits are organic silts with occasional animal dung.

SLS215, 36˚ 49’ 8.7” N, 44˚ 14’ 15.3” E, 681 m asl (Figure 5.13)

Cave SLS215 is another complex phreatic remnant, single-chambered and single-entranced, 6 m long and 8 m wide with floor made of gravelly sand.

SLS218, 36˚ 49’ 37.2” N, 44˚ 14’ 35.3” E, 771 m asl (Figure 5.14)

SLS218 is a phreatic tube remnant which is now terminated by cemented rockfall. The cave is single-chambered and single-entranced and measures 10 m in length and 9 m in width. The cave floor deposits are slightly organic slightly sandy silts.

Figure 5.12 Interior of SLS210, showing floor deposits. Photo C Hunt.

Figure 5.13 Part of SLS215.

Figure 5.14 SLS218, showing floor deposits.

5.5 Conclusions

This chapter summarised the geography, climate and vegetation of Kurdish Iraq and of the study area, explaining in details the main characteristics of the caves where the samples have been collected. The next chapter describes the methodology applied to collect samples from the locations mentioned above and the following laboratory techniques used to analyse the material.

6. Materials and methods

This chapter justifies and describes the methodology used to address the research questions. A detailed report of the activities undertaken during the different seasons of fieldwork is provided, as well as the rationale for the choice of the sampling sites and the techniques used to collect the samples. The background of pollen and particle size analysis is reported, followed by the description of the laboratory techniques undertaken in order to obtain, analyse and identify the pollen for the palynological analysis.

6.1 Fieldwork

Fieldwork was carried out during five seasons from 2014 to 2016.

6.1.1 First season: 2014 (Mar-Apr)

The first season of fieldwork consisted of three weeks of surveying and sampling at the site and in the surrounding landscape. The initial plan was to start the excavations and collect both stratigraphic and surface samples for pollen analysis; however, the unstable political situation caused delays in obtaining the related permits and the excavations did not start until the second season (end even then, the digging lasted for one week only because of complications in the political situation), restricting the sampling to the surface. Because of the short time available and the uncertainty about the future access to the site, it was decided that the pollen trapping approach used e.g. by Coles & Gilbertson (1994) was not practicable. However, the surface sediments of the caves were thought to provide a time-averaged view of the pollen fallout at any particular point in a cave and it was decided to sample them.

Considering that Shanidar Cave, the main focus of the research effort, was clearly highly disturbed by the presence of visitors, it was decided that samples from less-disturbed caves were needed for comparison. During the survey in the Shanidar Cave area and through conversation with local informants several caves were noticed; some of them were selected on the basis of their morphological characteristics and human and animal presence in order to understand the influence of those factors on the pollen composition and in particular: single vs double entrances, narrow vs wide shapes and human and/or animal presence or absence. Their locations were noted using handheld GPS units and on a Google Earth image. These GPS locations proved to be unreliable in the narrow, precipitously-sided valleys in the survey area; locations obtained using GPS, when compared with the Google Earth locations, showed considerable discrepancies. Surface samples were collected inside the caves and outside to provide a baseline of the local pollen rain close to the caves. Samples were also collected along an altitudinal transect from the top to the bottom of the mountain where the site of Shanidar is located in order to study the change of the vegetation with altitude but they were not analysed during this PhD because of the time available.

The sampling consisted of a trowel-full of surface sediment collected alongside a linear transect from the back to the front of each cave, avoiding areas where clear disturbance was present, in order to study the influence of sample location in the pollen composition and the distribution of anemophilous and entomophilous taxa at different distances from the cave entrance (Figures 6.1, 6.2 and 6.3). Additional samples were collected in Shanidar Cave along a transect going from one side to the other of the cave, along the cave mouth and along the perimeter (Figure 6.1). In cave SLS203, moss samples were collected along a linear transect inside the cave from polsters growing on seeps in the east wall, in order to compare the pollen from the polster material with the pollen recorded in the surface sediment samples, considering the inconsistencies usually noticed between these sampling methods (Cundill, 1991); mosses were not present in any of the other caves to provide similar samples. In addition, goat/sheep dung samples and dripping water samples were collected from inside Shanidar Cave in order to analyse the animal and water pollen input in the cave assemblage.

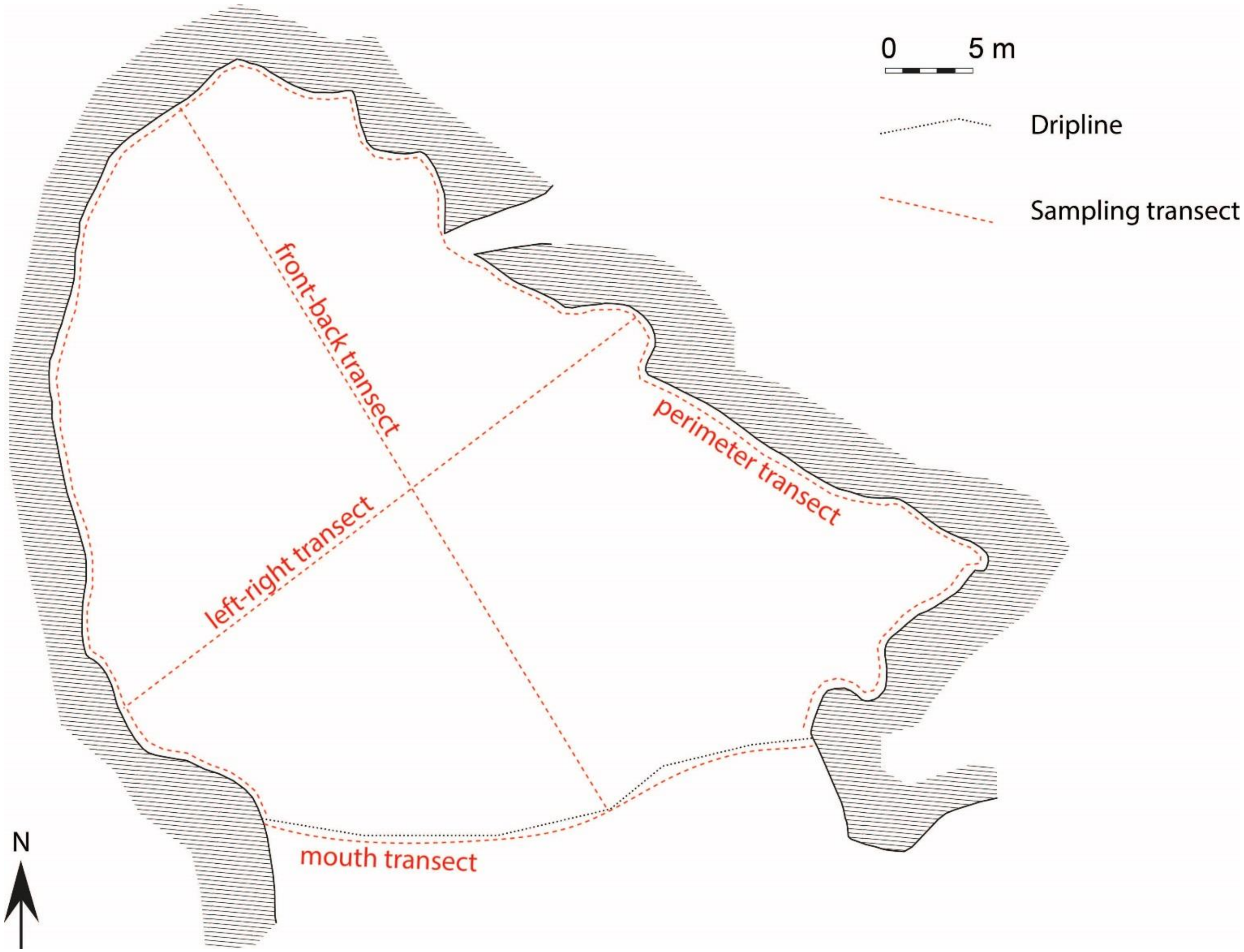


Figure 6.1 Shanidar Cave sampling transects.

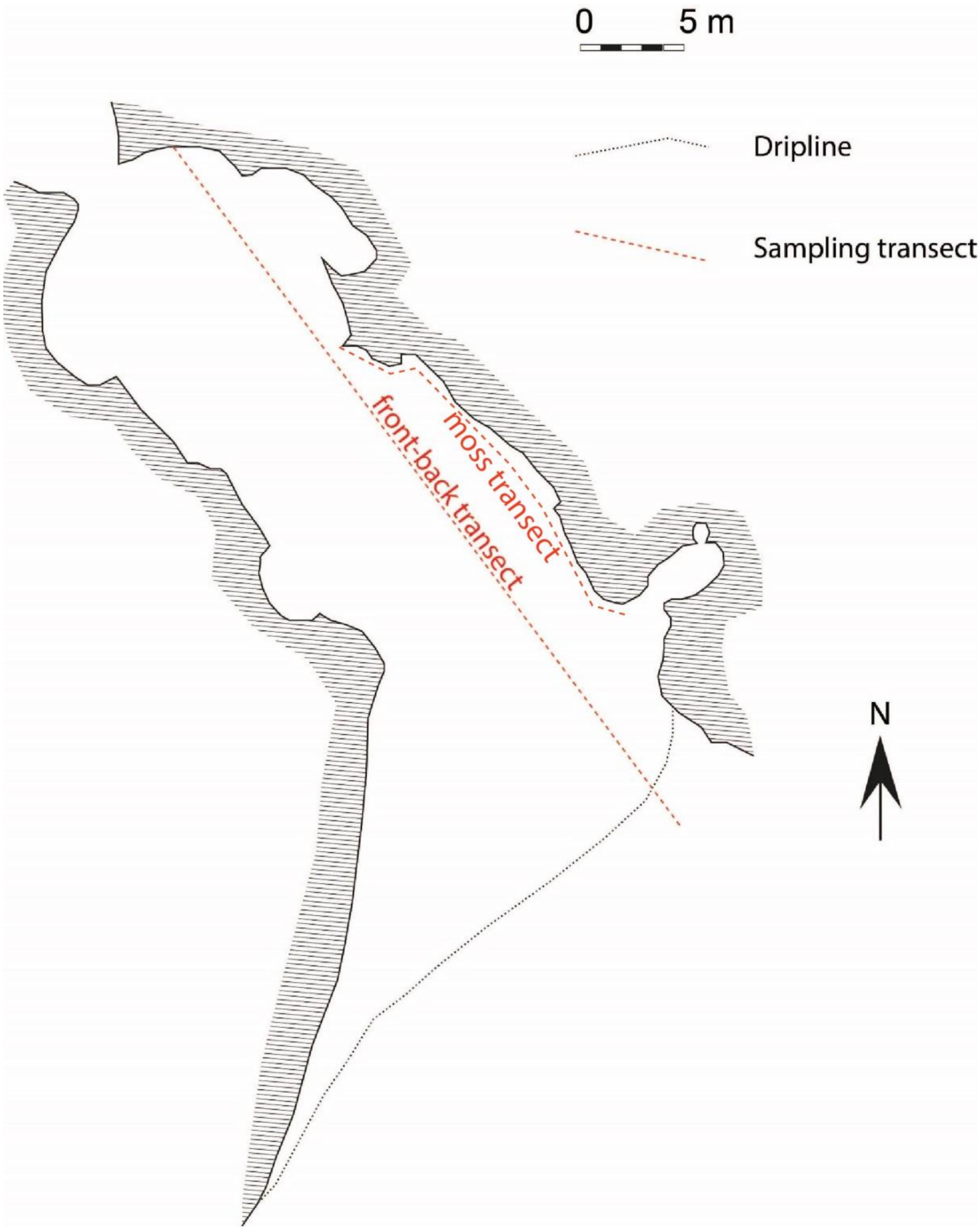


Figure 6.2 SLS203 (Caf Sidar) plan with sampling transect.

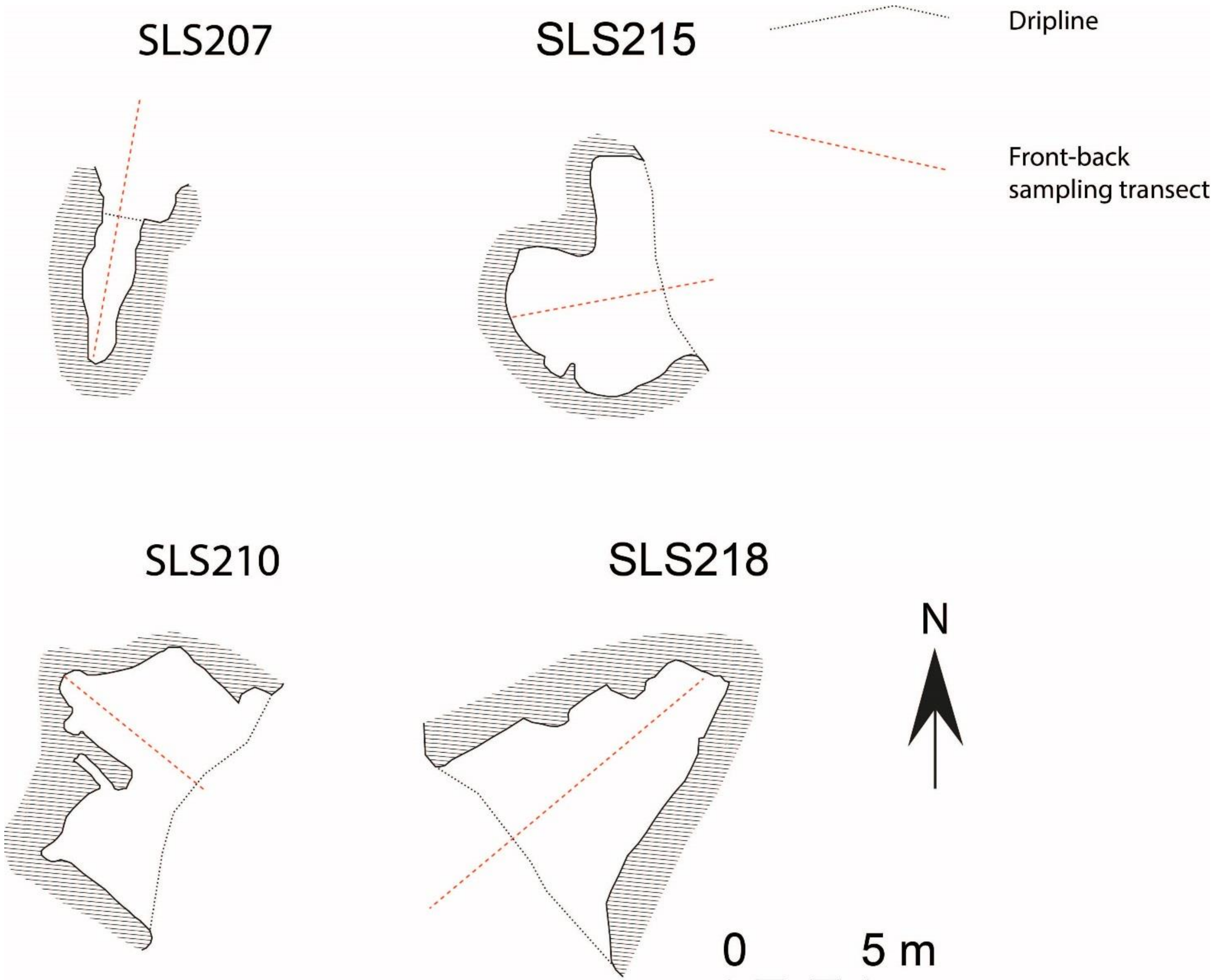


Figure 6.3 SLS207, SLS210, SLS215 and SLS218 cave plan and sampling transect

6.1.2 Second and Third season: 2015 (Mar-Apr, Aug-Sept)

A planned second season in August-September 2014 was aborted because of the incursion of an army of the so-called Islamic State into Kurdish Iraq. During the second and third field seasons, the focus of the Shanidar Project was almost exclusively archaeological, with the location of the edges of the Solecki trench and the beginning of clearance of vast quantities of rubbish and sediments from this. Fragmentary Neanderthal skeletal remains probably associated with Shanidar V, which had been partly excavated by Solecki, were located in backfill of the Solecki trench during the summer season. Some drip water samples were collected after periods of heavy rain. In the August-September season, stratigraphic sediment samples were taken from an initial sample column (Sample Column A) in sediments containing lithics assigned to the Early Upper Palaeolithic (Baradostian) Industry.

6.1.3 Fourth and Fifth season: 2016 (Mar-Apr, Aug-Sept)

Excavation continued during the Fourth and Fifth seasons, eventually reaching a depth of over 8 m from the initial sediment surface and deposits containing lithics assigned to the Middle Palaeolithic Mousterian Industry. The location of Shanidar V was cleared in the spring season and further Neanderthal bone was located and then carefully excavated in this area during both seasons. During the spring season, the location of Shanidar I was identified. Further sample columns were taken: Sample Column B was taken to replace Sample Column A, since organic preservation in Sample Column A was extremely poor. Sample Column B and all later sample columns were cut back over 30 cm from the cleaned sediment face before sampling in an attempt to improve organic preservation. Sample columns C and C(2) continued the stratigraphic coverage to the level of Shanidar I (Figure 6.4). The area around Shanidar V was too complex for a sample column; however, spot samples were taken around the Neanderthal bones during the spring season.

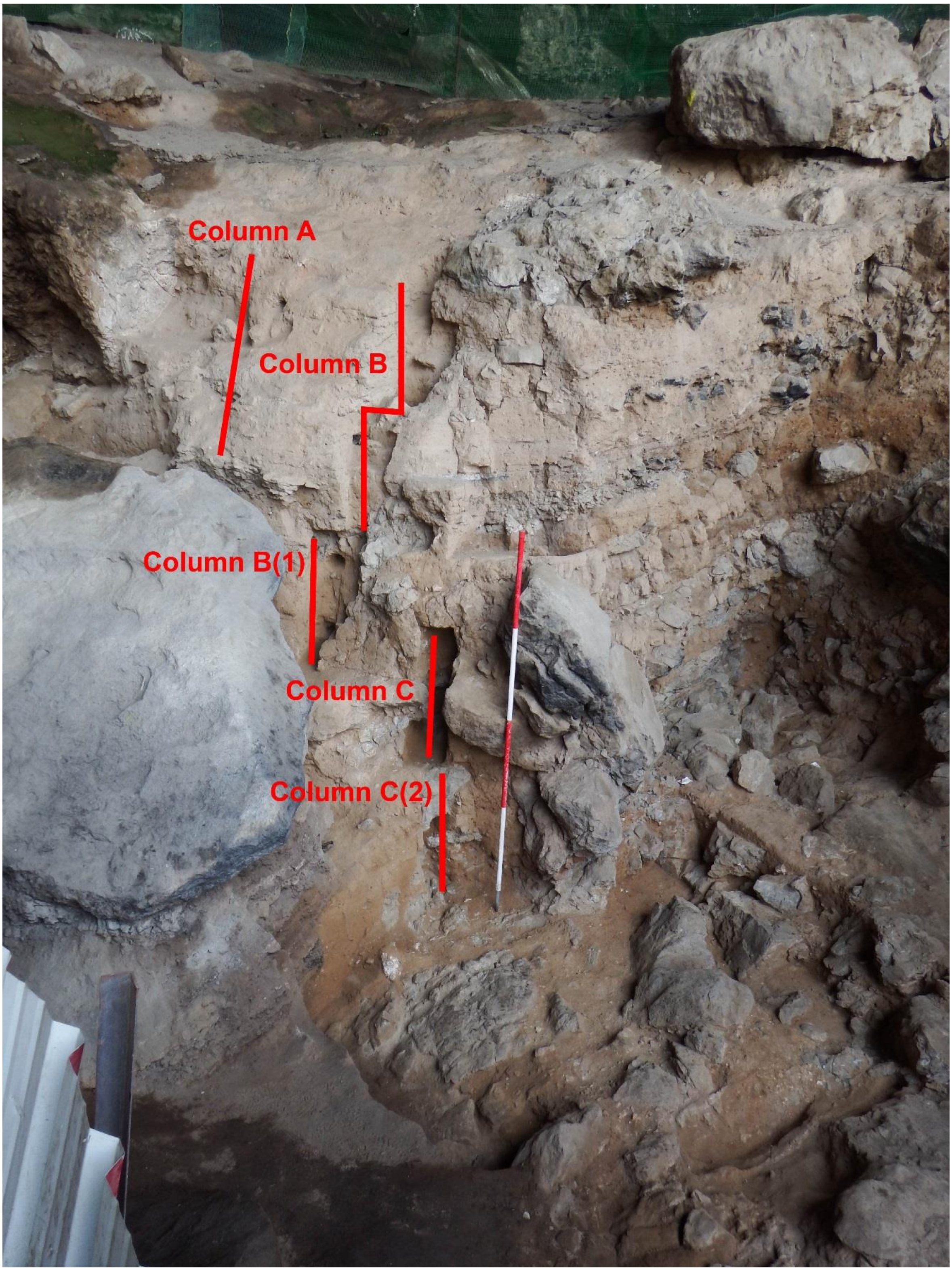


Figure 6.4 Location of Shanidar Cave stratigraphic columns (scale is a ranging pole 2 m long).

Taphonomic work during the 2016 seasons included the collection of animal droppings and other taphonomic comparatives, plus further drip-water samples. During the spring season, a rest-day was utilised to put out a series of sticky slides inside the cave, with two comparatives outside (following the Vaseline-coated slide method of Coles & Gilbertson, 1994 and Simpson & Hunt, 2009) to identify the pattern of pollen airfall during a single day (Figure 6.5). This would allow an evaluation of the distance into the cave that pollen might be distributed by wind.

Figure 6.5 Example of the sticky slides placed in Shanidar Cave.

At the end of the spring season, six modified Tauber-style pollen traps were deployed into inconspicuous locations inside and outside the cave, to trap the majority of the season’s pollen fallout (the oak pollen season had recently started). On going to collect the traps at the start of the summer season, it was discovered that only two of these traps had survived in a usable state. These were bagged in sterile self-seal bags and returned to the laboratory for analysis.

6.2 Laboratory work

6.2.1 Pollen analysis

Background

Pollen is one of the reproductive structures of angiosperms and gymnosperms and contains the male gamete of the plant; spores are the equivalent of pollen for cryptogams and represent the sporophyte stage of those plants. Most pollen grains have dimensions that range between 15 and 35 µm with very few exceeding 100 µm (Lowe & Walker, 2015). The wall of the grain consists of two layers: an inner layer, the *intine*, which is made of cellulose and an outer layer, the *exine*, made of a very resistant material called sporopollenin. Two layers can be identified in the exine: an inner, basal layer of *nexine* (non-sculptured exine) and an outer layer of *sexine* (sculptured exine) (Moore et al., 1991). In angiosperms, a complete sexine is characterised by two layers and consists of internal rod-like elements known as *columellae* covered by a roof-like layer called *tectum* (Walker & Doyle, 1975). The exine usually consists of two layers called *endexine* and *ektexine* (Figure 6.6). There are three basic exine structure types: in tectate grains, the exine is complete and consists of nexine, columellae and tectum; in semitectate grains, the tectal perforations become spaces for lumina; in intectate grains, the tectum is lost entirely and there are exposed columellae.

One of the main characteristics of pollen grains, important for identification, is the number and type of apertures, which are areas where the exine is thin or missing. The main functions of the apertures are to provide a space for the pollen tube to emerge at the time of germination and to allow changes in volume that happen because of changes in humidity. Apertures are classified based on their position, shape, structure, number and size. There are two types of apertures: *pores* – isodiametric - and furrows (*colpi*) – elongate, boat-shaped and with acute ends (Faegri & Iversen, 1950).

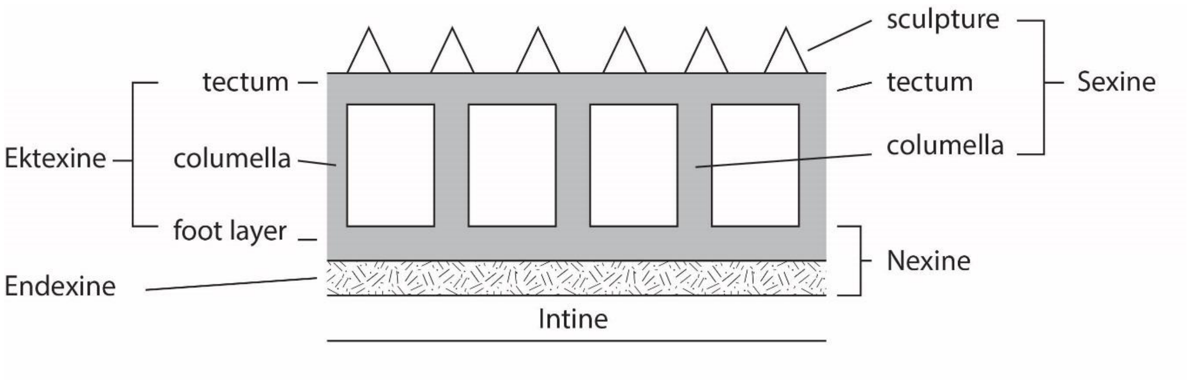


Figure 6.6 Pollen grain structure and terminology (modified by Moore et al., 1991).

With regards to the type of apertures, pollen can be classified as inaperturate (without any aperture), porate (with pori), colpate (with colpi) and colporate (with combined pori and colpi). Nomenclature is based on the type and number of apertures which is specified by adding the prefixes mono-, di-, tri-, tetra- penta-, hexa- and poly- before the aperture type name. The terms -zono- and -panto- are used to indicate equidistant apertures around the equator of the grain and scattered apertures respectively. In some taxa pollen grains are aggregated in *tetrads* or *polyads*. Another useful characteristic for the identification of the grains is their shape; however, it can vary significantly within the same species so it should only be used as indication (Moore et al., 1991). Simpson (2006) distinguishes three different shape types that are defined as the ratio of the polar diameter to the equatorial diameter (P/E ratio). When P/E is approximately 1, the grain is classified as spheroidal; when P/E ≥ ca. 1.2, the grain is prolate (elongate along the polar axes); when P/E ≤ ca. 0.8, the grain is oblate (compressed along the polar axis).

Finally, another common feature that helps in the identification of the grains is the structure and pattern of the exine, also known as sculpturing types (Figure 6.7). The type of investigation used to analyse the structure of the sexine is called LO-analysis (Erdtman, 1956) where L-O refers to the light-obscurity sequence on the optical microscope that allows holes and raised elements to be seen when focusing down.

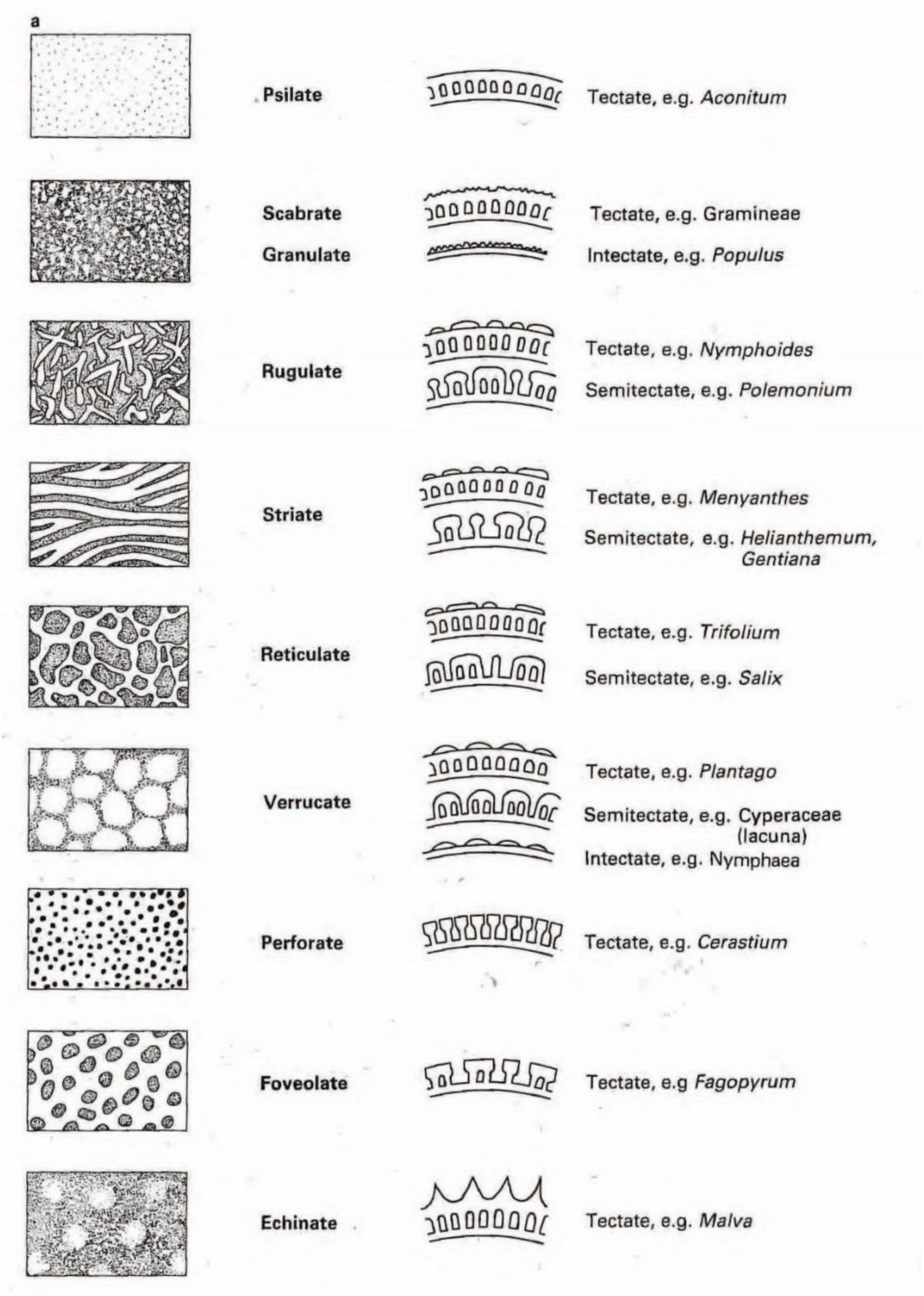


Figure 6.7 Diagram of different sculpturing types visible in surface view and optical section (Moore et al., 1991).

Pollen analysis

Pollen analysis is the study of fossil pollen and spores and represents one of the main techniques for the reconstruction of the past vegetation and environment at local, regional and continental scale (Seppä, 2006). Bennett and Willis (2001) summarise the principles of pollen analysis in the following statements:

1. Plants produce pollen and spores in abundance.
2. Most of the pollen produced falls and accumulates on the ground.
3. In anaerobic conditions, pollen and spores can be preserved (e.g. bogs, lakes).
4. The pollen rain over an area is represented by the pollen and spores that are mixed in the atmosphere.
5. The composition of the pollen rain is related to the composition of the vegetation in that area.
6. It is possible to identify pollen at different taxonomic levels.
7. The analysis of a sediment sample of known age provides the description of the vegetation in that area at a particular time.
8. When different samples from a sequence of sediments are available, it is possible to reconstruct the change of the vegetation during time.
9. When different pollen spectra are obtained from separate sediment sequences, it is possible to compare the history of vegetation in different areas.

The most common types of depositional environment where pollen and spore assemblages can be preserved are soils, caves, lakes, peats, ocean floor sediments, ice cores and organic deposits such as rodent middens. The first step of the palynological study consists in the collection of the samples, which can be extracted from exposed sections or obtained by sampling a cylindrical portion of sediment from depth using coring equipment.

The laboratory work to extract pollen aims to concentrate the pollen grains included in the sediments and separate them from the other organic and inorganic material. The sequence of procedures and chemicals used to achieve this goal depends on the nature and type of sediment and the authors concerned. Standard procedures include: digestion in potassium hydroxide (KOH), used in case of organic sediments to aid disaggregation (Faegri & Iversen, 1975); hydrochloric acid (HCl), used before treatment with KOH in those cases when there is an abundance of calcium carbonate (Moore et al., 1991); hydrofluoric acid (HF), used to remove silica and silicates (Assarson & Granlund, 1924); acetolysis - the hydrolysis of the polymers that form the cellulose into soluble monosaccharide units using concentrated sulphuric acid (H_2SO_4) and acetic anhydride ($C_4H_6O_3$) - useful in removing cellulose (Erdtman, 1960).

Additional techniques are the treatment of clay-rich samples with sodium pyrophosphate ($Na_4P_2O_7$), which acts as a deflocculant for the clay particles (Bates et al., 1978), or the use of density separation in case of minerogenic sediments, where a solution of sodium polytungstate and water is used to separate the particles according to their relative density (Nakagawa et al., 1998). Some of these techniques, however, present problems and hazards. In particular, treatment with HF is reported to affect grain size (Girard & Renault-Miskovsky, 1969; Faegri & Iversen, 1975) and to be dangerous both in solution and as vapour (Bennett & Willis, 2001) and acetolysis can cause swelling of the grains as well as being extremely dangerous due to be extremely corrosive and reactive with water (Van Asperen et al., 2016). Therefore, during this research, the laboratory technique adopted was slightly modified with details that can be found in the following *Method* section. The residue containing pollen is then stained, if necessary, using an organic colorant such as safranin to facilitate the identification of the grains and then mounted on a microscope slide using silicon oil or glycerine jelly as medium.

The counting procedure is carried out using an optical microscope and a 400x magnification, traversing the slide in a systematic way until a count of 250 to 500 grains is reached (Moore et al., 1991; Bennett & Willis, 2001; Lowe & Walker, 2015). The results of the counting are presented as pollen diagrams, which can be percentage pollen diagrams, where the taxa are represented in relation to their relative proportion; concentration pollen diagrams, where the taxa are represented in relation to their concentration and absolute pollen diagrams where the changes in the rate of accumulation of the taxa are shown over stratigraphic intervals.

Method

Because of the very low and variable pollen concentrations, it was decided not to add an exotic marker and to check after each stage of preparation the necessity of further stages in order to avoid worthless procedures. For all samples, a treatment with cold HCl 10% followed by hot KOH and sieving was applied while density separation - using a solution of sodium polytungstate (SPT) and water with a specific gravity of 1.9 (following Munsterman & Kerstholt, 1996) - and treatment with hot sodium pyrophosphate (following Bates et al., 1978) were used to separate mineral fragments and in case of clay-rich sediments respectively.

After the chemical treatment, the residue was then stained with aqueous safranin and mounted on microscope slides using glycerine. Pollen grains were identified (with reference to Reille, 1995; Moore et al., 1991 and Faegri & Iversen, 1975) and then counted using an optical microscope (Meiji MT4000 Series with magnification of ×400 and ×1000). Relative pollen percentages have been calculated on the basis of a pollen sum including all terrestrial pollen and spores to produce the relative pollen diagrams. Unidentified pollen grains reflect the fraction of deteriorated grains and their number was used as an indication of the preservation of the pollen and of the environmental conditions where the pollen has been found (Moore et al., 1991). Percentage pollen diagrams were produced using the software Tilia (Grimm, 1991,1993).

6.2.2 Particle size analysis

The stratigraphic samples collected from Shanidar Cave were prepared and analysed for pollen analysis following the methodology described in the related paragraph. However, they appeared to be sterile or containing very few pollen grains, compared to the results reported by Leroi-Gourhan (1975). Therefore it was decided to investigate the properties of the samples further through particle size analysis in order to understand the scarcity of pollen.

Background

Particle size is one of the most important characteristics of soils because it affects particle transport and deposition and can provide useful information about the transport and depositional history of the sediment under study (Blott et al., 2004). Different scales are used to define size categories; Table 6.1 shows the particle size fractions in mm and ϕ (phi) units according to Wentworth (1922) where the phi is calculated as $-\log_2$ of the diameter in mm with the advantage of using only integer numbers.

Table 6.1 The Wentworth scale of particle size fractions (Lowe & Walker, 2014).

Name	**mm scale**	**ϕ unit**
Boulder	>256	> -8
Cobble	256-64	-8 to -6
Pebble	64-4	-6 to -2
Granule	4-2	-2 to -1
Very coarse sand	2-1	-1 to 0
Coarse sand	1-0.5	0-1
Medium sand	0.5-0.25	1-2
Fine sand	0.25-0.125	2-3
Very fine sand	0.125-0.0625	3-4
Coarse silt	0.0625-0.0312	4-5
Medium silt	0.0312-0.0156	5-6
Fine silt	0.0156-0.0078	6-7
Very fine silt	0.0078-0.0039	7-8
Coarse clay	0.0039-0.00195	8-9
Medium clay	0.00195-0.00098	9-10

Particle size can be determined using different techniques

Sieve analysis is based on the weighing of particles retained in a graded stack of sieves and therefore is predicated by the dimensions of the intermediate axes of the particles (Gale & Hoare 1992).

Sedimentation analysis is based on Stokes' law, according to which when sediments are suspended in a liquid, the different fractions settle at different rates. The fractions can then be measured using a hydrometer or taking subsample using a pipette and weighting the samples over time to calculate the changing in concentration (Lowe & Walker, 2015).

Pulse counters count the voltage pulses produced when the sediment is suspended in an electrolyte that are proportional to the volumetric size of the particles (Lowe & Walker, 2015).

The s*edigraph method* is based on the sedimentation theory (Stokes' law) and uses a X-ray beam to detect changes in the concentration of suspended sediment during settling at different distances and specific times providing a distribution of the concentration of the different size classes (UCL Department of Geography, 2017).

Finally, l*aser diffraction analysis* uses a beam of monochromatic light that passes through the suspended sample. Because the particles diffract the light at different angles according to their size, then the grain size distribution can be calculated using several detectors that detect the scattered light (Beuselinck et al., 1998).

The different techniques measure slightly different aspects of the particle size, such as maximum caliper diameter, sieve diameter and equivalent spherical diameter, and therefore cannot be directly compared. The pipette method, pulse counters and sedigraph analysis are particularly indicated for silt and clay sediments while the sieving technique can be used only for sand and gravels (Pye & Blott, 2004).

Method

A total of 14 samples from Shanidar Cave column C(2) was analysed for particle size using laser diffraction analysis with a Beckman Coulter LS 13 320. Approximately 1 g of sample was placed into the machine after adding a deflocculant to prevent clumping of clay particles and the measurements were taken when the obscurity was between 10% and 15%. The results were analysed using the software GRADISTAT (Blott & Pye, 2001), which provides calculation of grain size statistics of approximately 50 samples per hour. The user is required to input the percentage of sediment for each size fraction in the integrated Microsoft Excel spreadsheet and the program then provides mean, mode(s), sorting (standard deviation), skewness, kurtosis and cumulative percentile values. The grain size follows a modified Udden-Wentworth scale and the textural classes are named following Folk (1954).

6.3 Data analysis

6.3.1 Linear regression analysis

Background

Linear regression is a statistical analysis that measures the relationship between two variables (a dependent or response variable and an independent or predictor variable). This model is described by a straight line relating the two variables explained by the following equation

$$y = \beta_0 + \beta_1 x + \varepsilon$$

where β_0 is the intercept, β_1 is the slope and ε a residual term measuring the difference between the predicted and the real values (Figure 6.8). β_0 and β_1 are determined using the method of least squared to find the minimum value of the sum of the squared residuals that represents the difference between the real value and the predicted value of the dependent variable (Montgomery et al., 2015).

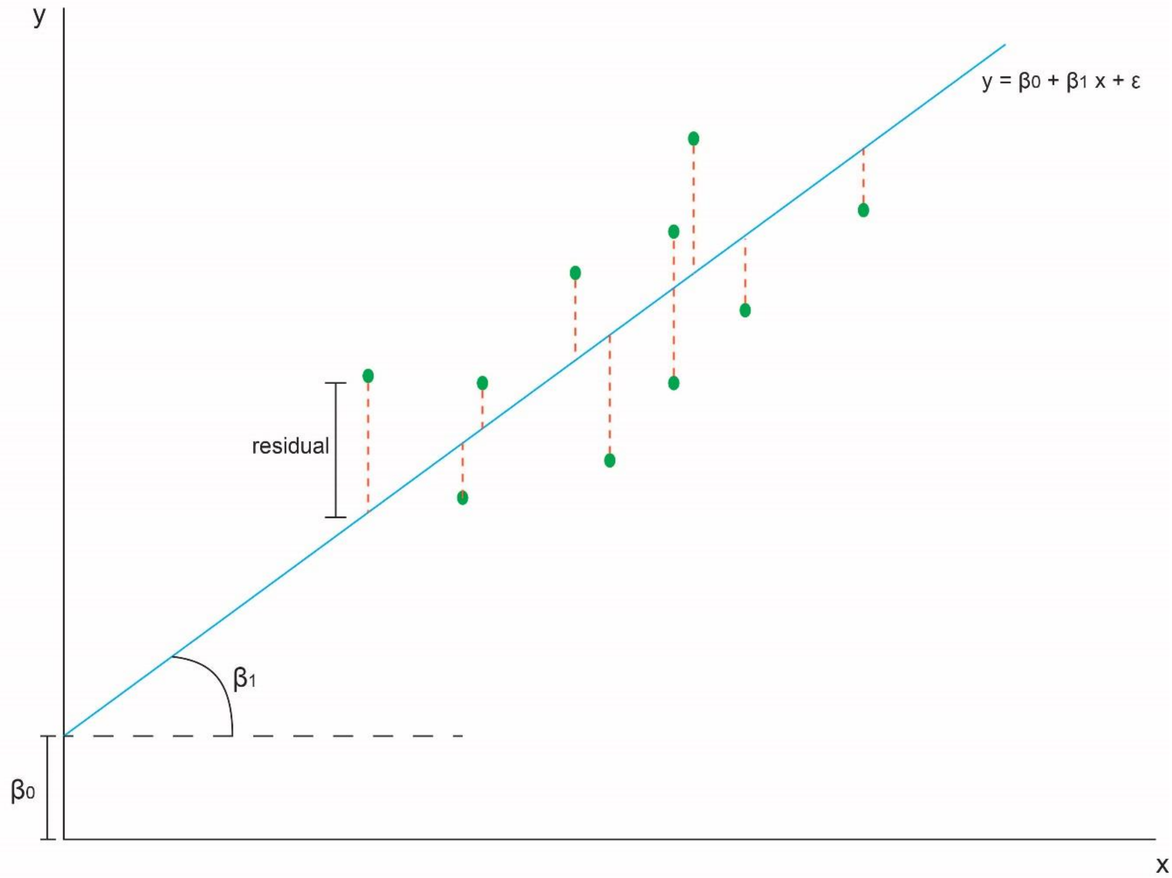


Figure 6.8 Graph showing a scatterplot of data (green dots) and a regression line (blue) with its intercept and slope. The red dashed lines indicate the residuals.

To assess the goodness of the model the value R^2 is used which represents the percentage of the variation of the data that can be explained by the model and is defined as

$$R^2 = SS_M / SS_T$$

where SS_M is the model sum of squares and SS_T the total sum of squares (Field, 2013).

Method

The relationship between anemophilous taxa and the distance of each sample from the cave distance was assessed using the linear regression analysis in RStudio. For each cave the total percentage of anemophilous taxa of each sample and the distance (m) from the cave entrance were analysed.

6.3.2 Interpolation

Cave iso-line maps of Shanidar Cave anemophilous and entomophilous total pollen percentages and sticky slides were carried out and drawn with ArcGis 9.3 in order to display trends in pollen distribution. Data were interpolated applying the Natural neighbour (NN) interpolation method that finds the values of the unsampled location by weighted averaging the nearest values according to their areas or volumes (Mitas & Mitasova, 1999). The natural neighbours of a points are those associated with the close Voronoi polygons and the weights to the unknown points are calculated from the overlap between the initial polygon constructed on the given points and the new polygons created around the interpolation points (Garnero & Godone, 2013).

6.4 Conclusions

This chapter introduced the materials analysed during this research and the techniques used for the preparation, from the collection during fieldwork to the chemical and mechanic techniques adopted in the laboratory. The results of the pollen and particle size analysis undertaken on both surface and stratigraphic samples are presented in the following chapter.

7. Results

This chapter presents the results of pollen and particle size analyses for each sampling site. Data from the front-back, right-left and perimeter transect as well as those from pollen traps, water samples and animal droppings from Shanidar Cave are described in order to analyse the influence of the sample location and the airborne, waterborne and human/animal-borne pollen in the composition of the final pollen assemblages. For all the other caves, pollen data from front-back transects are reported. Finally, the results from particle size analysis undertaken on stratigraphic samples from Shanidar Cave Column C(2) are given.

7.1 Pollen

Pollen percentages were used to produce pollen diagrams. Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen. For the front-back transects, three main zones – back, front and exterior – were defined on the basis of the percentage of anemophilous and entomophilous taxa according to the following criteria: the limit between the back and front zone was marked by a percentage of entomophilous taxa over 50%; if this criterion was not applicable because of fluctuations in the pollen curve, the limit between the zones was established by the mid value of the transect length.

7.1.1 Shanidar Cave

Front-back transect

12 surface samples from the front-back transect (9 samples, CL series), cave mouth transect (1 sample, SM series) and the areas outside the cave (2 samples, SS series) were analysed with a total of 60 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 508 (sample C08L) and the lowest of 121 (sample S16M) and pollen preservation was good (87.2–97.7% identifiable grains). Pollen percentages were used to produce a pollen diagram (Figure 7.1). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards to abundance, are Poaceae, Lactuceae, Cyperaceae, Caryophyllaceae, Asteraceae and *Quercus*. Herbs are

the more abundant (62.6-93.9%), followed by trees (0.6-22.6%) and shrubs (1.0-93.9%). The main characteristics of the pollen zones are described in Table 7.1.

Table 7.1 Shanidar Cave front-back transect description according to pollen zones.

Pollen zone	**Description**
Back	Trees are almost absent, with the exception of *Quercus*. Values reach 16.5% and increase from the back of the cave towards the front and then fluctuate around similar values. Among the shrubs, Rosaceae show a similar increasing trend. Asteraceae values remain almost constant around 5%; *Bidens* type, instead, shows a marked decrease from the back of the cave with the highest values recorded in the first two rear samples (21.0 and 22.5%). Cyperaceae are characterised by fluctuations without any clear pattern. Poaceae show a continuous presence around 10% while Cereal-type decreases from the back of the cave. Lactuceae show fluctuations but keep high values (11.2-29.6%).
Front	Pollen from other trees (e.g. *Betula, Pinus, Alnus*) appear, even if in very small quantities (<1%), with *Quercus* values still high (up to 14.2%) and almost constant throughout the zone. Rosaceae increase and reach their maximum (18.2%) at the end of the zone, near the cave entrance. Asteraceae maintain similar values with the exception of a single sample (C08L) with values up to almost 60%, while *Bidens*-type values keep decreasing down to 2.4%. Caryophyllaceae show lower values compared to the previous zone (around 3%) while Cyperaceae higher values (up to 12.2%). Lactuceae fluctuate around high values (20%). Poaceae disappear at the beginning of the zone and increase again only near the front of the cave while Cereal type maintain similar values (9.9-19.7%).
Exterior	Cupressaceae reach their maximum with values up to 6.4%, *Quercus* remains stable while other trees are not recorded with the exception of *Pinus*. Rosaceae show a slightly decreasing trend. Asteraceae almost disappear (<2%) with *Bidens*-type showing slightly higher values (2.1-5.8%) but not comparable with those recorded inside the cave. Cyperaceae show lower values (around 4.4%) but constant in all three samples. Poaceae reach their maximum (21.4%). Unidentified grains are higher than inside (up to 12.8%).

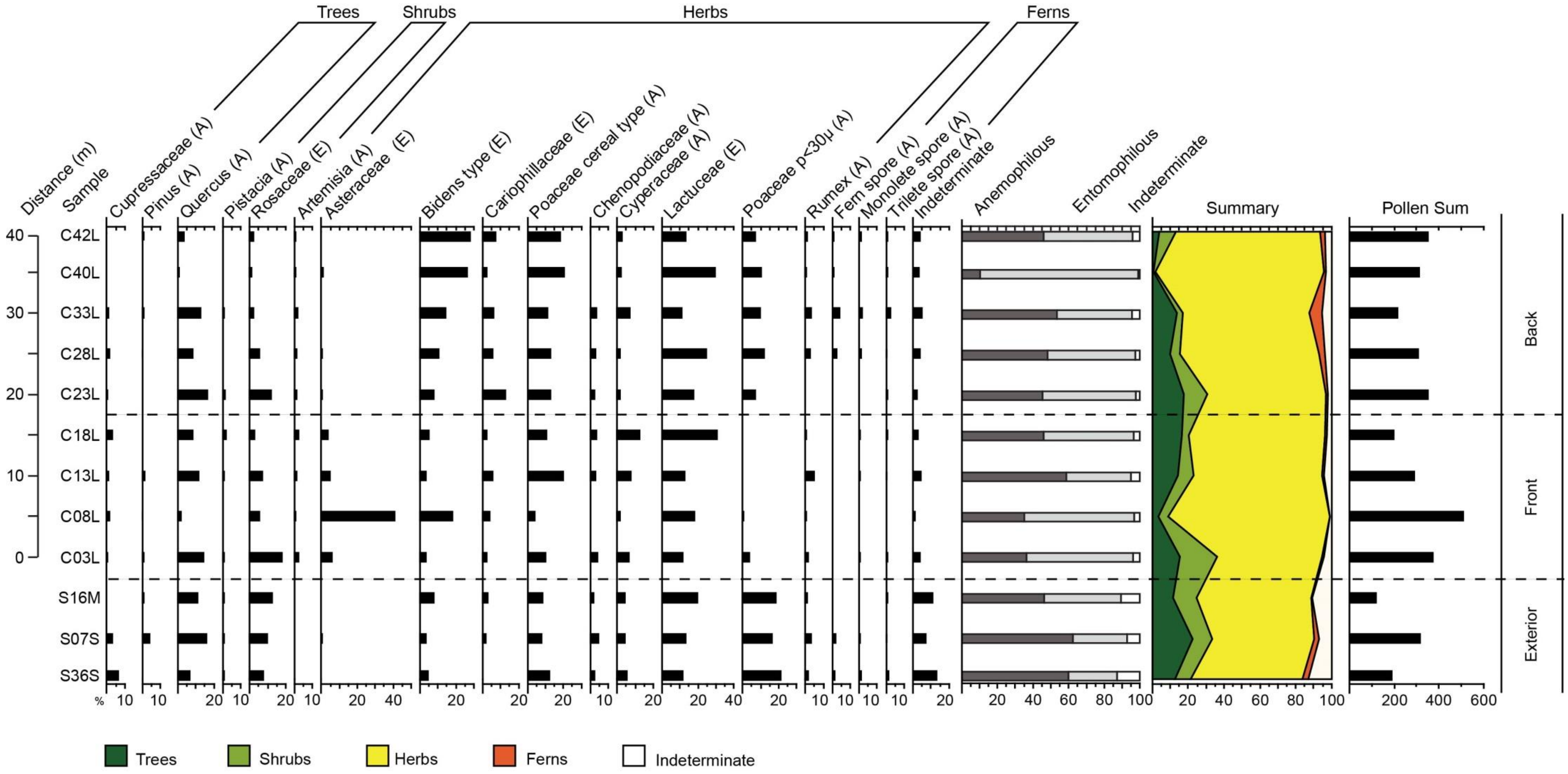


Figure 7.1 Pollen diagram of selected taxa from Shanidar Cave on a transect running from the cave back to outside the cave.

The output of the linear regression between anemophilous taxa and samples distance from the cave mouth is summarised as follows and described by the scatterplot in Figure 7.2.

```
Residuals:
   Min       1Q      Median     3Q       Max
-28.493   -8.134     3.189    6.337    14.359
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	37.3315	9.3452	3.995	0.00523 **
Dist	0.1659	0.3642	0.456	0.66252

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 14.22 on 7 degrees of freedom

Multiple R-squared: 0.02879,   Adjusted R-squared: -0.11

F-statistic: 0.2075 on 1 and 7 DF, p-value: 0.6625

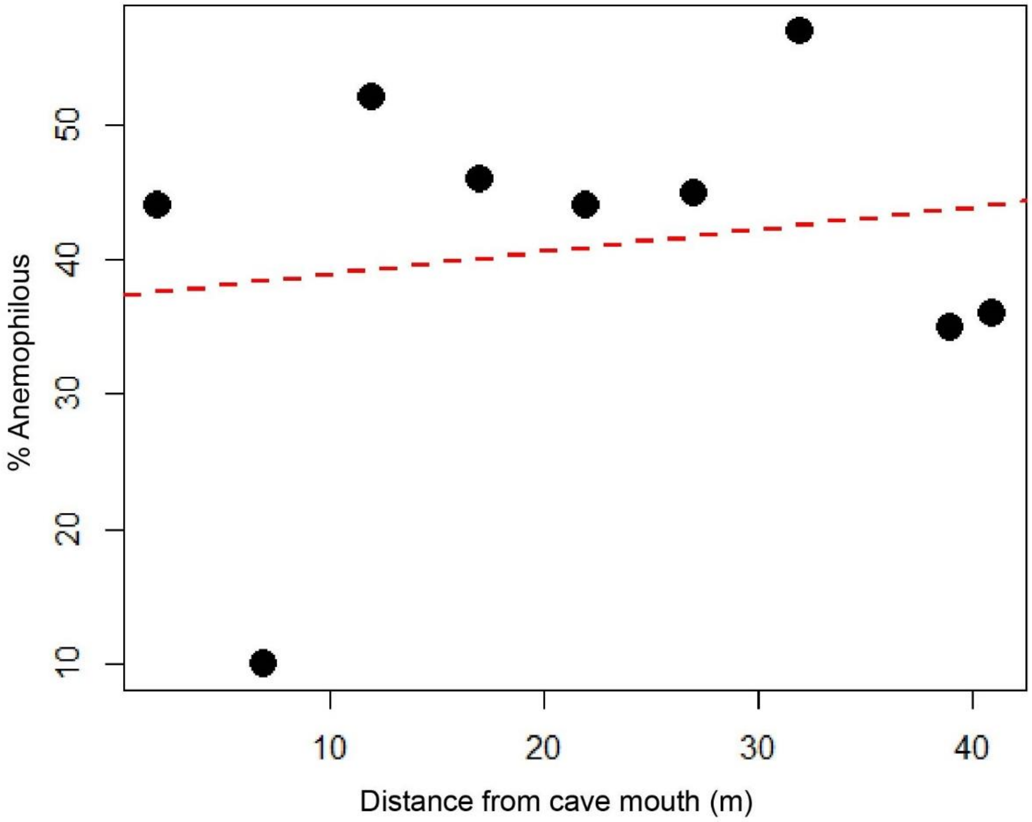


Figure 7.2 Scatterplot showing the relationship between the percentage of anemophilous taxa and the distance of the sample from the cave mouth in Shanidar Cave.

The results show that the two variables are independent as only the 2% of the variance (expressed by the R^2) found in the response variable (% anemophilous) can be explained by the distance from the cave mouth. Therefore at Shanidar other factors must play an important role in determining the distribution of anemophilous and entomophilous pollen in the cave.

Right-left transect

8 samples from the right-left transect (CW series) were analysed with a total of 34 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 269 (sample C02W) and the lowest of 96 (sample C22W). Pollen percentages were used to produce a pollen diagram (Figure 7.3). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards of abundance, are *Quercus,* Lactuceae, Asteraceae, Poaceae, *Pistacia* and Rosaceae. Herbs are the more abundant (50.7-78.4%), followed by trees (9.3-29.3%) and shrubs (5.1-17.1%). *Quercus,* Poaceae p<30µ and Poaceae 40<p<30µ show an increasing trend from right to left then change direction in the last two samples to the left side; other taxa, such as Lactuceae and Asteraceae, decrease going from the right to the left, Chenopodiaceae and Rosaceae show their highest values in the middle area and decrease towards the side of the cave while Cereal-type presents an opposite trend. *Pistacia* and Caryophyllaceae fluctuate around similar values throughout the transect without any clear pattern.

Perimeter transect

7 samples from the perimeter transect (CP series) were analysed with a total of 28 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 244 (sample C04P) and the lowest of 0 (samples C08P, C11P, C15P). Pollen percentages were used to produce a pollen diagram (Figure 7.4). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. Only four samples (C01P, C04P, C22P, C25P), collected on both side near the cave entrance, contained pollen grains while the others are sterile. The main taxa identified, with regards of abundance, are Lactuceae, Poaceae, Asteraceae, Caryophyllaceae, Chenopodiaceae and *Quercus*. Herbs are the more abundant (72.3-93.6%), followed by trees (1.2-14.2%) and shrubs (0.0-3.2%).

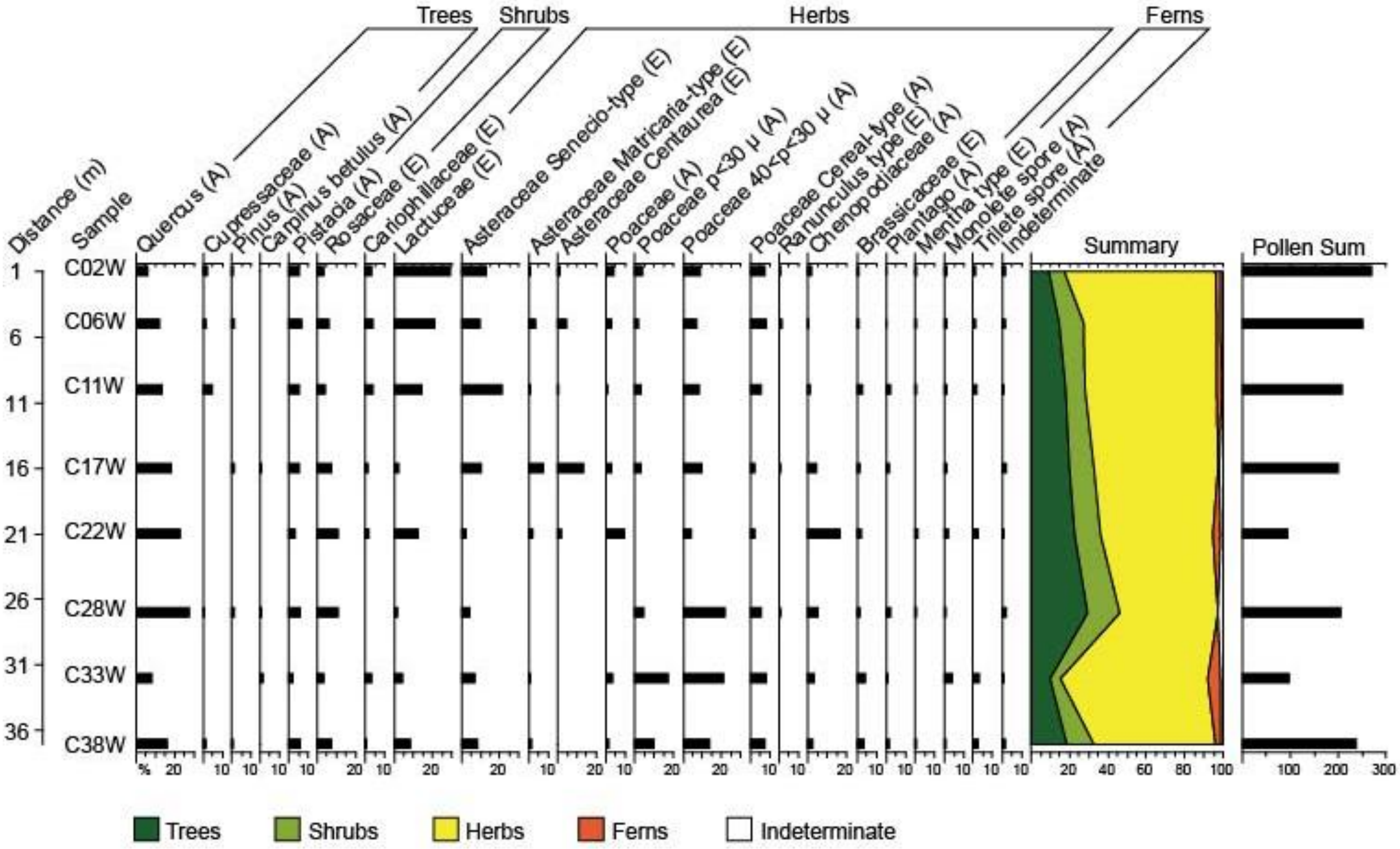


Figure 7.3 Pollen diagram of selected taxa from Shanidar Cave on a transect running from the right to the left of the cave.

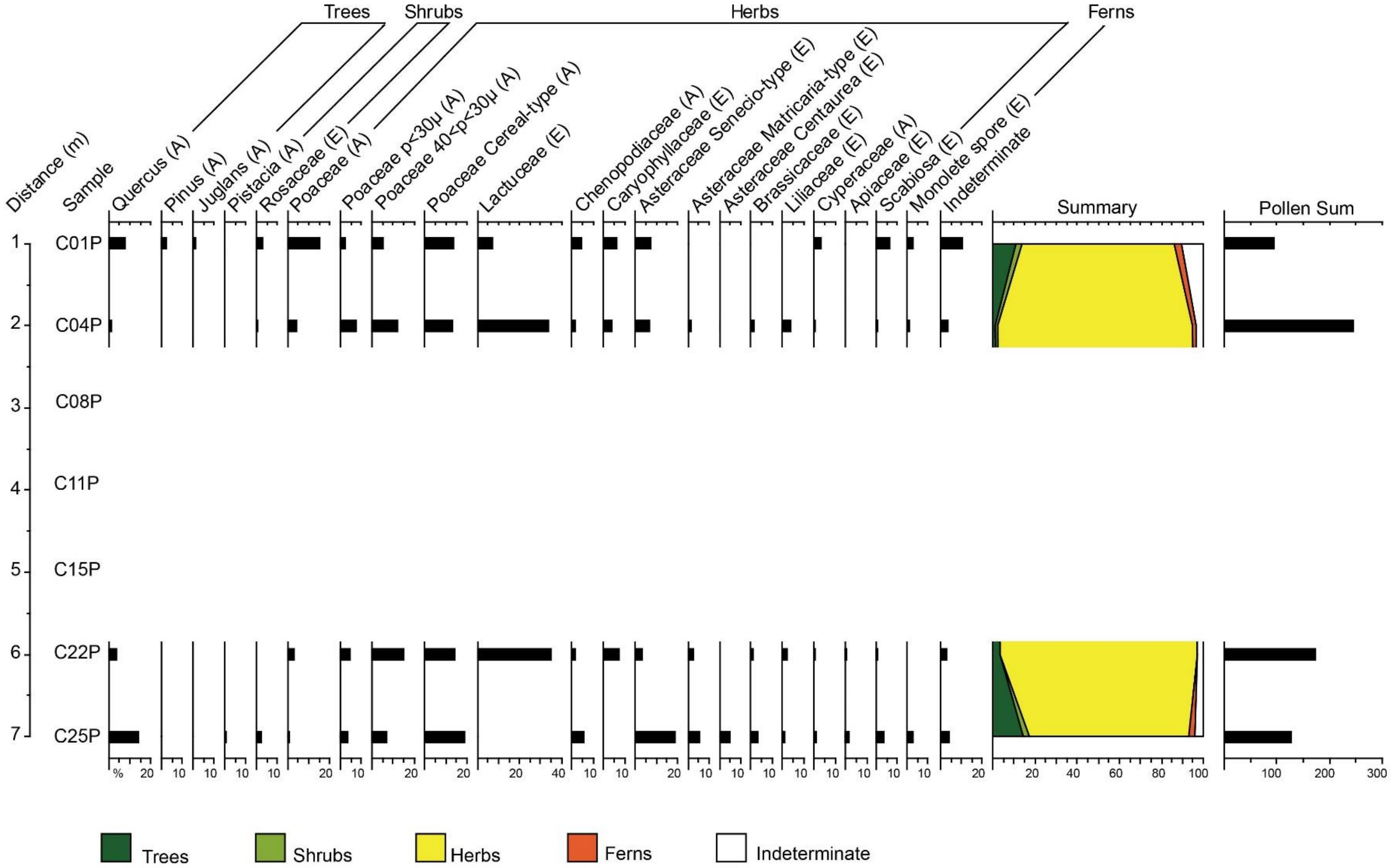


Figure 7.4 Pollen diagram of selected taxa from Shanidar Cave on a transect running along the perimeter of the cave.

The spatial patterns of anemophilous and entomophilous taxa recorded in the front-back, right-left and perimeter transects are represented by iso-line maps shown in Figure 7.5 and 7.6.

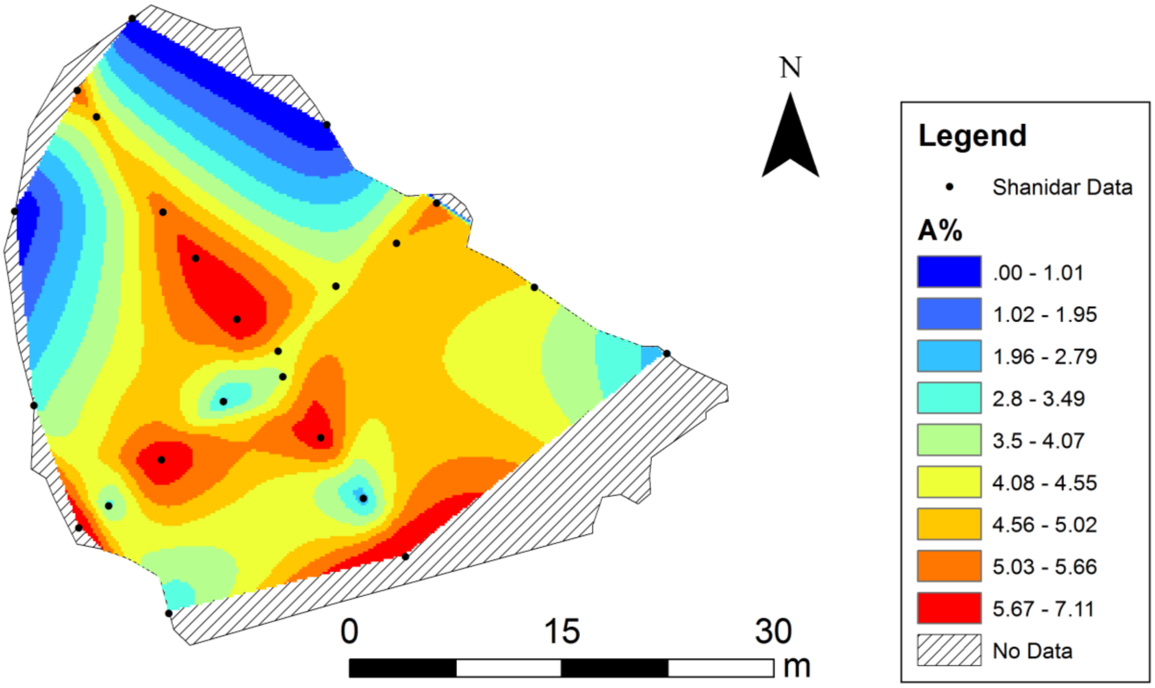


Figure 7.5 Shanidar Cave iso-line map showing the spatial patterns of anemophilous taxa percentages (drawn Tom Vincent).

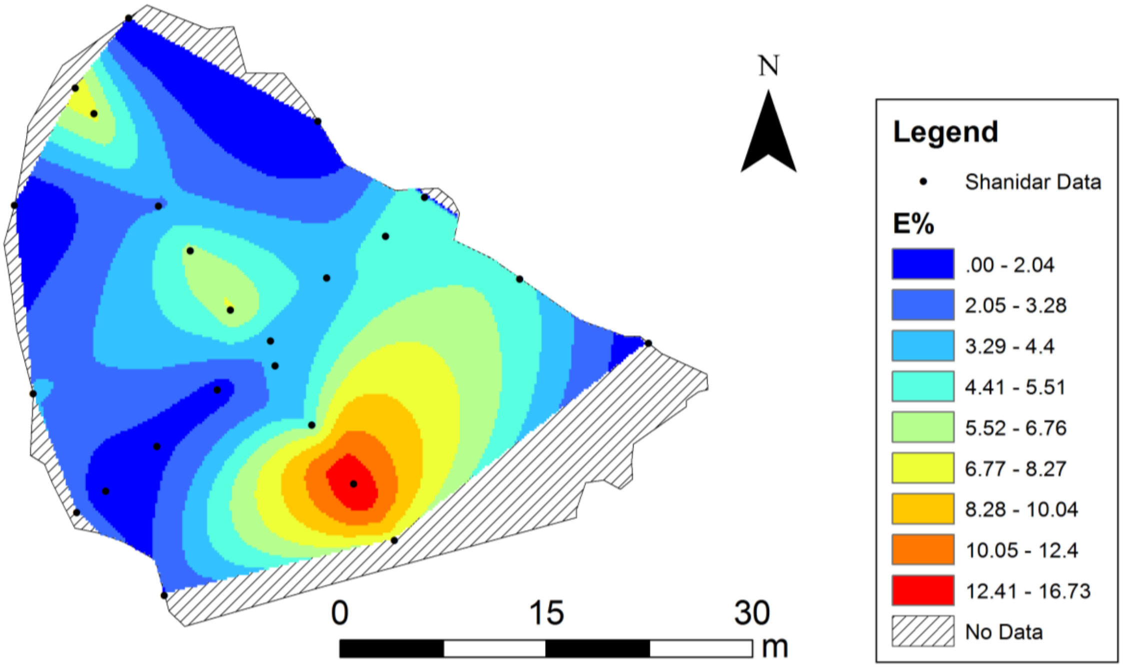
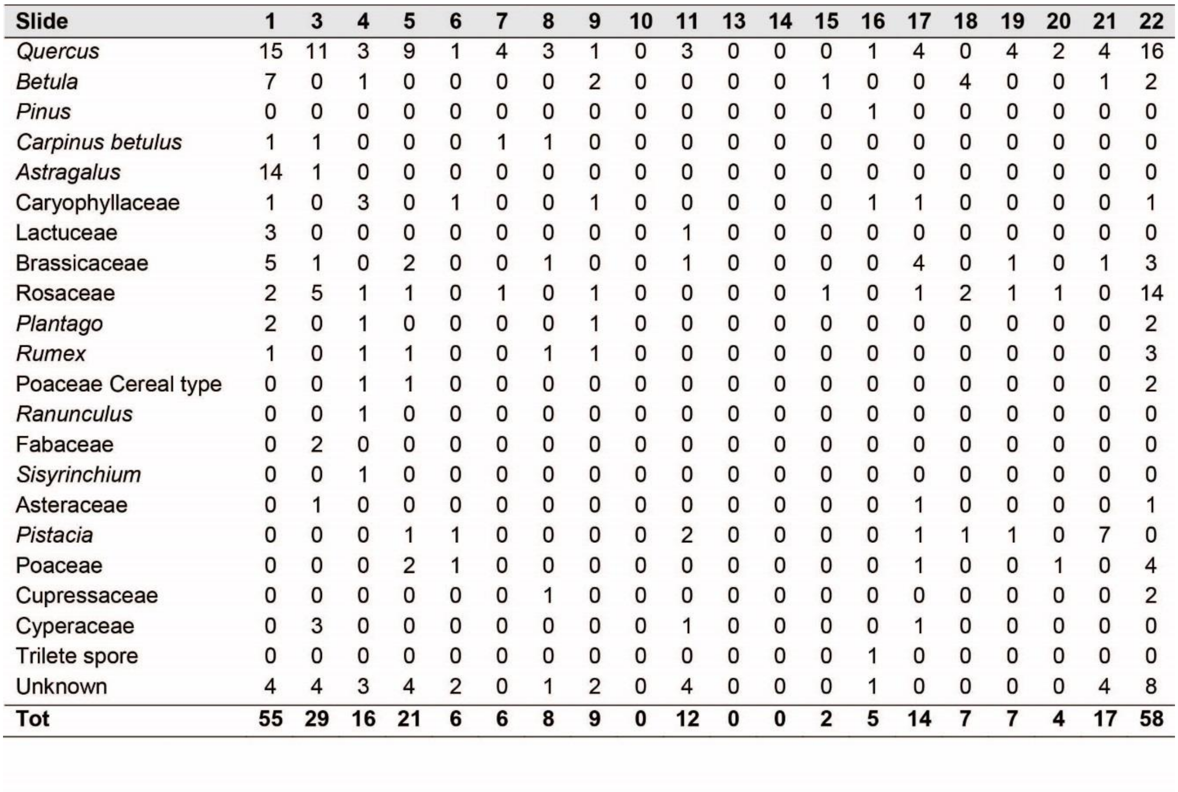


Figure 7.6 Shanidar Cave iso-line map showing the spatial patterns of entomophilous taxa percentages (drawn by Tom Vincent).

Sticky slides

Sixteen samples from the sticky slides (1-20 inside the cave, 21 and 22 outside as comparatives) were analysed with a total of 20 taxa identified (See Table 7.2 for the complete list and Figure 7.7 for sample locations). Two of the slides were too damaged and could not have been counted (Slide 2 and Slide 12). Pollen counts are very low and in the cave fluctuate between the highest value of 55 (Sample 1) and the lowest of 0 (Samples 9, 10 and 13). Generally, pollen influxes are higher along the mouth of the cave and diminish inwards. There are higher values on the eastern side of the cave interior. The main taxa identified, with regards to abundance, are *Quercus*, *Betula*, *Pistacia* and Rosaceae. Several entomophilous pollen, including Rosaceae, are quite well-represented showing that these taxa also disperse by wind. The spatial distribution of anemophilous and entomophilous taxa is shown in Figure 7.7.

Table 7.2 Shanidar Cave sticky slides pollen count



Slide	**1**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Quercus	15	11	3	9	1	4	3	1	0	3	0	0	0	1	4	0	4	2	4	16
Betula	7	0	1	0	0	0	0	2	0	0	0	0	1	0	0	4	0	0	1	2
Pinus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Carpinus betulus	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Astragalus	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Caryophyllaceae	1	0	3	0	1	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1
Lactuceae	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Brassicaceae	5	1	0	2	0	0	1	0	0	1	0	0	0	0	4	0	1	0	1	3
Rosaceae	2	5	1	1	0	1	0	1	0	0	0	0	1	0	1	2	1	1	0	14
Plantago	2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2
Rumex	1	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	3
Poaceae Cereal type	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Ranunculus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fabaceae	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sisyrinchium	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asteraceae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Pistacia	0	0	0	1	1	0	0	0	0	2	0	0	0	0	1	1	1	0	7	0
Poaceae	0	0	0	2	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	4
Cupressaceae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Cyperaceae	0	3	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0
Trilete spore	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Unknown	4	4	3	4	2	0	1	2	0	4	0	0	0	1	0	0	0	0	4	8
Tot	**55**	**29**	**16**	**21**	**6**	**6**	**8**	**9**	**0**	**12**	**0**	**0**	**2**	**5**	**14**	**7**	**7**	**4**	**17**	**58**

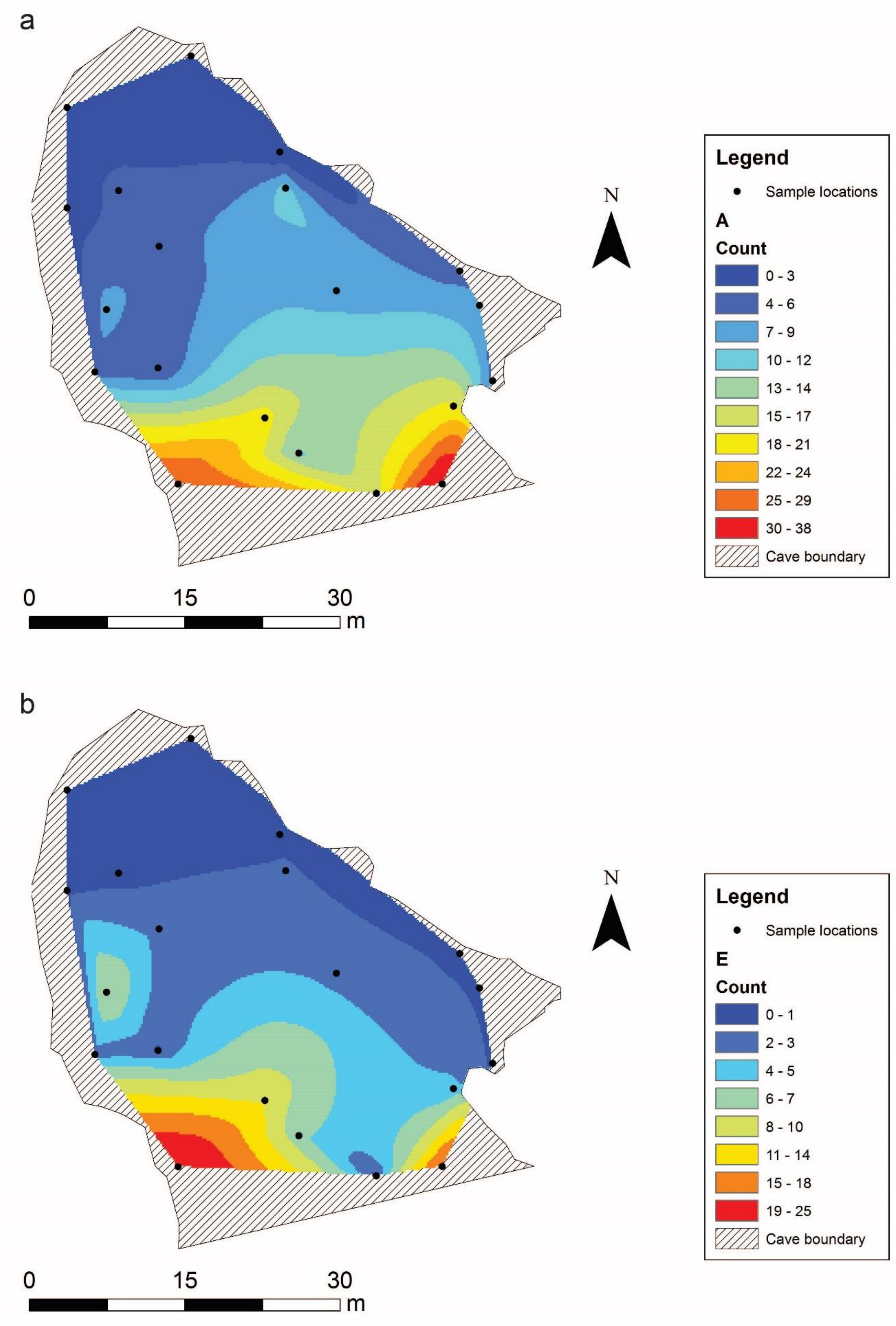


Figure 7.7 Iso-line maps of anemophilous taxa (a) and entomophilous taxa (b) on sticky slides in Shanidar Cave (drawn by Tom Vincent).

Water samples, pollen traps and animal droppings

Eight water samples, 2 pollen trap samples, 2 goat/sheep dung samples and 4 bird dropping samples were analysed. The water samples contained in total 3 pollen grains, the pollen traps 5 grains and the bird dropping 3 grains; only the samples from goat/sheep dung were richer in terms of number of grains (Table 7.3).

Table 7.3 Pollen data (raw counts) from water samples, pollen traps, goat/sheep dung and bird dropping from Shanidar Cave.

	Water samples								**Pollen Traps**		**Goat/sheep Dung**		**Bird Dropping**			
Sample	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**1**	**2**	**1**	**2**	**1**	**2**	**3**	**4**
Poaceae	1	0	0	0	0	0	0	0	1	1	5	3	0	1	0	0
Quercus	0	0	0	0	0	0	0	1	0	1	1	1	0	1	0	0
Brassicaceae	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Fabaceae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Cyperaceae	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Chenopodiaceae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Senecio-type	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Fern spores	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Vam	0	0	0	0	0	0	0	0	0	0	10	2	0	0	0	0
Indeterminate	0	0	0	0	0	0	1	0	1	1	5	2	0	0	0	0

Stratigraphic samples

The stratigraphic samples from column B(1), column C(2), the two samples from around the bones (<2252> and <2282>) and from the animal burrows (<2254> and < 2298>) were sterile. Only few grains in total have been counted (Figure 7.8-7.12).

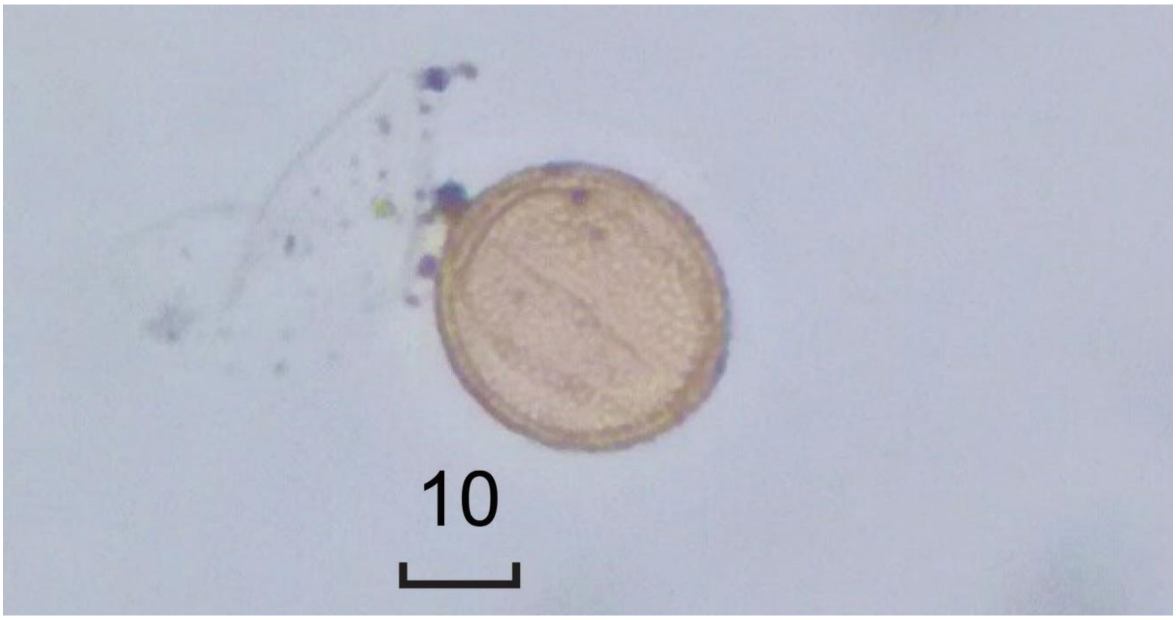


Figure 7.8 Pollen grain of Brassicaceae found in the sample located at 15-20 cm of depth in column C(2).

Figure 7.9 Pollen grain (probably Quercus) found in the sample located at 20-27 cm of depth in column C(2).

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Figure 7.10 Pollen grain (Alnus) found in the sample located at 43-48 cm of depth in column C(2).

Figure 7.11 Pollen grain (Betula) found in the sample located at 70-75 cm of depth in column C(2).

Figure 7.12 Pollen grain (Betula) found in the sample located at 43-48 cm of depth in column C(2).

7.1.2 SLS203

Front-back transect

Nine surface samples from the front-back transect and the areas outside the cave were analysed with a total of 40 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 492 (sample SLS203/S1) and the lowest of 241 (sample SLS203/1); preservation is good (92.5-97.7% identifiable grains) with the exception of the two outside samples where a higher percentage of grains (2.2-7.5%) was poorly preserved. Pollen percentages were used to produce a pollen diagram (Figure 7.13). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards of abundance, are Poaceae, Lactuceae, Cyperaceae, Caryophyllaceae and *Quercus*. Herbs are more abundant (75.2-97.0%), followed by trees (2.7-10.8%) and shrubs (0.3-5.5%). The main characteristics of the pollen zones are described in Table 7.4.

Moss transect

Six moss samples from the front-back transect were analysed with a total of 37 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 413 (sample SLS203/M4) and the lowest of 123 (sample SLS203/M1) and preservation is good (97.8-99.4% identifiable grains). Pollen percentages were used to produce a pollen diagram (Figure 7.14). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards of abundance, are Chenopodiaceae, Lactuceae, *Quercus*, Poaceae, Rosaceae, Asteraceae, monolete and trilete spores. Herbs are the more abundant (57.3-69.6%), followed by trees (1.7-15.3%) and shrubs (0.0-16.1%). Tree pollen is represented mainly by *Quercus* with values that increase from the back to the front (from 2.4% to 8.4%) and by little amount of *Pinus* (less than 5%) present throughout. Other taxa showing an increasing trend are Rosaceae and Chenopodiaceae, the latest with values starting from 5% and reaching almost 50%. Lactuceae start from high values (up to 30%) and decrease significantly after the first two samples; Poaceae also decrease. *Artemisia* and *Centaurea* show percentages lower than 5% throughout the diagram but both record a peak in one of the sample (SLS203/M4) reaching 40% and 50% respectively. Monolete and trilete spores are present especially in the first two samples near the back of the cave and then decrease, maintaining stable values lower than 5%.

Table 7.4 SLS203 front-back transect description according to pollen zones.

Pollen zone	**Description**
Back	Tree pollen is very low (<1%), with the only exception of Q*uercus* that shows constant values around 3% throughout the zone and *Pinus* that is present in the first part of the zone and then disappears. Among the herbs, Poaceae are the more abundant (up to 42.3%) with a decreasing trend from the back of the cave; Lactuceae have almost stable values around 15% while Bidens-type increases markedly reaching the highest value at the end of the zone (32.0%). Caryophyllaceae show low and stable values around 3% while Cyperaceae display higher values near the back of the cave (15.6%) and then decrease (0.7%).
Front	Tree pollen is represented only by *Quercus* that maintain the same values recorded in the previous zone. Lactuceae show a strong increase reaching their highest value (up to 40%). Poaceae, Bidens-type and Caryophyllaceae decrease while Cyperaceae disappear.
Exterior	*Quercus* values remain similar; *Pinus* reappears and reaches its highest values of 7.2%. Lactuceae values are similar to those at the rear and then increase again in the last samples reaching values up to 33%. Poaceae and *Bidens*-type percentages drop significantly (1.4% and 1.3% respectively), Cyperaceae increase again reaching values of 11.6%, Caryophyllaceae disappear, Liliaceae appear with significant values around 20% for the first time as well as monolete spores (up to 40%).

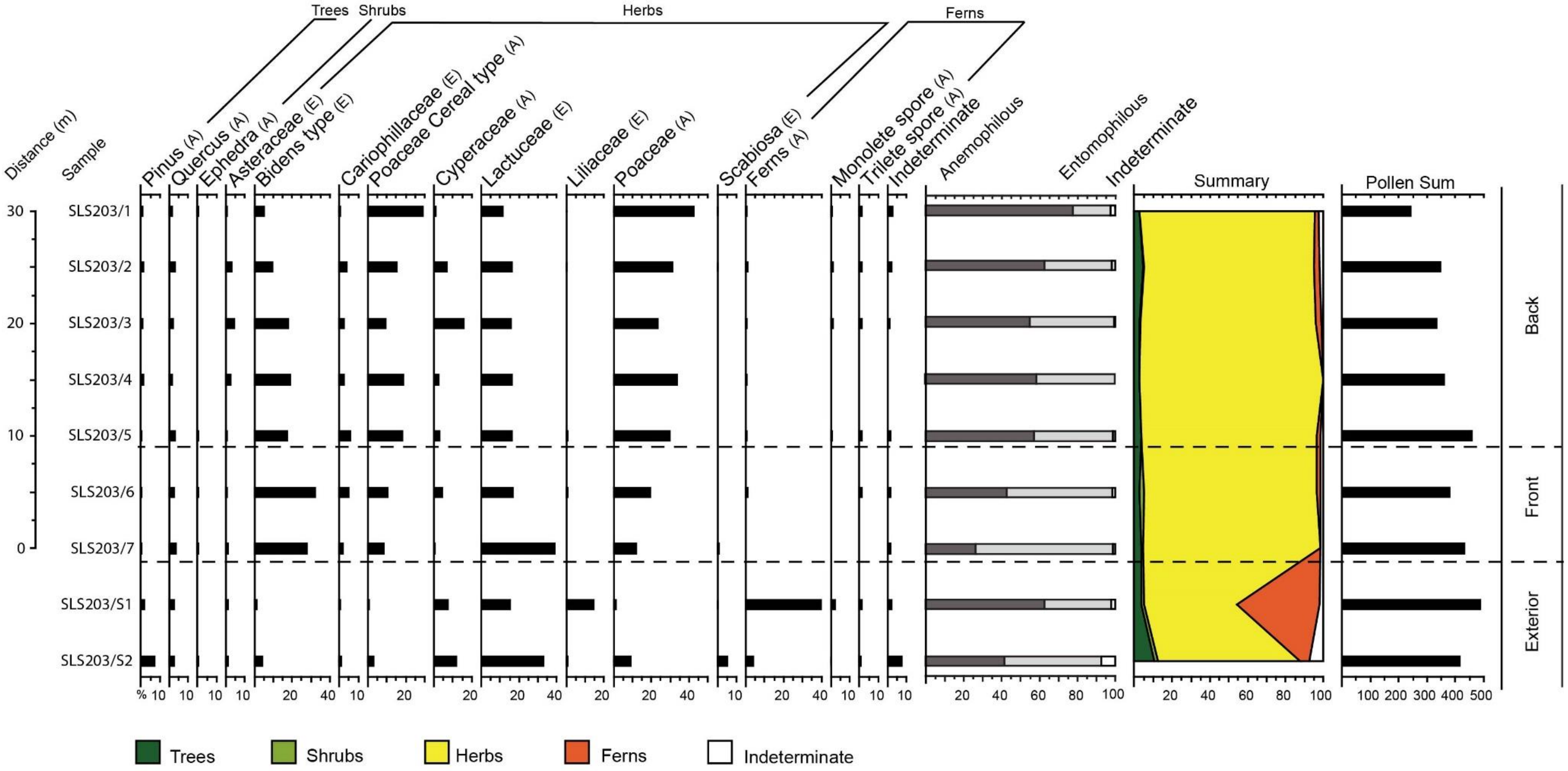

Figure 7.13 Pollen diagram of selected taxa from cave SLS203 on a transect running from the cave rear to beyond its entrance.

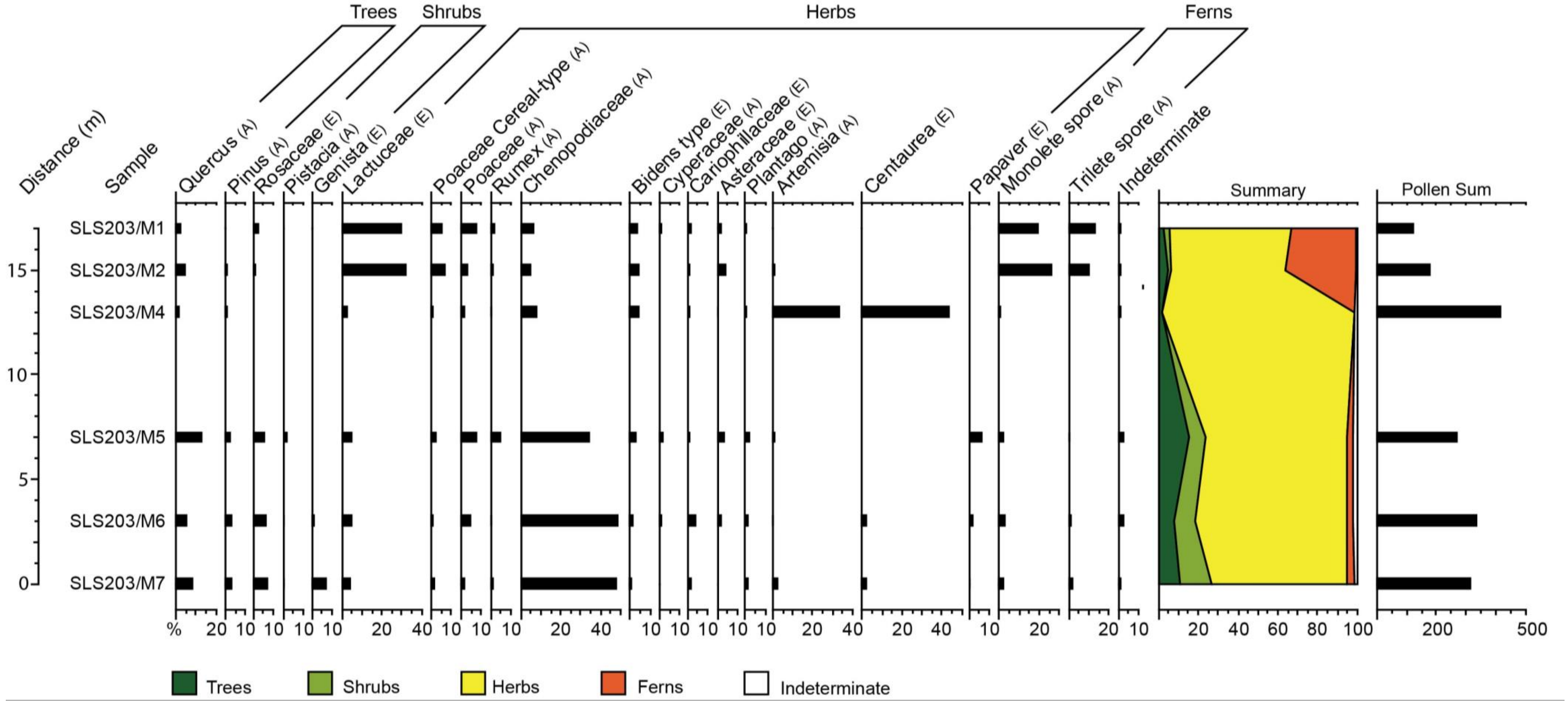

Figure 7.14 Pollen diagram of selected taxa from moss polster samples in cave SLS203.

The output of the linear regression between anemophilous taxa and samples distance from the cave mouth is summarised as follows and described by the scatterplot in Figure 7.15.

```
Residuals:
    1       2     3          4        5         6      7
-7.500  2.571  9.643  3.714 -6.214 -5.143  2.929
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	33.5000	4.7530	7.048	0.000888 ***
Dist	1.3857	0.2636	5.256	0.003310 **

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.975 on 5 degrees of freedom
Multiple R-squared:  0.8467,        Adjusted R-squared:  0.8161
F-statistic: 27.62 on 1 and 5 DF, p-value: 0.00331
```

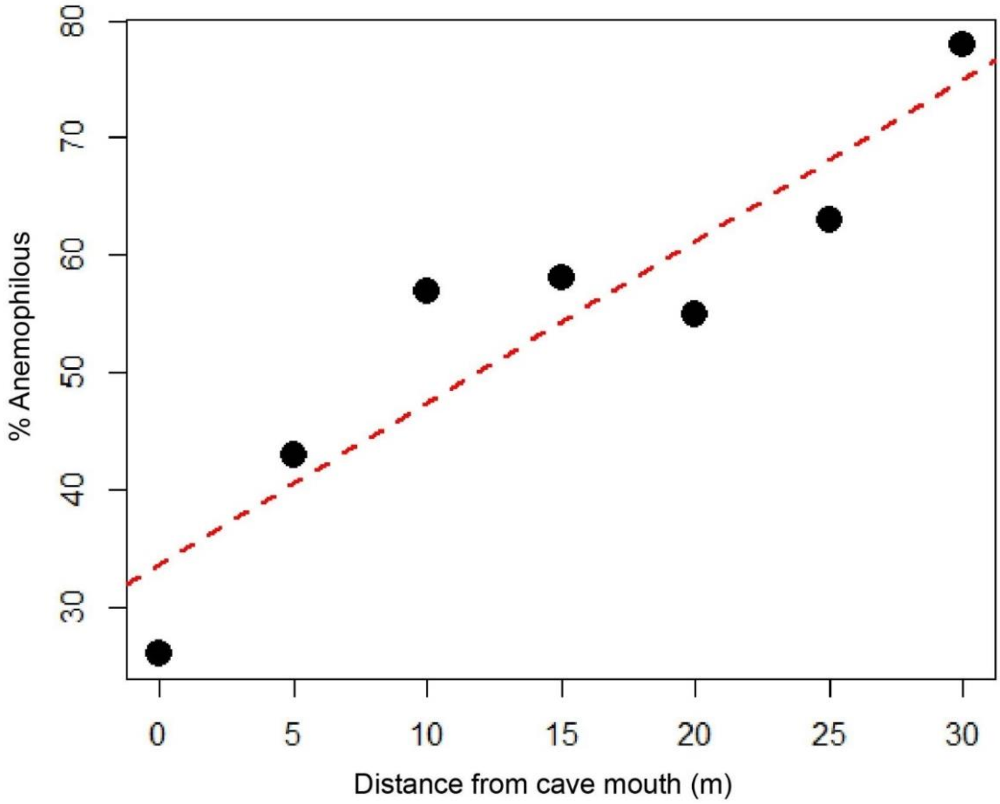

Figure 7.15 *Scatterplot showing the relationship between the percentage of anemophilous taxa and the distance of the sample from the cave mouth in SLS203.*

The results show that there is a strong positive correlation between the percentage of anemophilous taxa and the distance from the cave mouth because 84% of the variance (expressed by the R^2) found in the response variable can be explained by the predictor variable. The values of anemophilous taxa increase with distance from the cave mouth.

7.1.3 SLS207

Seven surface samples from the front-back transect and the areas outside the cave were analysed with a total of 36 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 344 (sample SLS207/2) and the lowest of 70 (sample SLS207/3); grain preservation was good (94.3-100% identifiable grains). Pollen percentages were used to produce a pollen diagram (Figure 7.16). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards of abundance, are Lactuceae, Asteraceae, Poaceae, *Quercus*, *Pistacia* and monolete spores. Herbs are the more abundant (12.9-96.7%), followed by trees (1.2-18.3%) and shrubs (0.0-2.4%). The main characteristics of the pollen zones are described in Table 7.5.

Table 7.5 SLS207 front-back transect description according to pollen zones

Pollen zone	Description
Back	Trees are represented mainly by *Quercus* with low values around 3%, increasing only at the end of the zone (16.1%). Lactuceae are the more abundant (62.5%) and decrease from the back of the cave; Asteraceae show the same trend but with lower values at the very back of the cave. Poaceae show similar values generally lower than 10% throughout the transect.
Front	*Quercus* shows the same values seen before, *Pinus* and *Pistacia* appear even if in very small percentages (<5%). Poaceae maintain similar values (2.5-4.7%). Lactuceae completely disappear in one of the sample and reappear in the next one. Asteraceae keep decreasing, reaching the lowest value of 1.1%. Monolete spores show a peak in this zone reaching values up to 70%.
Exterior	Cupressaceae appear for the first time in this zone with a value of 9.7%. *Quercus* remains stable while *Pistacia* shows a peak with values up to 40%. Lactuceae and Asteraceae almost disappear.

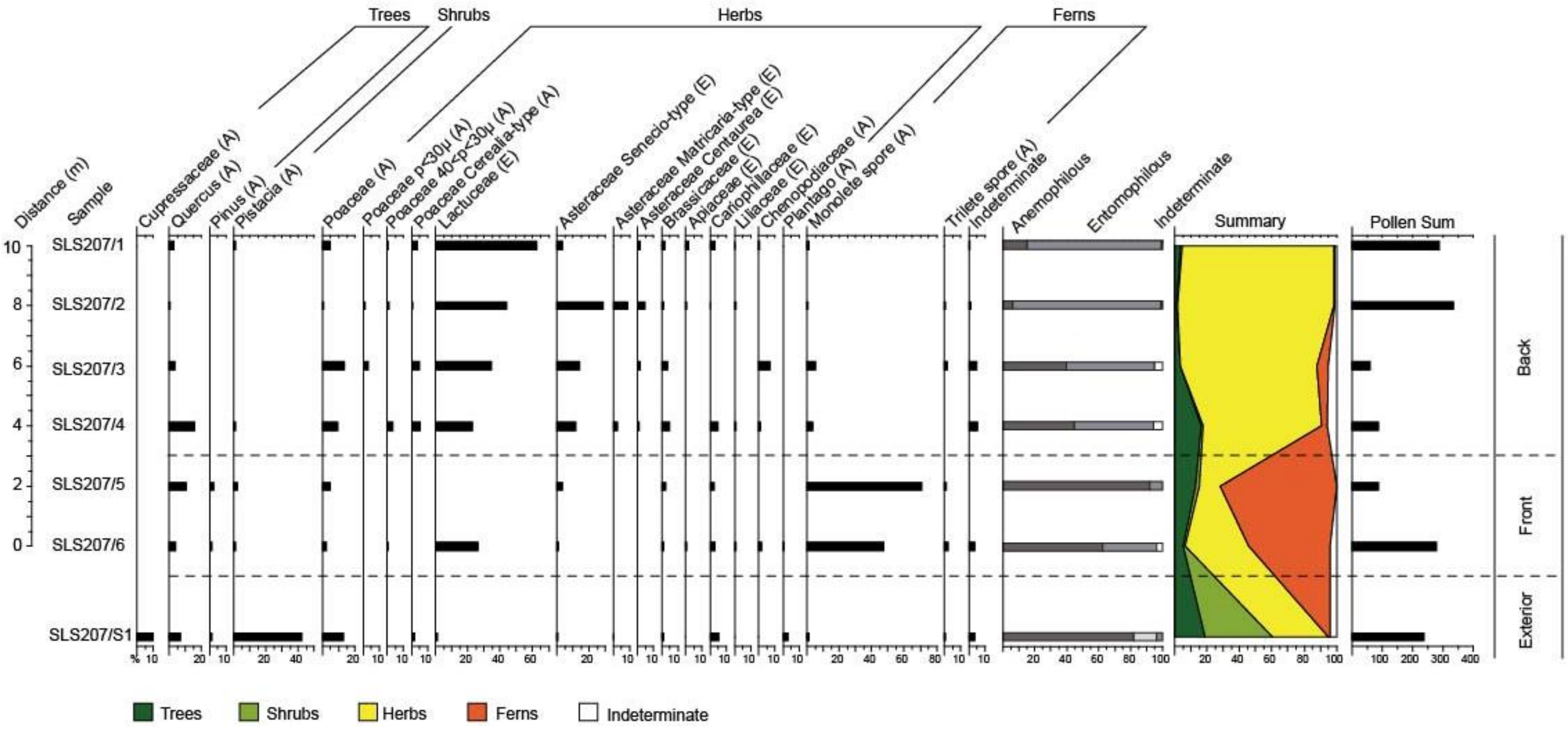

Figure 7.16 Pollen diagram of selected taxa from cave SLS207 on a transect running from the back of the cave to outside the cave.

The output of the linear regression between anemophilous taxa and samples distance from the cave mouth is summarised as follows and described by the scatterplot in Figure 7.17.

```
Residuals:
      1          2          3       4        5          6
-16.905  27.324  -5.448   3.781 -15.990   7.238
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	78.905	13.465	5.860	0.00423 **
Dist	-7.114	2.224	-3.199	0.03292 *

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 18.6 on 4 degrees of freedom

Multiple R-squared: 0.719,   Adjusted R-squared: 0.6488

F-statistic: 10.24 on 1 and 4 DF, p-value: 0.0329

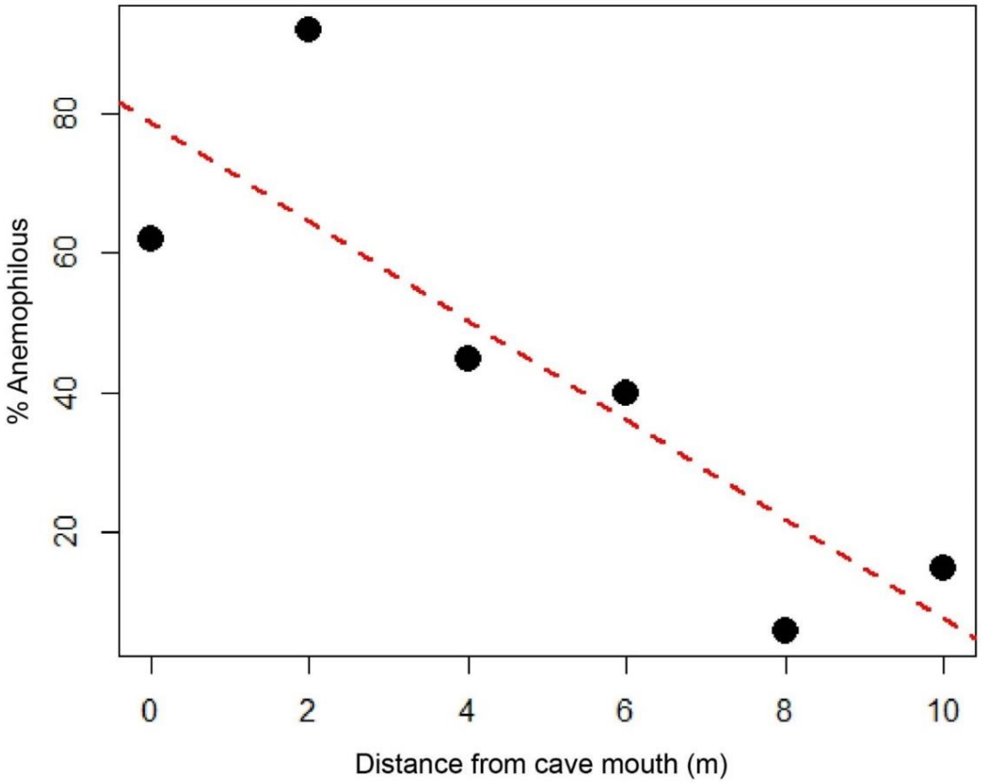

Figure 7.17 Scatterplot showing the relationship between the percentage of anemophilous taxa and the distance of the sample from the cave mouth in SLS207.

The results show that there is a strong negative correlation between the percentage of anemophilous taxa and the distance from the cave mouth because 71% of the variance (expressed by the R^2) found in the response variable can be explained by the predictor variable. The values of anemophilous are therefore indirectly correlated to distance from the cave mouth.

7.1.4 SLS210

Seven surface samples from the front-back transect and the areas outside the cave were analysed with a total of 52 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 674 (sample SLS210/4) and the lowest of 313 (sample SLS210/7) and preservation was good (96.7-99.2 identifiable grains). Pollen percentages were used to produce a pollen diagram (Figure 7.18). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards of abundance, are Lactuceae, *Quercus*, Asteraceae, Poaceae, Brassicaceae and *Pistacia*. Herbs are the more abundant (50.2-84.4%), followed by trees (11.1-33.7%) and shrubs (2.0-10.0%). The main characteristics of the pollen zones are described in Table 7.6.

Table 7.6 SLS210 front-back transect description according to pollen zones

Pollen zone	Description
Back	Tree pollen is represented mainly by *Quercus* with values that fluctuate around 20% and *Pinus* present throughout in very small quantities (<5%). *Pistacia* shows a lightly increasing pattern from the back of the cave to the end of the zone while Poaceae and Asteraceae decrease. Lactuceae are the most abundant with values up to 40% that fluctuate throughout the zone. Brassicaceae show a decreasing trend.
Front	The front zone is represented by a single sample near the cave mouth with *Quercus* values increasing up to 35% as well as *Pistacia* that reaches 10%. Other taxa don't show any particular change with the exception of Lactuceae, dropping to half the values of the previous zone.
Exterior	*Quercus* maintains high values around 30%. *Pinus* and Poaceae remain almost stable while Lactuceae keep decreasing reaching their minimum value around 15%.

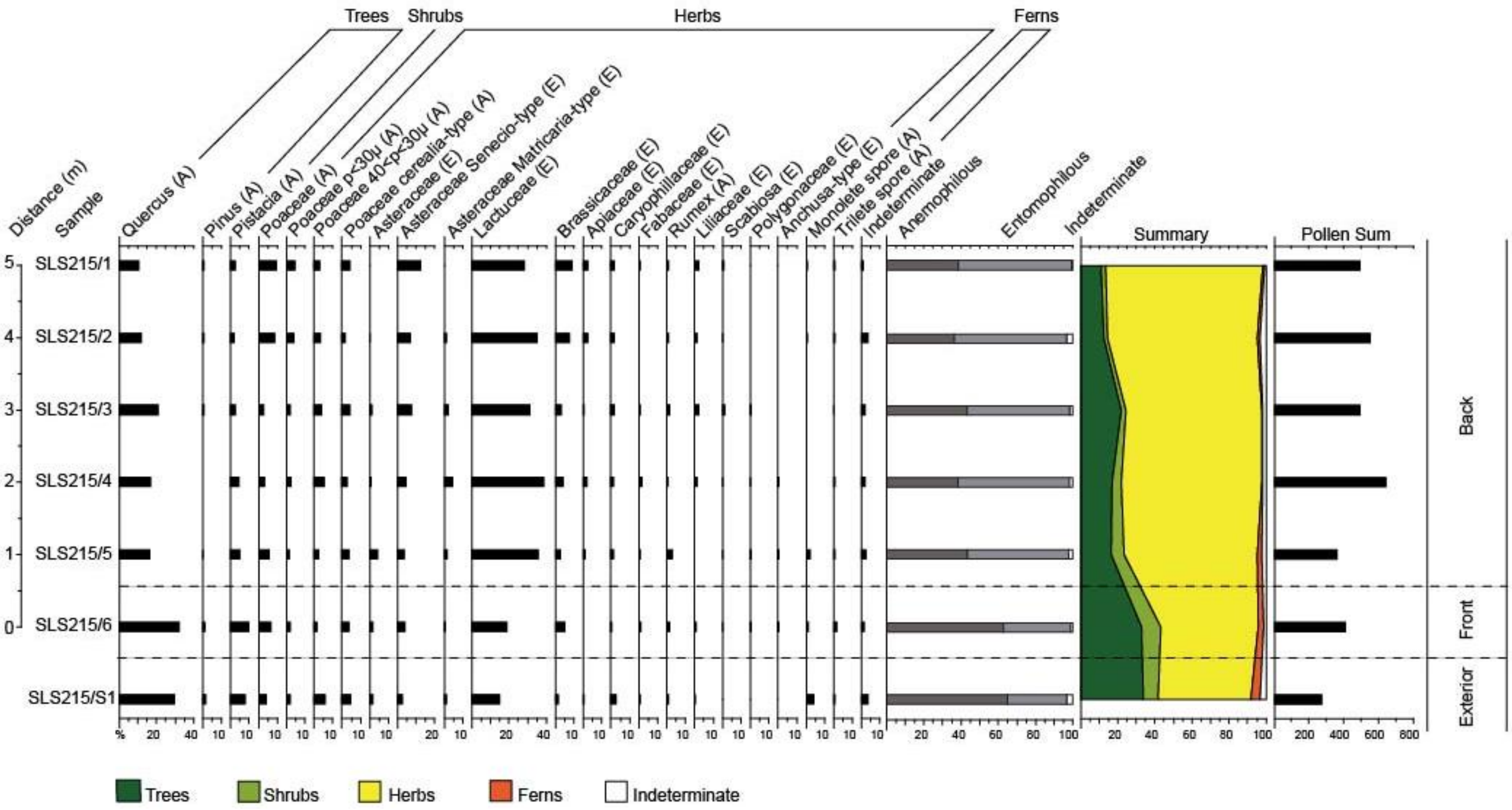

Figure 7.18 Pollen diagram of selected taxa from cave SLS210 on a transect running from the back of the cave to outside the cave.

The output of the linear regression between anemophilous taxa and samples distance from the cave mouth is summarised as follows and described by the scatterplot in Figure 7.19.

Residuals:

1 2 3 4 5 6
9.048 -5.838 -7.724 1.390 -1.495 4.619

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	53.952	5.132	10.513	0.000463 ***
Dist	-4.114	1.695	-2.427	0.072187

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 7.091 on 4 degrees of freedom

Multiple R-squared: 0.5956,   Adjusted R-squared: 0.4945

F-statistic: 5.892 on 1 and 4 DF, p-value: 0.07219

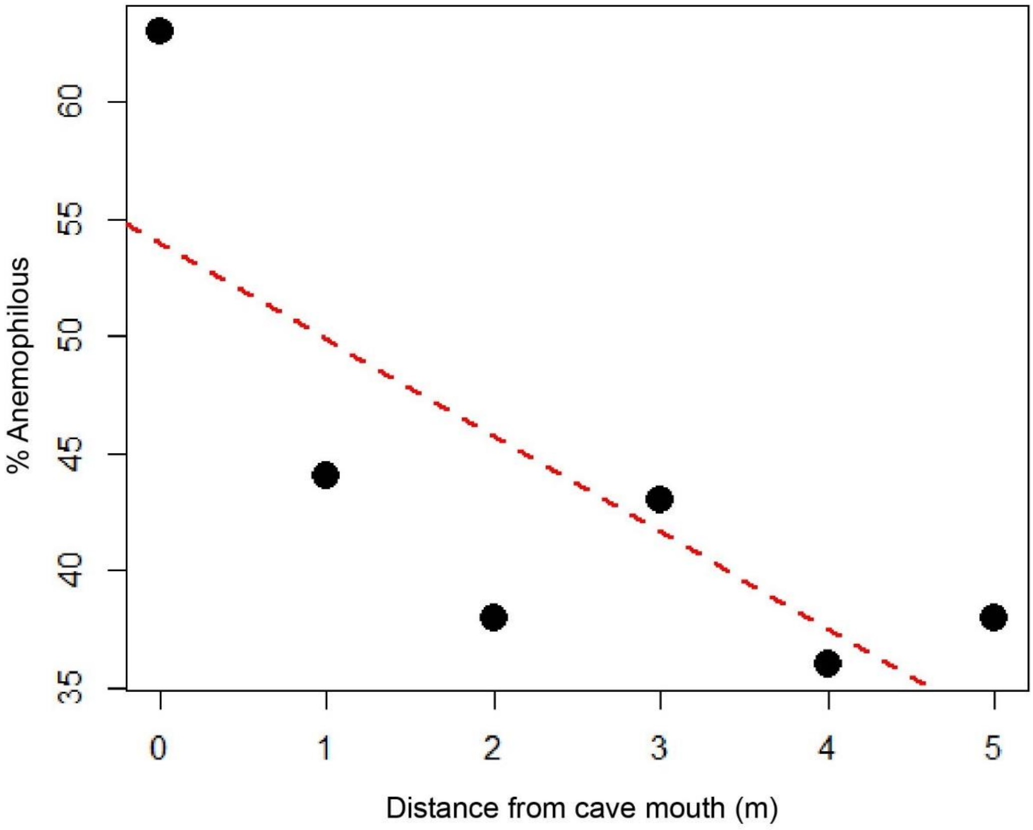

Figure 7.19 Scatterplot showing the relationship between the percentage of anemophilous taxa and the distance of the sample from the cave mouth in SLS210.

The results show that there is a negative correlation between the percentage of anemophilous taxa and the distance from the cave mouth because 59% of the variance (expressed by the R^2) found in the response variable can be explained by the predictor variable. The values of anemophilous taxa decrease with distance from the cave mouth.

7.1.5 SLS215

Six surface samples from the front-back transect and the areas outside the cave were analysed with a total of 37 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 312 (sample SLS215/3) and the lowest of 220 (sample SLS215/S1); pollen preservation was good (96.8-98.9% identifiable grains). Pollen percentages were used to produce a pollen diagram (Figure 7.20). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards to abundance, are Lactuceae, *Quercus*, Poaceae, *Pinus* and fern spores. Herbs are the more abundant (30.0-89.1%), followed by trees (4.2-34.5%) and shrubs (2.0-10.0%). The main characteristics of the pollen zones are described in Table 7.7.

Table 7.7 SLS215 front-back transect description according to pollen zones.

Pollen zone	Description
Back	Tree pollen is represented mainly by *Quercus* with values that increase from 3.2% at the back of the cave to 15.7% at the end of the zone; *Pinus* is also present with a percentage less than 5%. Lactuceae are the most abundant with values reaching the 60% at the back of the cave and decreasing throughout the zone. Asteraceae, Poaceae, Chenopodiaceae and fern spores don't show any particular trend with percentages fluctuating around similar values.
Front	*Quercus* values increase up to 30% with *Pinus* maintaining similar percentages and Cupressaceae appearing in the record. Lactuceae keep decreasing following the trend seen in the previous zone and reaching 23.3% while the other main taxa maintain similar values.
Exterior	*Pinus*, *Quercus*, Caryophyllaceae and Chenopodiaceae show values similar to the previous ones. Most of the other taxa that appear in small quantities (<5%) in the cave disappear from the record while fern spores reach their maximum (around 15%).

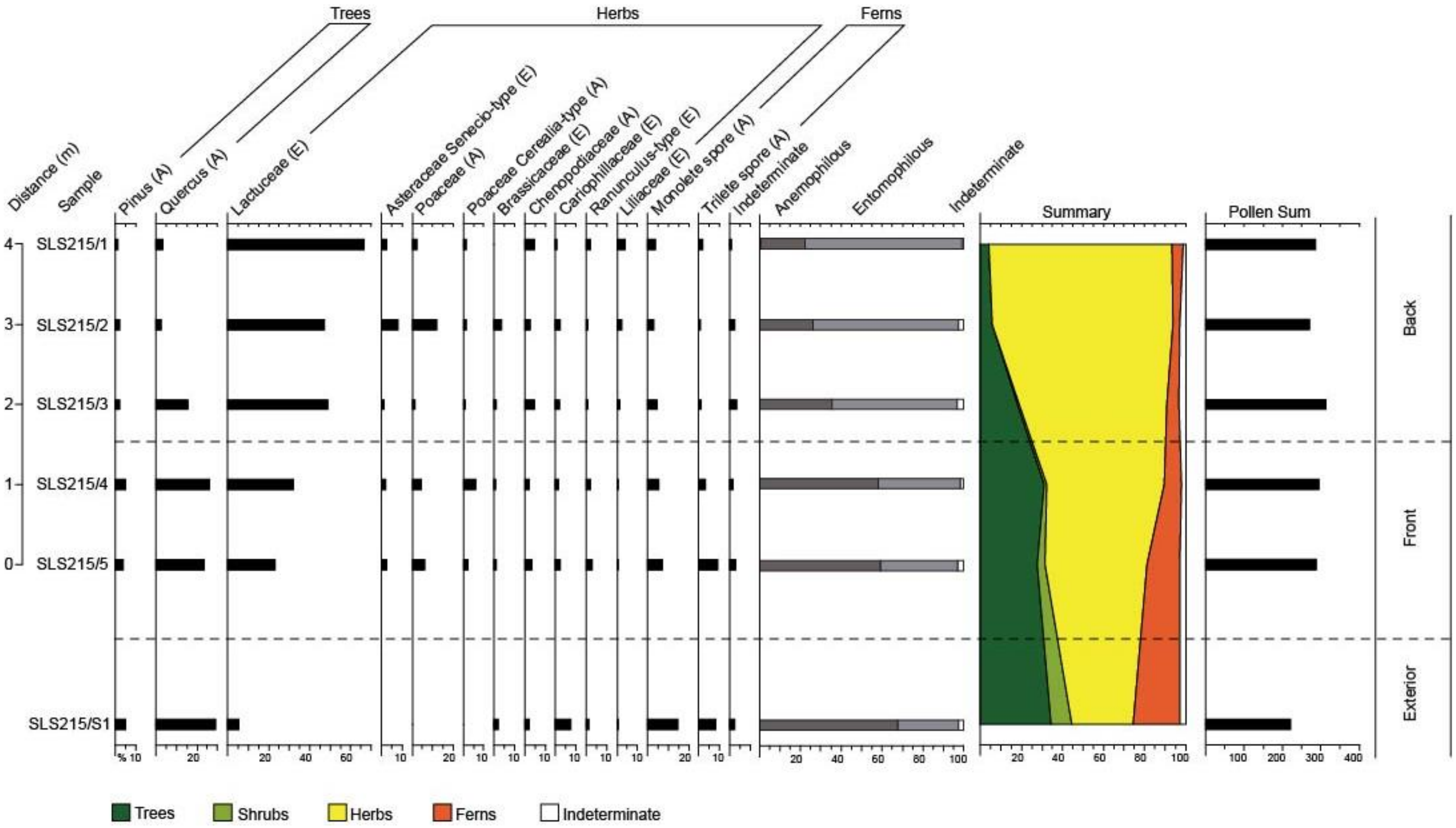

Figure 7.20 Pollen diagram of selected taxa from cave SLS215 on a transect running from the back of the cave to outside the cave.

The output of the linear regression between anemophilous taxa and samples distance from the cave mouth is summarised as follows and described by the scatterplot in Figure 7.21.

```
Residuals:
  1    2   3    4    5
-2.4  7.2 -4.2 -3.6  3.0
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	61.400	4.409	13.926	0.000802 ***
Dist	-10.600	1.800	-5.889	0.009773 **

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.692 on 3 degrees of freedom
Multiple R-squared:  0.9204,        Adjusted R-squared:  0.8938
F-statistic: 34.68 on 1 and 3 DF, p-value: 0.009773
```

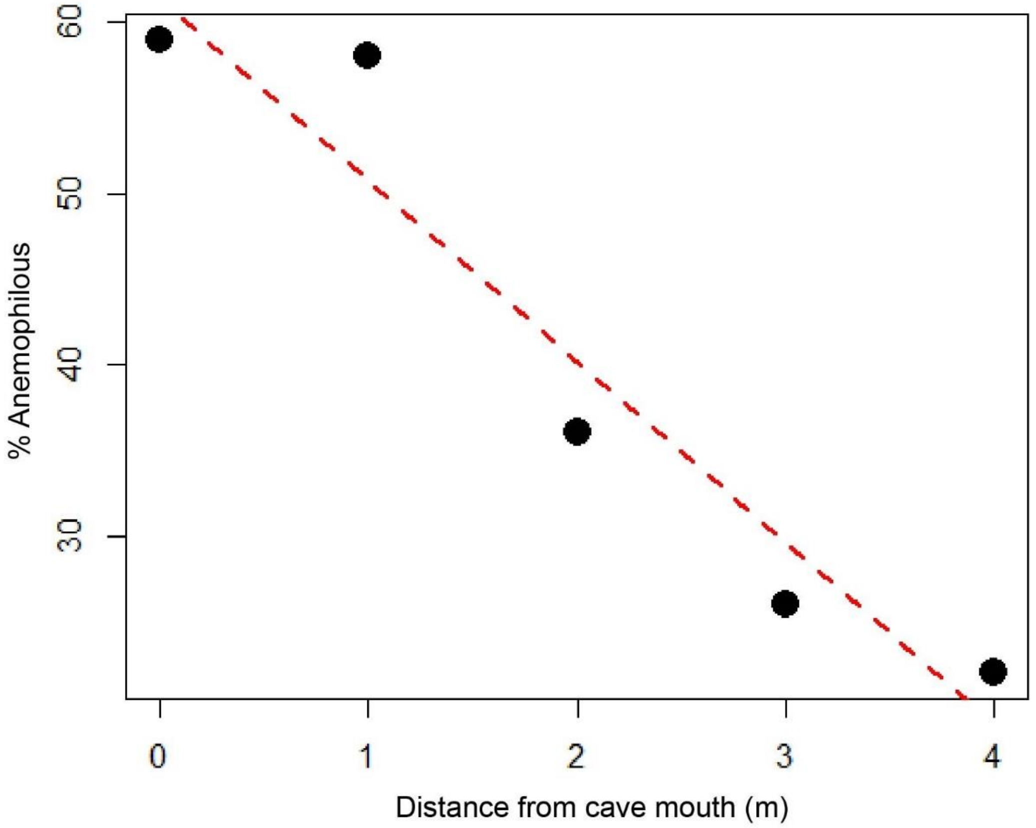

Figure 7.21 Scatterplot showing the relationship between the percentage of anemophilous taxa and the distance of the sample from the cave mouth in SLS215.

The results show that there is a very strong negative correlation between the percentage of anemophilous taxa and the distance from the cave mouth because 92% of the variance (expressed by the R^2) found in the response variable can be explained by the predictor variable. Therefore, the values of anemophilous taxa are indirectly correlated with distance from the cave mouth.

7.1.6 SLS218

Seven surface samples from the front-back transect and the areas outside the cave were analysed with a total of 39 pollen and spore taxa identified (see Appendix 2 for the complete list). Pollen counts fluctuate between the highest value of 300 (sample SLS218/1) and the lowest of 178 (sample SLS218/3); pollen preservation was good (97.9-99.0% identifiable grains). Pollen percentages were used to produce a pollen diagram (Figure 7.22). Relative pollen frequencies have been calculated on the basis of a pollen sum including all terrestrial pollen and spores. The main taxa identified, with regards of abundance, are Lactuceae, *Quercus*, Asteraceae, Poaceae and *Pistacia*. Herbs are the more abundant (41.4-92.6%), followed by trees (3.9-45.9%) and shrubs (0-11.5%). The main characteristics of the pollen zones are described in Table 7.8.

Table 7.8 SLS218 front-back transect description according to pollen zones.

Pollen zone	Description
Back	*Quercus* represents the main tree with values under 10% throughout the zone that increase only at the end reaching the 30%. *Pistacia* is absent at the back of the cave and appears from sample SLS218/3 with values that increase moving away from the back of the cave and reaching the 4.3%. Asteraceae values are variable with *Centaurea*-type being the most abundant and reaching values of 35%; Lactuceae are also abundant with values around 40% while Poaceae show a slight increase with distance from the back of the cave.
Front	*Quercus* increases again reaching the highest values of the diagram (40%) and then decreases; *Pistacia* and Poaceae increase. Lactuceae values continue to fluctuate but are slightly lower than the previous zone (around 25%) and Asteraceae decrease. All the other taxa don't show any particular trend with values low and almost stable throughout the diagram.
Exterior	*Quercus* values decrease again dropping to 10%. *Pistacia* remains stable with vales around 5%, Poaceae increase slightly and Asteraceae decrease.

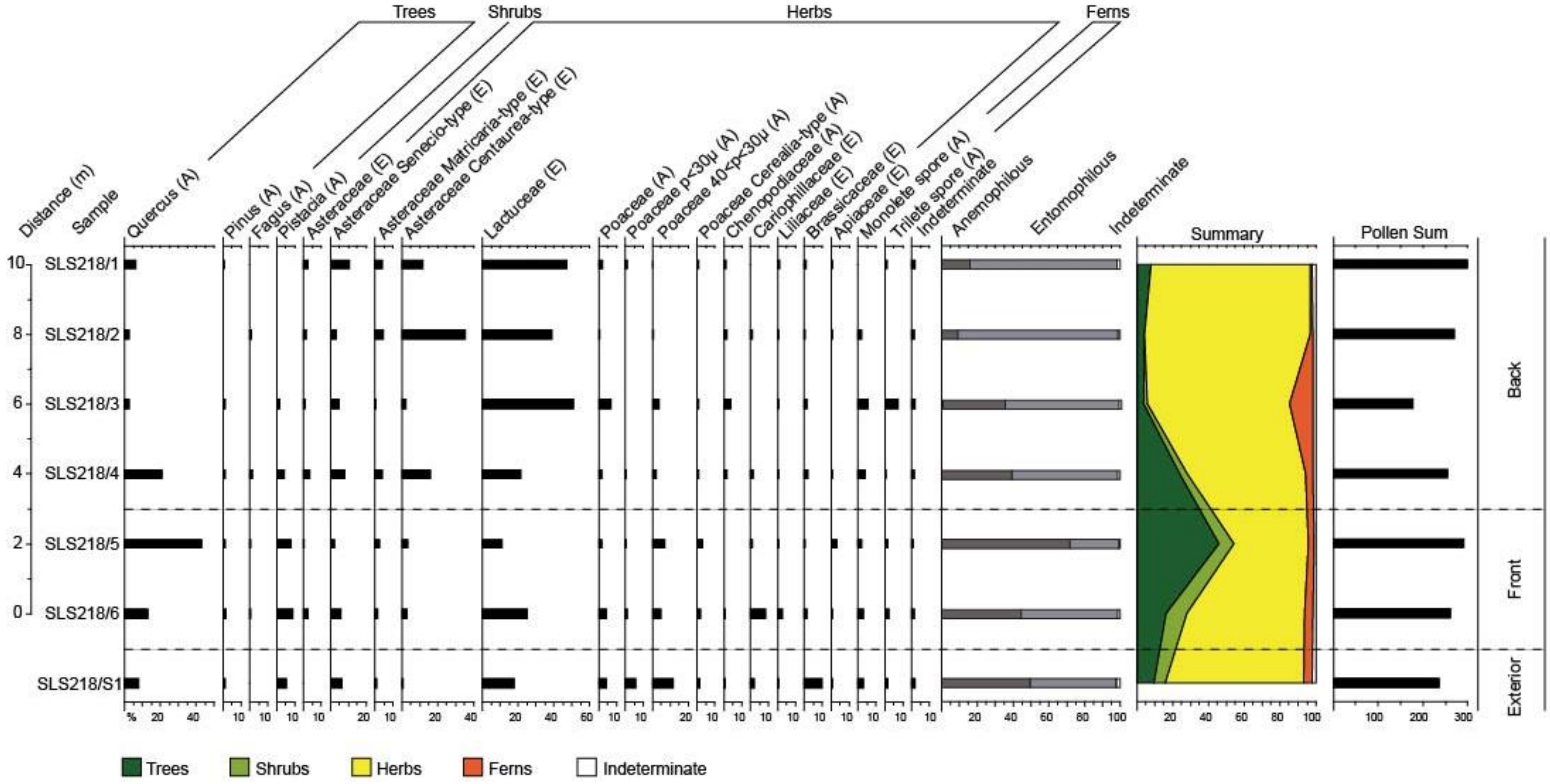

Figure 7.22 Pollen diagram of selected taxa from cave SLS218 on a transect running from the back of the cave to outside the cave.

The output of the linear regression between anemophilous taxa and samples distance from the cave mouth is summarised as follows and described by the scatterplot in Figure 7.23.

```
Residuals:
     1        2        3       4         5        6
-15.238  21.190  -1.381   4.048 -12.524   3.905
```

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	59.238	10.684	5.545	0.00517 **
Dist	-4.714	1.764	-2.672	0.05569

```
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 14.76 on 4 degrees of freedom
Multiple R-squared:  0.6409,        Adjusted R-squared:  0.5511
F-statistic: 7.139 on 1 and 4 DF, p-value: 0.05569
```

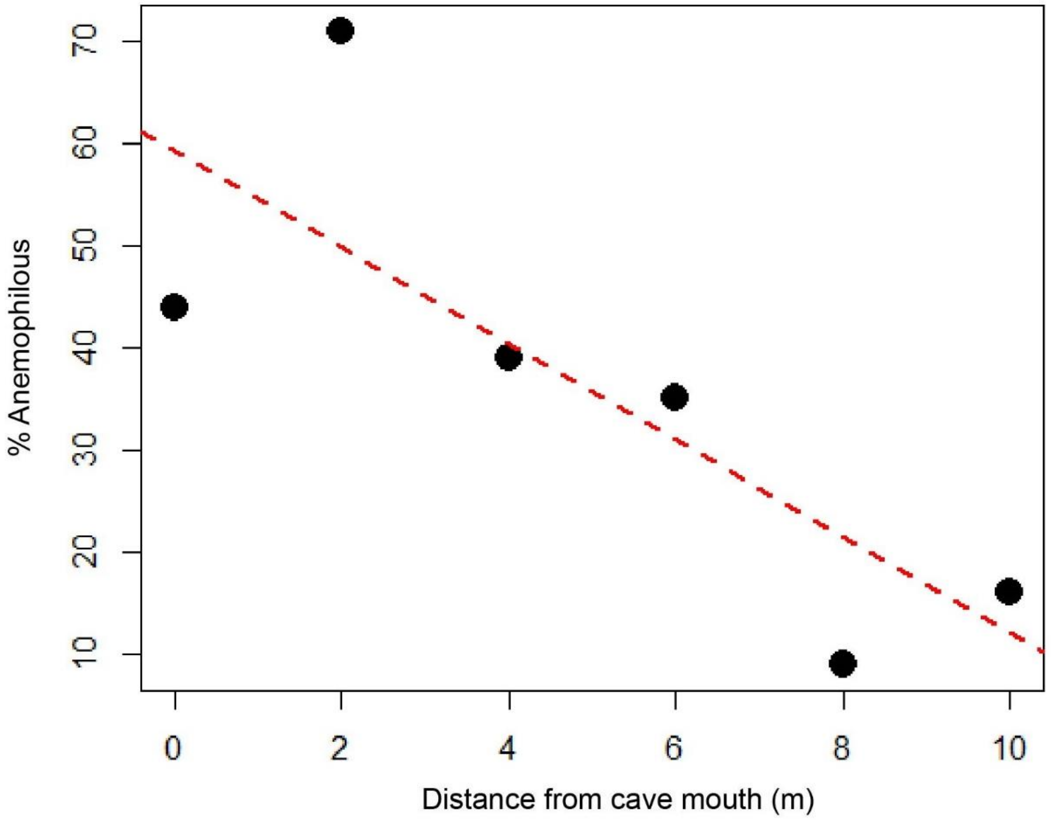

Figure 7.23 Scatterplot showing the relationship between the percentage of anemophilous taxa and the distance of the sample from the cave mouth in SLS215.

The results show that there is a strong negative correlation between the percentage of anemophilous taxa and the distance from the cave mouth because 64% of the variance (expressed by the R^2) found in the response variable can be explained by the predictor variable. The values of anemophilous taxa are indirectly correlated with distance from the cave mouth.

7.2 Particle size analysis

Laser diffraction particle size analysis has been undertaken on sediments from Shanidar Column C(2). A total of 14 samples was analysed with the sediment coming from layers 1 to 10 cm thick. Clay, silt and sand percentages obtained using the software Gradistat are summarized in Figure 7.24 and 7.25. The lower section of the column is dominated by sand. Moving towards the upper part of the section, the clay fraction remains almost constant throughout the column with values under 20% while silt increases and the sand fraction increases. The clay-silt-sand diagram shows three distinct clusters: the first one includes samples 1, 2, 3 and 4 (corresponding to the upper section of the column) and corresponds to the silt area of the diagram; the second one includes samples 5 to 13 (corresponding to the middle and lower section of the column) and is included in the sandy silt area; the third one includes sample 14 (the lowest of the column) and lies on the boundary between the sandy silt and the silty sand area.

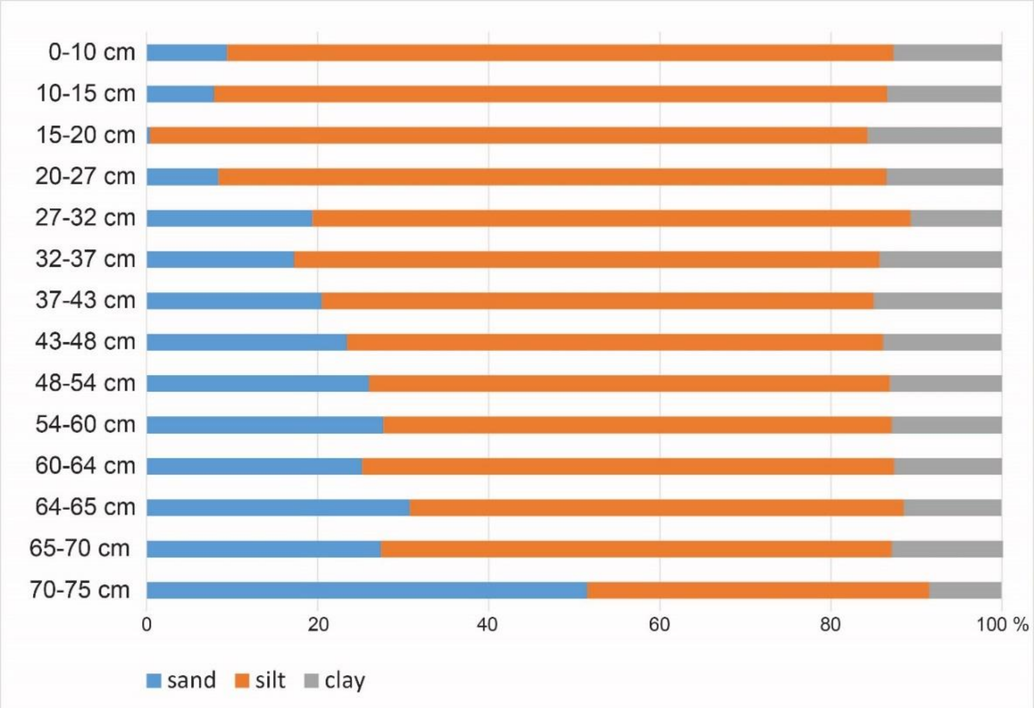

Figure 7.24 Particle size results from Shanidar column C(2) samples. Clay, silt and sand fractions are defined after a modified Udden-Wentworth grade scale (Blott & Pye, 2001).

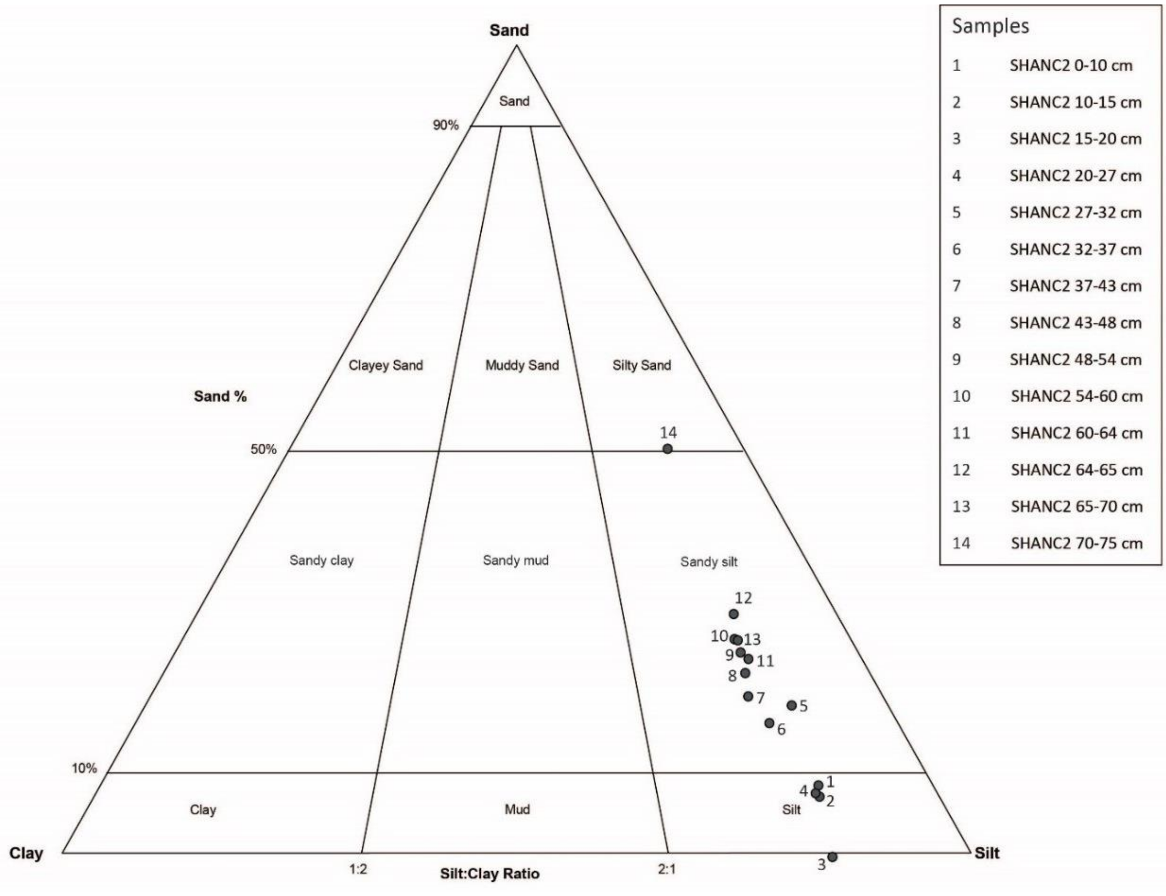

Figure 7.25 Clay-silt-sand diagram for the Column C (2) samples.

7.3 Conclusions

This chapter presented the results obtained from the pollen and particle size analysis undertaken on the surface and stratigraphic samples collected from Shanidar Cave, Cave SLS203, Cave SLS207, Cave SLS210, Cave SLS215 and Cave SLS218. The next chapter assesses the relevance of the results and discusses their implications in relation to sample location, cave morphology and pollen transport mechanisms. In addition, it deals with the significance of the data concerning Shanidar Cave stratigraphic samples and compares them to those published by Leroi-Gourhan.

8. Discussion

This chapter evaluates and discusses the implications of the results presented in the previous chapter. In particular, the influence of air, water and biotic transport and then the interaction of those factors on cave pollen assemblages is assessed. The possible causes of the pollen patterns in Shanidar are discussed on the basis of the data available from the combined transects. The results of the stratigraphic samples are analysed, a discussion on the possible cause of their sterility is provided and a comparison with previous palynological work is presented. Finally, limitations of the research and conclusions are given.

8.1 Airborne, water-borne and animal/human-borne pollen in caves

Airborne pollen

Sticky slides and pollen traps were placed in different locations in Shanidar Cave in order to record the airborne pollen over a period of 1 day and 6 months respectively. The counts for both types of traps are low, even if the sticky slides record shows a higher number of grains (up to 58, equivalent to 11.9 grains cm^2 per day in Sample 22) compared to the pollen traps that only contained respectively 2 and 3 pollen grains each (equivalent to 4 and 6 grains cm^2a^{-1}). To explain the results, one of the first elements to consider is the relative exposure of the two different types of traps: while the sticky slides were on the sediment surface, the pollen traps were located on shoring within the new excavation of the Barker team, where they might have been partially sheltered. Considering the relative low concentration of pollen in Shanidar Cave, as suggested by the necessity of a heavy liquid step during the pollen preparation in order to obtain enough pollen for a statistically significant count, the surface of the pollen traps was probably too small to capture significant pollen.

However, there are still some considerations that can be drawn from the sticky slides results. The samples that show the highest number of grains are Sample 1, 4, 5 and 22 (see Table 7.2), the first three being placed at the front of the cave and the last being a control sample collected outside the cave. The iso-line maps also show this trend with higher values on both sides of the cave entrance (Figure 7.7). The pattern is similar for both anemophilous and entomophilous taxa, suggesting that some of the entomophilous pollen is also transported by the wind. This finding is in accordance with previous studies in sac-like caves where the air flow has been calculated to reach 10 m inside the cave (Van Campo & Leroi-Gourhan, 1956). This explains the higher values of samples near the entrance compared with the ones further back into the cave. Considering the very low influx of anemophilous pollen of 4-6 grains per cm^2 per year, the pollen in the surface sediments of the cave must have been accumulated over a considerable number of years. Considerations about the representativeness of the taxa recorded in the sticky slides are more difficult considering the low number of grains that prevent any statistics. However, when comparing the taxa with the ones recorded in the surface transects (see Figure 7.1, 7.3 and 7.4), there is a general correspondence with *Quercus*, Rosaceae and Brassicaceae showing the highest percentages. These plants also correspond to our observations of the vegetation growing in the area around the cave, confirming the finding by Coles (1988) that up to 40% of the airborne pollen recorded appears to be representative of the vegetation growing within 100 m from the site.

Waterborne pollen

None of the caves studied have active streams entering the cave system so the only water source that can contain pollen is the drip water. The 8 water samples studied, collected in different years (2014, 2015 and 2016), contain almost no pollen with only 3 grains in total. This result is not surprising as similar studies undertaken in caves elsewhere show that the content of drip water can be very variable: Burney and Burney (1993) and Coles et al. (1989) reported no pollen in their samples from caves in New York and England respectively, while in Libya Simpson (2016) found a pollen composition of the drip-water samples similar to the local airfall pollen assemblage.

Animal-borne pollen

The input of pollen from animals can have a strong influence on cave pollen assemblages. However, here in Iraq the results from the animal dung samples show two different situations. The four samples of bird dropping contained only three pollen grains, suggesting that their influence in the pollen assemblage is not strong. This is in contrast with results from other caves in tropical environments, such as the Great Cave of Niah in Borneo, where the samples under the bird and bat roosting areas show enormous influx figures and different taxa than those recovered from the airfall area (Hunt & Rushworth, 2005). The samples from the goat/sheep dung, however, show higher values of pollen suggesting a possible input via this route. Obviously, their importance in the pollen assemblage is strictly related to the number of animals frequenting the cave and, therefore, the amount of dung accumulated on the soil. In Shanidar Cave, only sporadic dung samples were found at the time of the new excavations but, considering that the cave has been used until 50 years ago by local shepherds to keep their animals, it can be hypothesised that the amount of pollen brought by them was higher in the past. Hunt (unpublished) reported fumier deposits in Libya dominated by pollen taxa reflecting sheep, goats and cattle grazing several kilometres from the cave. Similarly, a recent study from El Mirador Cave in Spain reported how the fumier deposit of the cave produced an exceptional accumulation of pollen and other archaeobotanical remains (Verges et al., 2016). Moreover, the sticky slides results demonstrate how not all entomophilous pollen disperse by insects, complicating the situation, as reported by other authors (e.g. Martin et al., 2009).

8.2 Pollen transport patterns in cave transects

The pollen found in the cave surface transects represent the pollen coming from all the different sources analysed above with the addition of other possible sources such as humans or the cave entrance flora. Four of the caves (SLS207, SLS210, SLS215 and SLS218), all characterised by a single entrance and a sack-like shape, have a clear and consistent pattern in pollen distribution with anemophilous taxa more abundant near the entrance and entomophilous taxa more abundant at the back of the caves (Figure 8.2). It has been recorded by several authors in caves in different geographic areas and can be considered a general pattern in cases where other factors are not affecting the pollen influx: Van Campo and Leroi-Gourhan (1956), in their analysis of the three caves of Arcy-sur-Cure, found that the input of pollen carried by wind was prevailing at the entrance of the caves, up to 10 m from it in caves with a large entrance and up to 30 m in caves with a strong air flux; statistical analysis on patterns in caves in Spain showed evidence of anemophilous taxa abundance in the entrance area and zoophilous in the back area (Navarro Camacho et al., 2000; Navarro et al., 2001); data from Coles and Gilbertson (1994) on three caves in England confirmed the trend with airborne pollen rate decreasing with distance from the cave entrance but suggested the possibility of exceptions as shown by the results from one of those caves; De Porras et al. (2011) also suggested that this rule can vary from cave to cave since in their analysis of two caves in the Patagonian steppe of Argentina the pattern was not as strong as in the previous examples. However, the presence of other factors, and in particular of biotic material coming from sheep, influenced the pollen assemblage and explained the results.

In the Zagros Mountains, this pattern is most marked in the relatively narrow caves, such as SLS207, and less noticeable in broad caves, such as SLS210, probably because wider caves are more likely to have stronger air circulation than narrow caves which would, therefore, carry anemophilous pollen at the back of the cave. The size of the cave, instead, seems to not have influence as suggested by the similar results in SLS215, which is 4 m deep, and in SLS207 and SLS218, both over 8 m long. Figure 8.1 shows the relationship between the difference in percentages of entomophilous pollen between the front and the back of sac-like caves and the length/breadth ratio suggesting how this difference is higher for long and narrow caves compared to shorter and wider ones. The two caves that show different results are Shanidar Cave and Cave SLS203. Cave SLS203 shows an opposite pattern compared to that reported in the other caves with entomophilous taxa more abundant near the cave entrance. However, the presence of a second entrance at the back of the cave has a strong influence on the air circulation patterns, as noticed during the excavation. In addition, sheep and cattle are being kept sometimes overnight in the cave and they might be responsible for the pollen, bringing and depositing it with the abundant dung on the floor of the cave.

In Shanidar Cave, the anemophilous/entomophilous pattern is still visible but considerably less clear, probably because of the disturbance and mixing of the surface sediments by the people visiting the cave or because of the geometry of the cave that facilitates air circulation. Reynolds et al. (2016), during the recent excavations at the site, reported a lateral air circulation from west to east that could have influenced the pollen depositional pattern in the cave. Also, human presence has been demonstrated to be an important factor in some caves in terms of pollen input. Both Coles and Gilbertson (1994) and Van Campo and Leroi-Gourhan (1956) reported an increase in pollen deposition in caves that were highly visited compared to the ones with lower or no human presence.

At Shanidar Cave, the only studied site to have a constant and significant human presence, the pollen concentration was sufficiently low that a heavy liquid step was required to obtain a statistically significant number of grains, suggesting that the visitors did not import much pollen into the cave on their feet and that their main contribution was the mixing of the surface sediments.

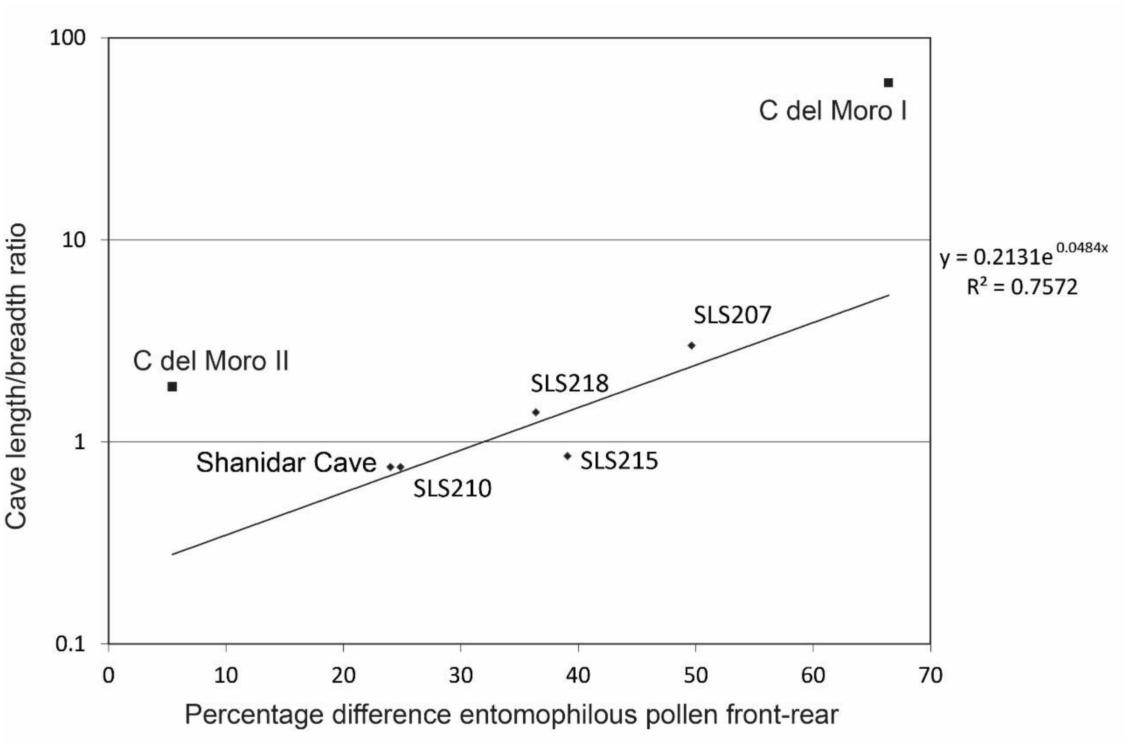

Figure 8.1 Plot of the relationship between the difference in percentages of entomophilous pollen between front and rear of sac-like caves in Kurdish Iraq and Spain (data from Navarro et al., 2001) and the cave geometry (represented by the length/width ratio).

The other factor that could have had an impact in the pollen influx is the presence of an entrance flora, influencing the air flow by acting as a filter or introducing bias in the pollen diagram by shedding pollen grains and spores that do not represent the broader local vegetation. Examples of this effect can be found in caves in temperate areas such as England and France where Hunt and Gale (1986) and Coles et al. (1989) reported caves where the entrances were largely blocked by ferns. Coles and Gilbertson (1994) also recorded that at Creswell Crags the entrance flora, represented by ferns, made up the 20 to 40% of the total pollen, introducing a strong bias in the pollen diagram. In Iraq, ferns were present only in two of the caves studied and in small quantity. The main species noted were *Adiantum* spp. in SLS207 and Shanidar Cave, probably represented in SLS207 pollen diagram by the monolete spore curve (see Figure 7.16), while in Shanidar they do not seem to have had a strong influence on the pollen record.

These observations have important archaeological and palaeoecological implications for cave-palynological studies for several reasons. The first aspect relates to sampling strategies: because there are regular and relatively predictable pollen deposition patterns in simple sac-like caves, the sampling location should take account of it in caves of this type. Samples collected near the cave entrance will better represent anemophilous pollen, while samples collected from the back areas of the cave will show a better representation of entomophilous pollen. In general, previous studies have suggested how the best sampling areas are the ones far from the cave walls and in the central area of the cave (Navarro et al., 2001), where there would also be an average representation of both wind- and insect-pollinated taxa without a pre-eminence of one or another. This effect is likely to influence palaeoecological deductions drawn by the pollen diagram, especially regarding the arboreal/non-arboreal ratio, considering that anemophilous taxa include many trees while most of the entomophilous taxa are herbs or shrubs. The second consideration relates to geomorphologically complex caves. The rules seen above work well in simple sac-like caves but when the caves have multiple entrances or chambers and, therefore, a complex network and air circulation patterns, a preliminary taphonomic study is essential in order to take into account the processes acting in them. Finally, considering other sources of complexity that include human activity, wild animals and livestock, meteoric water and the presence of cave entrance flora, it is necessary to understand their weight in the final composition of the pollen assemblage in order to correctly interpret the information acquired from the pollen diagram.

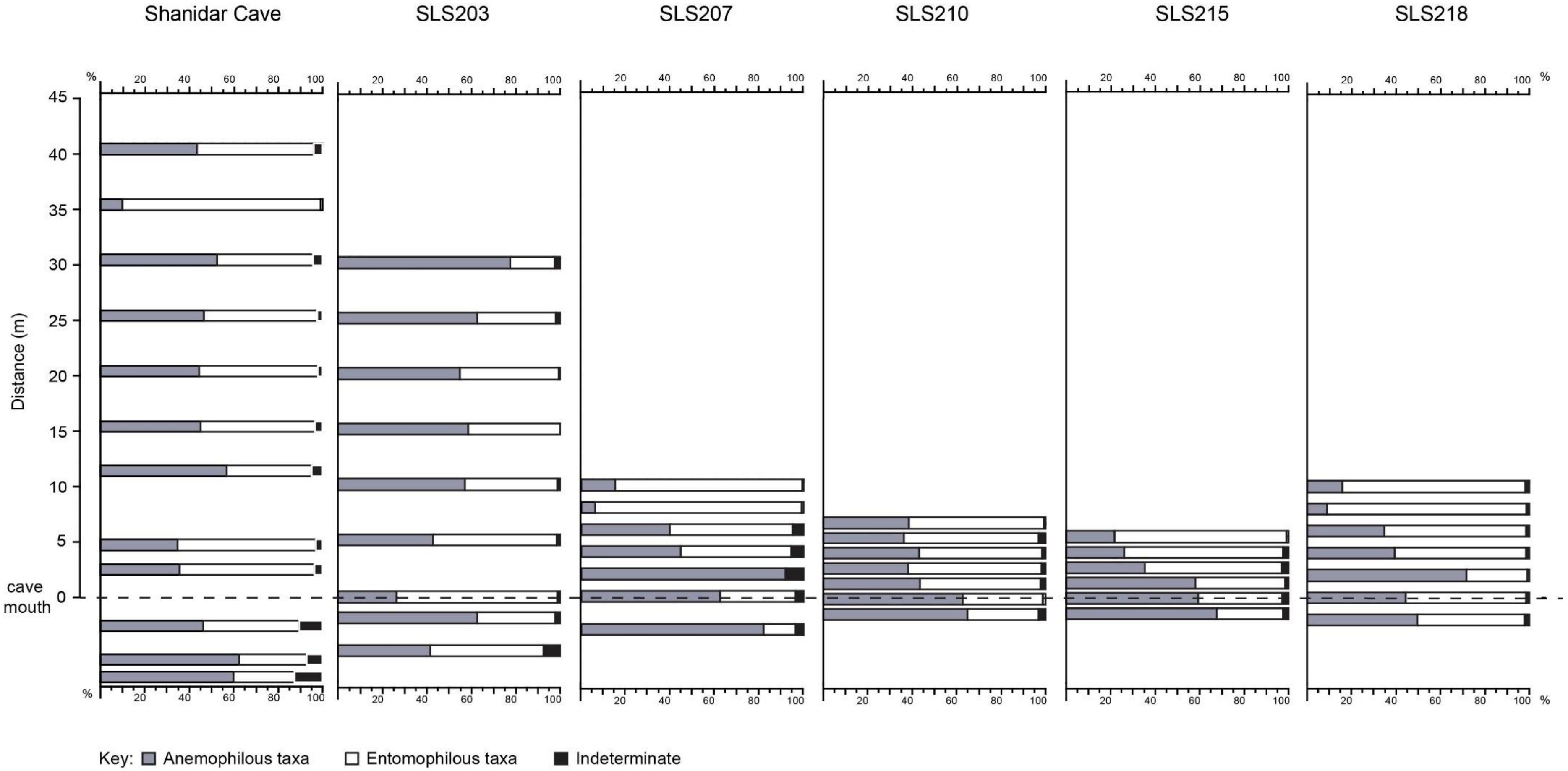

Figure 8.2 Distribution of anemophilous and entomophilous taxa in the sampled caves.

8.3 Shanidar Cave combined transects

The collection of samples alongside different transects in Shanidar Cave allows further considerations regarding the pollen distribution compared to the single transects available from the other caves. There are some general similarities among the three transects such as the prevalence of herbs compared with trees and shrubs and the main taxa recorded. However, there are also differences in the patterns shown by different taxa alongside the transects and in the pollen counts trend. In the front-back transect, the total pollen sum does not show any particular trend with values fluctuating throughout while it shows a slight pattern in the right-left transect with higher values at the two extremes that decrease towards the centre. Some of the taxa also show a trend of increasing or decreasing percentages going from one side of the cave to the other and, in particular, Lactuceae and Asteraceae are more abundant on the right side while Poaceae on the left side, indicating possible air influx and/or animal activity.

The samples collected from the perimeter are interesting because the only samples containing pollen are the ones close to the cave entrance while the ones further back are sterile. Shanidar Cave mouth is wide and the movement of air is facilitated in the areas near it; therefore those samples, even though they were near the cave walls, were probably still easily reached by the wind while the others alongside the perimeter were more protected. However, the taxa recorded are both anemophilous and entomophilous so it might also be that the pollen found there is being moved from other points of the cave by the wind or people and not being transported by the wind or insects from outside.

The iso-line maps related to concentration of anemophilous and entomophilous taxa (see Figure 7.5 and 7.6) shows that their distribution is not as clear as in the other caves. The anomalous Asteraceae values of one of the samples at the front possibly related to a bee nest, however, influence the distribution. Certainly the presence of people visiting the cave is one of the factors adding complexity to the pollen distribution, considering that none of the other caves present the same situation. The highest pollen concentrations shown in the maps follow a path from front to back down the axis of the cave and another path from front to right, where the entrance of the second small chamber and a spring are located. This probably reflects the path tourists and animals would have taken in the cave, perhaps suggesting that some pollen came in and was spread into the cave on visitors' and animals feet. This hypothesis is supported by the difference with the trends shown by the iso-line maps related to the sticky slides where the majority of the pollen is found on both sides of the cave entrance, suggesting that in Shanidar the distribution of the pollen is determined by a complex interaction of several factors more than just the air circulation.

8.4 Shanidar Cave stratigraphic samples

The stratigraphic samples collected from column B(1), corresponding to the top 1.5 m of exposed deposits and relating to the top part of the Baradostian (Upper Palaeolithic), and column C(2), corresponding to the lowest part of the Baradostian and the top of the Mousterian, contain almost no pollen, with the exception of a few grains, some of which are showing cell contents suggesting they are contaminants. This contrasts with the analysis undertaken on the stratigraphic samples by Leroi-Gourhan during Solecki's excavations of the cave, which were more successful. She reported the results of 17 samples, the oldest collected at 9.69 m of depth, with pollen counts fluctuating between the lowest value of 43 grains - sample D8, at 6.40 m depth, from the Mousterian - and the highest of 712 - sample D9, 1.70 m depth, in the Proto-Neolithic layer (Leroi-Gourhan, 1998), which is no longer available to be sampled. The paper, however, does not report any information about the quantity of sample processed and the methodology used. In a previous paper, Solecki and Leroi-Gourhan (1961) reported that the first attempt of pollen analysis on the samples collected in 1957 by Gunnar Erdtman (University of Stockholm) gave negative results (the samples were pollen-sterile) and that therefore Leroi-Gourhan tried '*her method of pollen analysis on the duplicate Shanidar samples*'.

Field observation by C Hunt (pers. comm. 2016) during the 2016 excavation season suggested that the weathering crust around the old Solecki Trench was over 0.8 m deep. Within that zone, although bones, mollusc shells and sedimentary structures were visible and apparently in good preservation, the cave sediment was noticeably more compact and slightly paler in colour than the deposits further away from the old trench. This most likely means that there has been build-up of calcium carbonate in the sediments adjacent to the old trench and some measure of decay of organic matter might thus be anticipated. It has become clear that sample columns B(1) and C(2) were not taken far enough away from the old trench wall for them to have complete integrity. Further, unpublished facies analysis by Hunt and mollusc analysis by E. Hill (pers. comm. to C Hunt, 2017) suggests that the majority of the stratigraphic samples corresponding to column B(1) and C(2) belongs to mudflow deposits derived from aeolian sediments similar to British coversands (e.g. Gilbertson & Hawkins 1983) and that they represent sediments deposited during stadials.

During stadials, the deposition of pollen per unit volume of sediment was probably very low due to the cold climate and high sediment flux. The particle size data related to column C(2) confirm this possibility as the samples are dominated by coarse silt and sand. It can be hypothesized that Leroi-Gourhan processed a large amount of sediment in order to obtain a significant pollen count. It is unlikely that the methodology used could have made such a difference in the results as, when we checked the samples in order to determine whether the method used was impacting the presence of pollen, we didn’t find any grains even when we only sieved the soil without using any other chemical process. Therefore, if the sediment contained pollen, it must have been so sparse that was impossible to detect it in the small amount of soil that we used for the analysis. Unfortunately, the size of samples collected was restricted the due to the difficulty of bringing them back from Iraq but a different sampling strategy must be used in the next seasons of excavation in order to test this hypothesis.

It is still possible to compare Leroi-Gourhan’s results with the surface samples from Shanidar and the other caves in order to analyse the vegetation types. Considering the main taxa recorded in the Leroi-Gourhan (1998) pollen diagram (see Figure 4.4), almost all of them have been found in the modern samples. However, the presence of older grains (probably dated to the end of the Tertiary) in the Mesolithic layer (Solecki & Leroi-Gourhan, 1961) and the dominance of Lactuceae in most of the pollen diagram suggest possible taphonomic issues related to the pollen assemblage. In particular, considering the presence of Lactuceae in pollen diagrams, Bottema (1975b) reports extremely high percentages of this taxon in samples from prehistoric culture layers in comparison with modern surface samples where relatively high percentages (10-30%) are found when these plants grow over the collected samples. She explains this over-representation with possible transport by mammals, infiltration from younger layers, the result of the activity of burrowing bees and selective corrosion (Havinga, 1971).

In fact, in several cases high Lactuceae percentages are positively correlated with an increase in indeterminate grains and low pollen concentration (Mercuri et al., 2010). However, experiments on pollen oxidation show that other taxa are more resistant to oxidation that Lactuceae and that oxidation affects all taxa, not leading to over-representation (Lebreton et al. 2010).

The extremely high amount of Lactuceae always recovered in cave sediments and archaeological contexts remains therefore an issue and even if the presence of the plants near the cave entrances has been suggested as possible explanation, other taphonomic processes could be involved. In fact, in the studies on modern pollen rain available for the Near East, Lactuceae never appear as one of the main taxa (El-Moslimany, 1990; Djamali et al., 2009; Ramenzani et al., 2013) and the relatively high amount (13%) reported by Davies & Fall (2001) is related, according to the authors, to the association between Lactuceae and disturbed archaeological soils. On the contrary, the pollen assemblages from the caves under investigation in this thesis show always high values of Lactuceae that reach 70% in caves SLS215 and SLS207 (Fiacconi & Hunt, 2017, Appendix 4) (see Figure 7.20 and 7.16), supporting the idea that other taphonomic issues might be involved in the process.

Considering the flowers found with Shanidar IV skeleton - *Achillea, Centaurea, Muscari, Senecio, Althaeaea* and *Ephedra* - three of them (*Centaurea, Senecio* and *Ephedra*) have been recorded in the modern samples. However, some of the others might be included in the pollen identified as Asteraceae because an identification to a species level was not possible. One of the facts used by Solecki and Leroi-Gourhan (Solecki, 1975, 1977; Leroi-Gourhan, 1975) to support their conclusion that complete flowers were introduced intentionally into the cave was that seven of the taxa identified were found in clusters. However, clumps of pollen have been found in the present study for different taxa, such as Chenopodiaceae, *Centaurea*, Lactuceae, Apiaceae, Poaceae and Brassicaceae, and in all the caves, even the ones where human presence was not recorded, suggesting that the grouping of grains noted by Leroi-Gourhan can occur naturally (Figure 8.3 and 8.4). In fact, even if anemophilous taxa usually disperse pollen as single grains while entomophilous taxa can disperse in clumps, clumps of pollen have been observed in dispersion studies of many common wind-pollinated species (Fig 8.3. Martin et al., 2009). Even though this does not exclude the possibility of flowers being deposited by Neanderthals, it definitely demonstrates that the presence of clumps is not a proof itself.

Figure 8.3 Clumps of Poaceae pollen from surface sediments in Shanidar Cave.

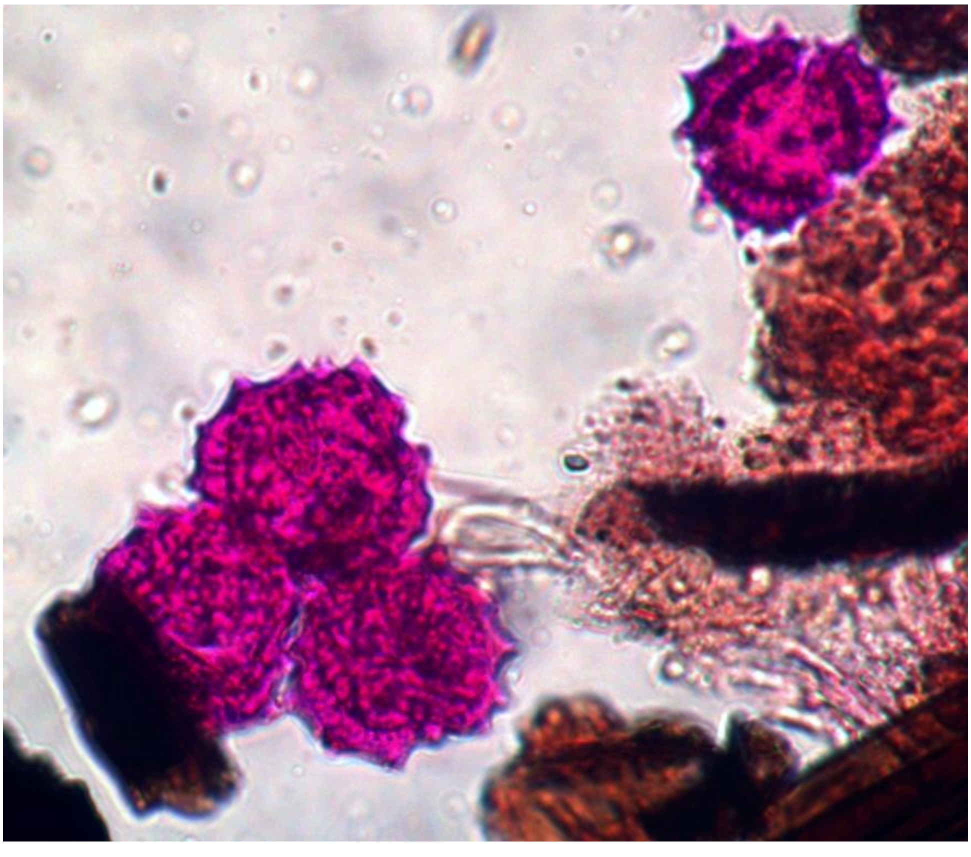

Figure 8.4 Clumps of Asteraceae pollen from surface sediments in Shanidar Cave.

8.5 Research limitations

Despite the new information and important implications provided by the results presented so far, this research reveals some limitations. Firstly, the unstable political situation in Iraq delayed the start of the excavations and caused other complications during some of the fieldwork seasons; therefore, considering the impossibility to achieve the initial aim, the focus was moved on different aspects of the research.

Secondly, all the caves chosen for sampling are simple sac-like caves, with the exception of SLS203; this strategy limited the analysis of pollen behaviour to caves with this shape and the same type of study should be undertaken in caves with complex morphology to see if common patterns can be recognised. Moreover, the number of caves with human and animal presence and water input should be increased in order to explore the influence of these factors further.

Thirdly, the representativeness of the cave pollen spectra was tested on the basis of observations of the local vegetation and a limited number of samples collected from the area outside the cave; a proper vegetational survey is needed in order to study the relationship between the pollen rain and the vegetation and then the relationship between the cave and the open-air assemblages.

Finally, considering the sterility of the stratigraphic samples from Shanidar Cave, a different sampling strategy might be needed with bigger sample size to obtain a sufficient number of pollen grains. In fact, the few grains recovered were in good condition, suggesting that the absence of pollen might be related to low deposition more than preservation issues.

8.6 Conclusions

The results obtained from the analysis of pollen recovered from several caves in the Zagros Mountains of Kurdish Iraq provided important information to explore the influence of different factors in the composition of cave pollen assemblages. Depositional and post-depositional factors have been demonstrated to influence the pollen through several processes, such as sedimentation rates and process energy (Hunt et al., 2015), removal and/or redeposition of the sediments (Campbell, 1999), preservation and differential destruction of the grains (Havinga, 1964; Faegri & Iversen, 1975; McGarry & Caseldine, 2004; Lebreton et al., 2010) and in transit and *in situ* deterioration (Campbell & Campbell, 1994). However, even before the influence of the processes mentioned above, those that relate to pollen transport can influence the assemblage and create biases.

Aerial transport: the influence of aerially-transported pollen in the cave assemblage is higher near the cave entrances compared to rear areas, as shown in previous studies (Van Campo & Leroi-Gourhan, 1956; Burney & Burney, 1993; Navarro et al., 2001). In addition, the aerially-transported taxa recorded are similar to those found in the cave surface pollen assemblages and to the pollen assemblages among vegetation nearby, in accordance to previous observations where the airborne pollen recorded came from the vegetation just outside the cave (Coles, 1988).

Water transport: the influence of water is variable, as demonstrated by negative results with water samples containing no pollen from the caves under investigation, similarly to what found by Burney & Burney (1993) and Coles et al., (1989), and those with water samples containing a pollen composition similar to the surface samples (Simpson, 2016).

Animal transport: different animals can have a different influence on the pollen composition. In Kurdish Iraq, the bird dropping contained no pollen, contrary to the findings by Hunt & Rushworth (2005) in tropical environments where the roosting areas of the cave had higher pollen concentration and different taxa composition compared to other areas. However, the goat/sheep samples showed higher pollen values suggesting that in the past their influence might have been much higher, as shown in other cases in caves elsewhere (Hunt, unpubl.; Verges et al., 2016). In addition, the prevalence of entomophilous pollen near the back of the cave and anemophilous pollen near the cave entrance can be considered as a general trend as observed in Kurdish Iraq and numerous times in caves elsewhere (van Campo & Leroi-Gourgan, 1956; Burney & Burney, 1993; Coles & Gilbertson, 1994; Prieto & Carrión, 1999; Camacho et al., 2000; Navarro et al., 2001; Navarro et al., 2002; Hunt & Rushworth, 2005).

Human transport: humans can transport pollen in several ways, such as by introducing food in the cave (Hunt, 2007; 2012) or through their faeces (Hunt et al., 2011). In general, higher values of pollen are associated with human presence (Van Campo & Leroi-Gourhan, 1956); at Shanidar Cave, the human influence is the mixing of surface sediment and pollen caused by the visitors, as suggested by the anemophilous/entomophilous trend that is less clear than in caves with the same morphology but without human presence.

Cave geomorphology: the importance of the cave morphology and complexity is shown by the results of SLS203, the only cave with two entrances, where the general trend of anemophilous and entomophilous taxa distribution is inverted compared to the other caves. Van Campo & Leroi-Gourhan (1956) also reported that pollen was carried further distances in caves with draughts and Navarro et al. (2002) demonstrated how small entrances and long and narrow shape are associated with lower pollen concentration.

The relationship and interconnection between the above factors (Figure 8.5) is responsible for the composition of the final pollen assemblage.

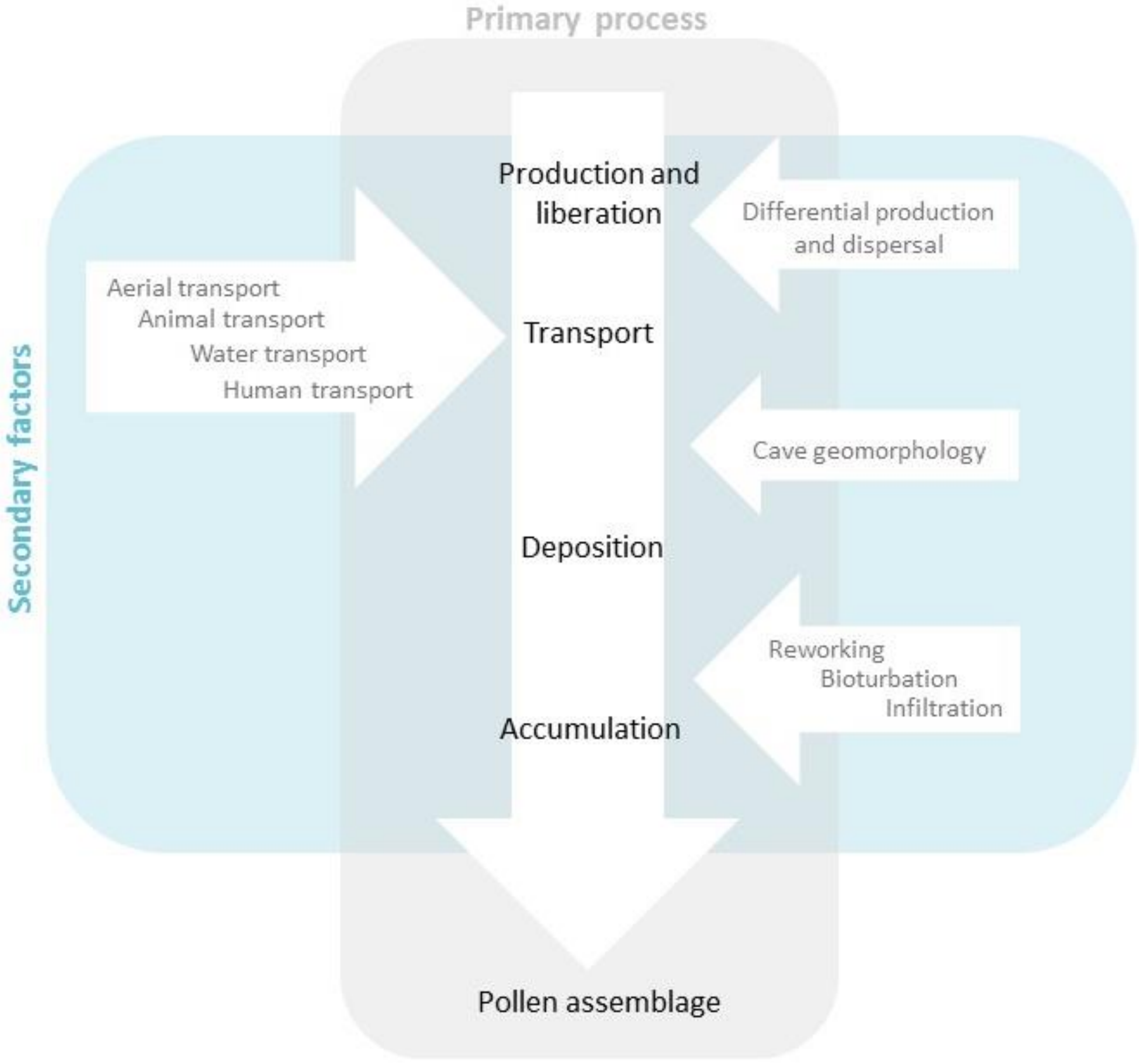

Figure 8.5 Proposed taphonomic model for the formation of cave pollen fossil assemblages (modified from Coles et al., 1989).

The next chapter summarises the main points and findings of the research considering them in relation to the original hypothesis, draws a conclusion on their implications and suggests future research and practical applications.

9. Conclusions

9.1 Introduction

The aim of this research was to investigate the problem of the ‘Shanidar flower burial’ by understanding the mechanisms involved in pollen transport, deposition and accumulation in caves and determining the influence of external factors (e.g. drip water, cave-entrance flora and human and animal presence) on the composition of the pollen assemblage. Palynological and particle-size analyses were undertaken on surface and stratigraphic samples from the archaeological site of Shanidar Cave, in the Zagros Mountains of Kurdish Iraq, and from other five caves in the surrounding area.

9.2 Key findings

- The pollen traps and sticky slides catching the airfall pollen from Shanidar Cave showed extremely low pollen concentration suggesting a general low pollen influx. The highest number of grains was found in the samples near the cave entrance and in the control sample outside, where the influence of the air current is still prevailing, as demonstrated by Van Campo & Leroi-Gourhan (1956).
- The main taxa recorded correspond to those representing the vegetation in the cave area, in accordance with Coles (1988) who found that up to 40% of the airborne pollen was representative of the vegetation growing within 100m from the site. The water samples, collected from dripping water inside the cave, contained no pollen, as seen in previous studies (Coles et al., 1989; Burney & Burney, 1993), but cases of pollen-rich water with similar composition to the airfall assemblages are also reported (Simpson, 2016).
- The bird dropping samples were again sterile indicating no input from those animals to the pollen assemblage, contrary to the findings of Hunt and Rushworth (2005) in tropical environments. However, the goat/sheep samples contained pollen, even if in small amounts, suggesting likely higher influence when more animals were kept in the cave in the past, as noticed in other caves (Hunt, unpubl.; Verges et al., 2016).
- The importance of those factors appeared to be different in some of the caves under investigation, showing general trends but also exceptions. The simple

sac-like caves with little or no influence of secondary factors (SLS207, 210, 215 and 218) showed a positive correlation between anemophilous pollen and vicinity to the cave entrance and between entomophilous pollen and distance from the cave entrance. This pattern has been recorded by several authors in caves elsewhere (Van Campo & Leroi-Gourhan, 1956; Coles and Gilbertson, 1994; Navarro Camacho et al., 2000; Navarro et al., 2001) and can be considered a general trend.

- The opposite trend was seen in Cave SLS203, with anemophilous and entomophilous percentages inverted. However, this cave is open, at the back, on a cliff face and acts as a wind tunnel with strong draughts observed during recent excavations at the site (Reynolds et al., 2016) and is still used by local shepherds as a night shelter for the animals. De Porras et al. (2011) and Prieto and Carrion (1999) also reported similar results supporting the idea that when other factors are involved, the patterns of pollen distribution can be changed.
- Shanidar Cave differs from this trend with a complex and less clear anemophilous/entomophilous distribution compared with the previous caves. In this case, the high influx of tourists visiting the site every day creates a mixing of the surface sediments and, therefore, of the pollen distribution. Human influence has also been reported by Van Campo & Leroi-Gourhan (1956), Hunt (2007; 2012) and Hunt et al. (2011).
- The stratigraphic samples collected from columns B(1) and C(2), corresponding to the Upper Palaeolithic and Mousterian respectively, were sterile or contained few pollen grains, in contrast with Leroi-Gourhan's (1998) analysis where she counted a minimum of 43 grains/sample. Unpublished facies analysis by Hunt and mollusc analysis by E. Hill (pers. comm. to C Hunt, 2017) suggest that the samples came from mudflow deposits derived from aeolian sediments deposited during stadials, where the deposition of pollen per unit volume of sediment was probably very low due to the cold climate and high sediment flux. A revaluation of Leroi-Gourhan's (1998) pollen analysis showed possible indications of taphonomic issues related to her assemblage, such as the presence of older pollen grains in the Mesolithic layer (Solecki and Leroi-Gourhan, 1961) and the abundance of Lactuceae, often associated with disturbed soils from cultural layers (Bottema, 1975b). Her interpretation of the unusual pollen content of two of the samples associated to Shanidar IV as a flower tribute to the dead (Solecki, 1975, 1977; Leroi-Gourhan, 1975), were

based on the amount of pollen and the species recovered and the clumps of some of the grains in groups. However, clumps of pollen of both anemophilous and entomophilous taxa have been found in the present study for different taxa and in all the caves, even the ones where human presence was not recorded, suggesting that the grouping can occur naturally, as reported previously (Martin et al., 2009).

The results of the analyses undertaken on the transect samples allowed the understanding of the pollen taphonomy in simple sac-like caves through the comparison with previous research in other areas; in addition, the study of the single factors that can influence the pollen assemblage through the use of pollen traps, water collection and animal dung helped the understanding of the impact of those factors in more complex caves. The problems during the fieldwork related to the difficult political situation of the country impeded the complete analysis of the stratigraphic samples and, therefore, the reconstruction of the vegetational changes in the area through time and the clarification of the origin of the pollen found with one of the skeletons and the debate surrounding it. However, the revaluation of the previous palynological work and the analysis of the stratigraphic samples available allowed the understanding of the sedimentation history of the cave and of the lack of pollen and helped in the explanation of previous results.

9.3 Future work

Future work could improve the generalization of the results on pollen taphonomy through the analysis of a higher number of caves located in the same area and differing in water, animal, human presence and complexity of morphology. Moreover, a proper vegetational survey of the Iraqi Zagros Mountains would allow the understanding of the connection between pollen rain and vegetation and, therefore, a better comprehension of the relationship between cave and open-air assemblages. Considering Shanidar Cave, further excavations at the site would allow the collection of bigger sized samples in order to test the hypothesis about the lack of pollen in the stratigraphic samples and permit a reconstruction of the environments from the time of Neanderthals until present days. The improvement of the information available on the site would also benefit the population that consider Shanidar Cave as an important element of the local society because of its cultural and touristic importance.

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Appendices

Appendix 1

A1.1 Caves surface transect samples

Site	Sample number	Distance (m)	Location
Shanidar Cave	C42L	41	Front-back
Shanidar Cave	C40L	39	Front-back
Shanidar Cave	C33L	31	Front-back
Shanidar Cave	C28L	27	Front-back
Shanidar Cave	C23L	22	Front-back
Shanidar Cave	C18L	17	Front-back
Shanidar Cave	C13L	12	Front-back
Shanidar Cave	C08L	7	Front-back
Shanidar Cave	C03L	2	Front-back
Shanidar Cave	S16M	0	Cave mouth
Shanidar Cave	S07S	-	Exterior
Shanidar Cave	S36S	-	Exterior
Shanidar Cave	C02W	1	Right-left
Shanidar Cave	C06W	5	Right-left
Shanidar Cave	C11W	10	Right-left
Shanidar Cave	C22W	21	Right-left
Shanidar Cave	C28W	27	Right-left
Shanidar Cave	C33W	32	Right-left
Shanidar Cave	C38W	37	Right-left
Shanidar Cave	C01P	-	Perimeter
Shanidar Cave	C04P	-	Perimeter
Shanidar Cave	C08P	-	Perimeter
Shanidar Cave	C11P	-	Perimeter
Shanidar Cave	C15P	-	Perimeter
Shanidar Cave	C22P	-	Perimeter
Shanidar Cave	C25P	-	Perimeter
SLS203	SLS203/1	30	Front-back
SLS203	SLS203/2	25	Front-back
SLS203	SLS203/3	20	Front-back
SLS203	SLS203/4	15	Front-back
SLS203	SLS203/5	10	Front-back
SLS203	SLS203/6	5	Front-back
SLS203	SLS203/7	0	Cave mouth
SLS203	SLS203/S1	-	Exterior
SLS203	SLS203/S2	-	Exterior

SLS203	SLS203/M1	15	Moss transect
SLS203	SLS203/M2	17	Moss transect
SLS203	SLS203/M4	19	Moss transect
SLS203	SLS203/M5	25	Moss transect
SLS203	SLS203/M6	29	Moss transect
SLS203	SLS203/M7	32	Moss transect
SLS207	SLS207/1	10	Front-back
SLS207	SLS207/2	8	Front-back
SLS207	SLS207/3	6	Front-back
SLS207	SLS207/4	4	Front-back
SLS207	SLS207/5	2	Front-back
SLS207	SLS207/6	0	Cave mouth
SLS207	SLS207/S1		Exterior
SLS210	SLS210/1	5	Front-back
SLS210	SLS210/2	4	Front-back
SLS210	SLS210/3	3	Front-back
SLS210	SLS210/4	2	Front-back
SLS210	SLS210/5	1	Front-back
SLS210	SLS210/6	0	Cave mouth
SLS210	SLS210/S1	-	Exterior
SLS215	SLS215/1	4	Front-back
SLS215	SLS215/2	3	Front-back
SLS215	SLS215/3	2	Front-back
SLS215	SLS215/4	1	Front-back
SLS215	SLS215/5	0	Cave mouth
SLS215	SLS215/S1	-	Exterior
SLS218	SLS218/1	10	Front-back
SLS218	SLS218/2	8	Front-back
SLS218	SLS218/3	6	Front-back
SLS218	SLS218/4	4	Front-back
SLS218	SLS218/5	2	Front-back
SLS218	SLS218/6	0	Cave mouth
SLS218	SLS218/S1	-	Exterior

A1.2 Shanidar cave water, air and animal dung samples.

Site	Type	Sample
Shanidar Cave	Sticky slide	1
Shanidar Cave	Sticky slide	3
Shanidar Cave	Sticky slide	4
Shanidar Cave	Sticky slide	5
Shanidar Cave	Sticky slide	6
Shanidar Cave	Sticky slide	7
Shanidar Cave	Sticky slide	8
Shanidar Cave	Sticky slide	9
Shanidar Cave	Sticky slide	10
Shanidar Cave	Sticky slide	11
Shanidar Cave	Sticky slide	13
Shanidar Cave	Sticky slide	14
Shanidar Cave	Sticky slide	15
Shanidar Cave	Sticky slide	16
Shanidar Cave	Sticky slide	17
Shanidar Cave	Sticky slide	18
Shanidar Cave	Sticky slide	19
Shanidar Cave	Sticky slide	20
Shanidar Cave	Sticky slide	21
Shanidar Cave	Sticky slide	22
Shanidar Cave	Pollen trap	Front transect
Shanidar Cave	Pollen trap	Back transect
Shanidar Cave	Water sample	<2719>
Shanidar Cave	Water sample	<2720>
Shanidar Cave	Water sample	<2721>
Shanidar Cave	Water sample	Drip water inside cave
Shanidar Cave	Water sample	Drip water inside cave - rainy day
Shanidar Cave	Water sample	Rain water outside cave
Shanidar Cave	Water sample	Rain water outside cave
Shanidar Cave	Water sample	Dripwater
Shanidar Cave	Goat/sheep dung	C01D
Shanidar Cave	Goat/sheep dung	C02D
Shanidar Cave	Bird dropping	<2942>
Shanidar Cave	Bird dropping	<2941>
Shanidar Cave	Bird dropping	<2831>
Shanidar Cave	Bird dropping	<2770>

A1.3 Shanidar Cave stratigraphic samples

Site	Sample	Column	Depth (cm)	Info
Shanidar Cave	<2211>	B(1)	0-8	
Shanidar Cave	<2214>	B(1)	8-11	
Shanidar Cave	<2217>	B(1)	11-16	
Shanidar Cave	<2220>	B(1)	16-22	
Shanidar Cave	<2223>	B(1)	22-27	
Shanidar Cave	<2226>	B(1)	27-32	
Shanidar Cave	<2229>	B(1)	32-37	
Shanidar Cave	<2232>	B(1)	37-39	
Shanidar Cave	<2252>	B	-	Around bones
Shanidar Cave	<2282>	B	-	Around bones
Shanidar Cave	<3053>	C(2)	0-10	
Shanidar Cave	<3055>	C(2)	10-15	
Shanidar Cave	<3058>	C(2)	15-20	
Shanidar Cave	<3061>	C(2)	20-27	
Shanidar Cave	<3063>	C(2)	27-32	
Shanidar Cave	<3067>	C(2)	32-37	
Shanidar Cave	<3069>	C(2)	37-43	
Shanidar Cave	<3072>	C(2)	43-48	
Shanidar Cave	<3075>	C(2)	48-54	
Shanidar Cave	<3078>	C(2)	54-60	
Shanidar Cave	<3158>	C(2)	60-64	
Shanidar Cave	<3161>	C(2)	64-65	
Shanidar Cave	<3164>	C(2)	65-70	
Shanidar Cave	<3169>	C(2)	70-75	
Shanidar Cave	<2254>	C(2)	-	Animal burrow
Shanidar Cave	<2298>	C(2)	-	Animal burrow

Appendix 2

A2.1 Raw pollen counts for Shanidar Cave front-back transect

	C03L	**C08L**	**C13L**	**C18L**	**C23L**	**C28L**	**C33L**	**C40L**	**C42L**	**S16M**	**S07S**	**S36S**
Acer	0	0	2	0	0	0	0	0	0	0	0	0
Allium type	1	0	0	0	0	0	0	0	0	0	0	0
Alnus	0	0	0	2	1	0	0	0	0	0	0	0
Anchusa	1	0	0	0	0	0	0	0	0	0	0	0
Anemone type	4	0	1	0	0	0	0	0	0	0	0	0
Apiaceae	1	0	0	0	0	0	0	0	0	0	0	0
Artemisia	9	2	3	4	4	3	4	1	2	0	0	0
Asteraceae (large)	21	207	14	7	1	1	0	2	0	0	1	0
Astragalus type	1	0	0	0	0	4	2	3	0	0	1	0
Betula	0	0	0	2	0	0	0	0	0	0	0	0
Bidens type	13	91	9	10	26	32	30	82	98	9	11	8
Buxus	0	0	0	0	0	0	0	0	25	0	0	0
Caryophyllaceae	8	20	16	4	44	16	13	7	25	3	6	0
Celtis	4	0	0	0	0	0	0	0	1	0	0	0
Centaurea	1	0	10	0	1	2	2	1	0	0	0	0
Chenopodiaceae	14	0	9	7	9	8	7	0	1	2	14	4
Cupressaceae	1	7	3	6	2	4	2	0	0	0	10	12
Cyperaceae	25	8	22	24	6	4	15	6	10	5	14	10
Digitalis	0	0	0	0	0	1	0	0	0	0	0	0
Dipsacaceae	4	0	0	0	0	0	0	0	0	0	0	0
Echium	1	0	0	0	0	0	0	0	0	0	0	0

Ephedra	0	0	0	0	0	0	0	0	0	0	1	1
Ericaceae	1	0	0	0	0	0	0	0	0	0	0	0
Euphorbia	2	0	0	0	0	0	0	0	0	0	0	0
Fern spore	0	0	0	0	0	7	8	2	2	0	6	2
Gallium type	0	2	0	0	0	0	0	0	0	0	0	0
Hippophae	0	1	1	0	3	0	0	0	0	0	0	0
Juniperus type	1	0	1	0	0	1	0	0	0	0	0	0
Lactuceae	43	92	37	60	62	75	24	92	46	24	41	22
Larix	0	0	0	5	0	0	0	0	0	0	0	0
Liliaceae	1	3	3	6	2	2	0	0	4	1	1	1
Liliaceae (Fritillaria type)	1	0	0	0	0	0	0	0	0	0	0	0
Lilium catharticum	0	0	1	0	0	0	0	0	0	0	0	0
Monolete spore	2	0	1	1	0	3	3	0	4	0	1	2
Ostrya carpinifolia	1	0	0	0	0	0	0	0	0	0	0	0
Papaver	8	4	3	0	5	0	0	0	0	0	5	0
Pinus	3	2	4	0	0	1	1	0	2	1	12	0
Pistacia	3	0	2	3	4	0	1	0	0	1	2	1
Plantago	1	0	0	0	2	1	0	0	0	0	0	0
Poaceae cereal type	37	19	57	21	44	39	24	64	65	10	25	23
Poaceae p<30µ	13	2	0	0	24	36	21	31	24	22	51	40
Quercus	53	8	33	16	58	25	27	2	11	13	50	12
Ranunculus type	1	1	5	0	0	0	0	0	0	0	0	5
Rhamnus	0	1	0	0	0	0	1	0	0	0	1	0
Rosaceae	68	26	20	5	41	16	5	3	7	15	31	14
Rumex	6	3	13	1	0	8	7	1	4	1	10	3
Saxifragus	2	0	0	0	0	0	0	0	0	0	0	0
Scabiosa	0	1	2	4	1	2	0	1	1	0	0	1

Solanaceae	0	0	0	0	1	1	0	0	0	0	0	0
Trifolium	1	0	0	0	0	1	1	1	1	0	0	0
Trilete spore	2	0	1	1	3	1	5	2	3	1	1	2
Verbena	0	0	0	0	0	1	0	0	0	0	0	0
Vicia type	0	1	0	0	0	1	1	0	3	0	0	0
Vitis	0	0	2	0	0	0	0	0	0	0	0	0
Zelkova	0	0	0	1	0	0	0	0	0	0	0	0
Indeterminate	15	6	13	5	8	11	11	10	14	13	23	24

A2.2 Raw pollen counts for Shanidar Cave left-right transect.

	C02W	**C06W**	**C11W**	**C17W**	**C22W**	**C28W**	**C33W**	**C38W**
Anchusa type	0	0	2	0	0	0	0	0
Apiaceae	0	0	1	3	0	0	1	0
Asteraceae Artemisia	0	1	0	0	0	1	0	0
Asteraceae Centaurea	3	12	1	27	2	0	0	0
Asteraceae Echinops	0	0	0	0	0	0	0	1
Asteraceae Matricaria-type	3	9	2	15	2	0	1	3
Asteraceae Senecio-type	35	24	43	21	2	9	7	20
Brassicaceae	2	2	6	3	2	3	4	9
Caryophyllaceae	9	9	8	3	2	0	3	2
Carpinus betulus	0	0	0	1	0	1	1	0
Chenopodiaceae	5	1	2	9	16	10	3	6
Cupressaceae	5	4	10	0	0	1	0	3
Cyperaceae	0	2	1	0	0	0	0	0
Fabaceae	0	0	0	0	0	0	1	3
Genista	0	0	0	1	0	1	0	3
Juglans	1	0	0	1	0	0	1	1
Lactuceae	78	53	30	4	12	4	4	20
Liliaceae	0	1	1	0	0	1	0	0
Mentha type	2	1	1	0	1	1	0	1
Monolete spore	4	3	2	2	2	1	4	2
Pinus	2	2	0	2	0	2	0	1
Pistacia	13	17	11	10	3	12	2	14
Plantago	1	1	4	3	0	4	1	4

Poaceae	11	7	1	6	9	0	3	3
Poaceae 40<p<30µ	25	18	18	20	4	45	21	32
Poaceae Cereal-type	20	21	11	4	2	12	8	18
Poaceae p<30µ	10	5	6	7	0	9	17	23
Quercus	17	30	28	36	22	56	8	39
Ranunculus type	1	3	0	1	0	1	0	0
Rosaceae	9	15	9	15	10	22	3	17
Rumex	0	0	0	1	0	1	1	2
Scabiosa	3	3	1	2	2	2	0	1
Sparganium	3	0	3	0	0	1	0	2
Trilete spore	3	3	3	0	2	0	3	5
Indeterminate	4	3	2	4	1	5	1	3

A2.3 Raw pollen counts for Shanidar Cave perimeter transect.

	C01P	**C04P**	**C08P**	**C11P**	**C15P**	**C22P**	**C25P**
Apiaceae	0	0	0	0	0	1	2
Asteraceae Centaurea	0	1	0	0	0	0	6
Asteraceae Matricaria-type	0	4	0	0	0	4	7
Asteraceae Senecio-type	7	16	0	0	0	6	24
Brassicaceae	0	3	0	0	0	2	4
Caryophyllaceae	6	9	0	0	0	13	0
Chenopodiaceae	4	4	0	0	0	3	7
Cyperaceae	3	1	0	0	0	1	1
Fabaceae	0	1	0	0	0	0	0
Iridaceae	0	0	0	0	0	1	0
Juglans	1	0	0	0	0	0	0
Lactuceae	7	83	0	0	0	60	0
Liliaceae	0	9	0	0	0	4	1
Mentha type	0	1	0	0	0	1	0
Monolete spore	3	3	0	0	0	0	4
Pinus	2	0	0	0	0	0	0
Pistacia	0	0	0	0	0	0	1
Plantago	0	0	0	0	0	1	0
Poaceae	14	10	0	0	0	5	1
Poaceae 40<p<30µ	5	30	0	0	0	26	9
Poaceae Cereal-type	13	32	0	0	0	25	24
Poaceae p<30µ	2	18	0	0	0	8	4
Polygonaceae	0	1	0	0	0	0	1
Quercus	7	3	0	0	0	6	18
Rosaceae	3	2	0	0	0	0	3
Scabiosa	6	1	0	0	0	1	4
Sparganium	1	2	0	0	0	0	1
Trilete spore	0	2	0	0	0	0	0
Indeterminate	10	8	0	0	0	5	5

A2.4 Raw pollen counts for SLS203 front-back transect.

	SLS203/1	**SLS203/2**	**SLS203/3**	**SLS203/4**	**SLS203/5**	**SLS203/6**	**SLS203/7**	**SLS203/S1**	**SLS203/S2**
Alnus	0	0	0	0	0	0	0	0	1
Artemisia	1	1	1	0	1	0	0	0	4
Asteraceae	1	11	14	8	3	2	5	4	5
Astragalus	0	2	0	1	0	0	0	0	0
Betula	0	1	0	0	0	0	1	0	3
Bidens type	12	34	59	69	80	121	119	6	18
Botrychium	0	0	0	0	0	0	0	6	0
Brassicaceae	0	0	11	3	0	0	2	0	0
Caryophyllaceae	1	13	8	8	27	18	7	2	3
Celtis	0	0	0	0	0	0	2	0	1
Chenopodiaceae	1	3	1	0	0	1	3	13	1
Crategus	1	0	0	0	0	0	0	0	0
Cyperaceae	2	23	52	9	13	16	3	36	48
Ephedra	1	0	0	0	1	1	1	0	1
Ericaceae	0	0	0	0	0	0	0	1	1
Fabaceae	0	0	0	0	0	0	0	1	0
Fern	1	4	2	1	1	3	0	194	17
Genista	0	0	0	0	0	1	3	2	3
Helianthemum	0	2	1	0	0	0	1	0	0
Hypericum	0	0	0	0	0	0	0	3	3
Juniperus	0	2	1	0	0	7	0	0	3
Lactuceae	27	56	52	58	74	63	166	75	137
Liliaceae	0	1	0	0	2	2	0	71	2

Monolete spore	1	3	4	0	2	0	0	11	1
Papaver	2	1	1	0	0	1	1	0	0
Pinus	2	4	3	4	2	2	1	8	30
Pistacia	0	0	0	0	0	0	1	3	2
Poaceae	102	109	78	122	137	74	51	7	38
Poaceae Cereal type	70	54	31	67	84	40	37	3	12
Potentilla type	0	1	0	1	3	2	2	3	1
Quercus	4	11	6	6	14	9	14	11	11
Rhamnus	0	0	1	0	1	0	0	2	0
Rosaceae	0	0	1	0	0	0	1	4	11
Rumex	0	0	0	2	0	4	1	6	0
Scabiosa	1	1	0	0	0	0	2	2	22
Taxodiaceae	0	0	0	0	0	0	0	1	0
Trifolium	0	0	0	2	1	0	0	0	1
Trilete spore	3	4	4	0	7	5	0	6	3
Vicia type	0	0	0	0	0	0	0	0	1
Zelkova	2	0	0	0	0	0	0	0	0
Indeterminate	6	7	3	0	6	6	6	11	31

A2.5 Raw pollen counts for SLS203 moss transect.

	SLS203/M1	**SLS203/M2**	**SLS203/M4**	**SLS203/M5**	**SLS203/M6**	**SLS203/M7**
Anthemis type	1	0	0	0	0	2
Apiaceae	0	0	0	1	0	0
Artemisia	0	1	139	3	1	8
Asteraceae	2	7	2	8	7	0
Astragalus	0	1	0	0	0	1
Betula	0	0	0	0	2	0
Bidens type	4	8	19	7	5	1
Campanula	0	0	0	0	4	1
Caryophyllaceae	2	1	3	3	12	6
Centaurea	0	0	180	0	6	7
Chenopodiaceae	8	8	31	92	162	150
Cupressaceae	0	0	0	2	3	0
Cyperaceae	1	0	0	3	2	0
Ephedra	0	0	0	0	0	3
Gallium	0	0	0	0	0	1
Genista	0	0	0	0	3	22
Geranium	0	0	0	0	7	0
Hippophae	0	0	0	0	3	3
Hypericum	0	0	0	0	2	0
Lactuceae	37	57	9	12	16	13
Liliaceae	2	0	2	0	2	1
Monolete spore	24	46	2	6	8	6
Papaver	0	0	0	17	6	1

Pinus	0	1	1	6	9	8
Pistacia	0	0	0	5	2	1
Plantago	1	0	1	6	5	4
Poaceae	9	6	5	21	14	5
Poaceae Cereal type	6	12	1	6	2	5
Quercus	3	8	6	35	16	26
Ranunculus	0	0	1	0	0	2
Rhamnus	1	0	0	0	2	0
Rosaceae	3	2	0	15	21	21
Rumex	2	1	2	13	1	3
Scabiosa	0	0	0	0	1	0
Senecio type	0	0	1	0	0	0
Trilete spore	16	18	0	1	2	6
Vicia type	0	0	3	0	0	0
Indeterminate	1	1	5	6	7	4

A2.6 Raw pollen counts for SLS207 front-back transect.

	SLS207/1	**SLS207/2**	**SLS207/3**	**SLS207/4**	**SLS207/5**	**SLS207/6**	**SLS207/S1**
Apiaceae	5	2	0	0	0	1	0
Asteraceae	22	3	0	0	0	0	0
Asteraceae Centaurea	4	16	1	1	0	0	0
Asteraceae Matricaria-type	0	30	0	2	0	0	1
Asteraceae Senecio-type	10	95	8	10	3	3	1
Atraphaxis	0	1	0	0	0	0	0
Brassicaceae	6	4	2	4	2	4	3
Caryophyllaceae	8	1	0	4	2	9	12
Chenopodiaceae	2	0	4	1	0	5	0
Chicorioideaea	180	147	20	20	0	72	2
Cupressaceae	0	0	0	0	0	0	23
Cyperaceae	0	1	0	0	0	0	3
Ephedra	0	1	0	0	0	0	0
Fagus	0	2	0	0	0	0	0
Geranium	0	0	0	0	0	0	3
Juglans	0	0	0	0	0	0	2
Lamiaceae	3	2	0	0	0	0	0
Liliaceae	1	3	0	1	0	2	0
Mentha type	0	0	0	0	0	1	0
Monolete spore	3	1	3	3	60	132	2
Pinus	1	0	0	0	2	4	3
Pistacia	3	0	0	1	2	3	100
Plantago	0	0	0	0	0	2	8

Poaceae	13	3	8	8	4	7	31
Poaceae 40<p<30µ	2	3	0	3	0	1	0
Poaceae p<30µ	1	5	2	0	0	1	0
Poaceae cereal type	10	2	3	5	0	0	5
Polygonaceae	1	0	1	0	0	0	1
Quercus	9	2	2	14	9	11	16
Ranunculus type	2	4	0	1	0	1	0
Rumex	0	0	0	4	0	0	0
Scabiosa	0	1	0	0	0	0	0
Trilete spore	0	1	1	0	1	7	1
Tuberaria	0	0	0	0	0	0	11
Typha	0	0	0	0	0	0	1
Indeterminate	2	4	3	5	0	11	9

A2.7 Raw pollen counts for SLS210 front-back transect.

	SLS210/1	**SLS210/2**	**SLS210/3**	**SLS210/4**	**SLS210/5**	**SLS210/6**	**SLS210/7**
Anchusa-type	0	0	0	1	1	1	0
Apiaceae	13	12	3	11	3	0	1
Apiaceae clumps	2	0	0	0	0	0	0
Asteraceae	0	1	5	3	14	6	5
Asteraceae Artemisia	0	1	1	0	3	2	0
Asteraceae Centaurea	1	0	4	0	3	0	1
Asteraceae Echinops	1	0	2	1	1	0	0
Asteraceae Matricaria-type	0	6	11	29	6	3	3
Asteraceae Senecio-type	60	39	37	28	13	16	6
Asteraceae Serratula-type	2	0	0	0	0	0	0
Astragalus-type	3	0	0	0	0	0	0
Boraginaceae	7	0	0	0	0	0	0
Brassicaceae	45	40	15	27	9	21	4
Campanulaceae	0	0	0	0	2	0	6
Caryophyllaceae	9	10	8	8	4	2	7
Carpinus betutlus	0	1	0	0	0	0	1
Chenopodiaceae	1	3	2	1	0	3	0
Chicorioideae	140	194	154	250	128	76	41
Cupressaceae	0	0	2	0	0	0	5
Cyperaceae	0	0	2	0	3	1	0
Dipsacaceae	0	2	0	0	0	0	0
Ephedra	0	0	2	0	2	0	0
Eryngium	0	0	3	0	0	0	0

Fabaceae	3	0	3	10	3	4	1
Hypericum	0	1	2	0	0	0	1
Hyppopae rhamnoides	0	0	0	4	2	0	0
Liliaceae	11	7	11	7	0	3	1
Mentha-type	2	0	0	3	1	1	0
Monolete spore	3	4	2	1	7	5	11
Pinus	3	2	3	0	1	4	4
Pistacia	11	11	12	27	18	40	22
Plantago coronopus-type	4	0	4	3	1	1	1
Plantago lanceolata-type	0	3	4	2	0	0	0
Poaceae	47	47	14	21	20	27	12
Poaceae 40<p<30µ	15	20	18	34	9	5	16
Poaceae cerealia-type	21	11	22	17	14	16	13
Poaceae clumps	1	0	0	0	1	0	0
Poaceae p<30µ	23	21	11	16	5	8	5
Polygonaceae	0	0	3	1	2	1	0
Quercus	52	66	102	108	59	131	81
Ranunculaceae	0	0	1	1	0	4	7
Rhamnaceaea	1	0	0	2	3	1	0
Rumex	5	6	7	3	10	6	3
Sanguisorba	1	2	4	4	0	2	0
Saxifraga	0	0	0	0	0	3	2
Scabiosa	2	1	5	1	1	1	0
Sidertis-type	0	0	1	0	0	0	0
Sisyrinchium	2	19	3	4	1	1	1
Trilete spore	2	3	1	3	2	6	2
Indeterminate	4	18	8	12	8	6	9

A2.8 Raw pollen counts for SLS215 front-back transect.

	SLS215/1	**SLS215/2**	**SLS215/3**	**SLS215/4**	**SLS215/5**	**SLS215/S1**
Alnus	0	1	0	0	0	0
Apiaceae	0	2	6	0	1	1
Asteraceae	1	2	4	1	7	0
Asteraceae Echinops	0	0	0	0	1	0
Asteraceae Matricaria-type	0	0	1	0	1	1
Asteraceae Senecio-type	7	22	4	6	7	0
Boraginaceae	1	4	0	1	2	0
Brassicaceae	0	10	4	2	3	4
Campanulaceae	0	1	0	0	0	0
Caryophyllaceae	2	6	6	4	7	16
Chenopodiaceae	13	7	14	6	10	5
Corylus	0	1	0	0	0	1
Cupressaceae	0	0	0	2	9	6
Cyperaceae	3	0	2	1	2	0
Fabaceae	0	1	0	0	0	0
Genista	0	0	2	2	2	11
Geranium	0	1	0	0	0	1
Hypericum	0	0	0	0	0	11
Lactuceae	190	128	153	94	67	12
Liliaceae	11	6	4	2	2	1
Medicago	0	0	1	0	0	1
Mentha-type	0	1	1	0	0	0
Monolete spore	11	8	14	16	20	32

Papaveraceae	0	0	1	0	0	0
Pinus	3	6	7	15	11	11
Pistacia	0	0	0	0	1	5
Plantago	0	0	1	0	0	1
Poaceae	7	33	4	13	18	0
Poaceae 40<p<30μ	2	0	1	12	0	0
Poaceae Cerealia-type	4	4	3	18	6	0
Poaceae p< 30μ	1	0	6	2	0	0
Polygonaceae	0	2	0	0	0	0
Quercus	9	7	49	76	68	64
Ranunculus-type	6	2	3	6	9	3
Rumex	4	2	6	1	0	6
Scabiosa	0	0	0	0	0	3
Sisyrinchium	2	5	1	0	0	0
Trilete spore	5	2	4	9	26	18
Indeterminate	3	7	10	5	8	6

A2.9 Raw pollen counts for SLS218 front-back transect.

	SLS218/1	**SLS218/2**	**SLS218/3**	**SLS218/4**	**SLS218/5**	**SLS218/6**	**SLS218/S1**
Apiaceae	1	2	0	2	10	1	1
Asteraceae	8	4	2	9	2	6	0
Asteraceae Centaurea-type	35	96	4	40	10	7	1
Asteraceae Echinops	0	1	1	0	0	0	0
Asteraceae Matricaria-type	12	13	1	10	8	4	2
Asteraceae Senecio-type	32	9	9	20	6	16	15
Betula	0	0	0	0	0	0	1
Brassicaceae	2	1	2	5	1	3	23
Caryophyllaceae	0	3	0	3	2	21	5
Carpinus betulus	0	0	0	0	0	1	0
Chenopodiaceae	3	4	7	4	0	2	2
Cupressaceae	3	1	0	0	2	2	1
Cyperaceae	2	0	1	1	2	2	1
Fabaceae	1	0	0	0	0	0	0
Fagus	0	2	0	4	2	1	0
Genista	1	0	0	0	0	6	2
Geranium	0	0	0	0	3	0	0
Lactuceae	142	105	91	54	32	65	42
Liliaceae	3	2	1	1	1	7	1
Mentha-type	0	0	0	0	1	2	4
Monolete spore	0	5	10	10	5	7	7
Papaver	0	1	0	0	0	0	0
Pinus	2	1	2	3	4	5	3

Pistacia	0	0	3	11	24	24	13
Plantago	0	0	0	0	0	1	3
Poaceae	7	2	12	4	5	11	10
Poaceae 40<p<30µ	1	2	7	5	20	13	28
Poaceae Cerealia-type	3	0	2	2	9	5	3
Poaceae p< 30µ	3	0	0	1	1	3	13
Polygonaceae	3	1	0	3	0	0	0
Primulaceae	2	0	0	0	0	0	0
Quercus	18	7	5	53	126	34	18
Ranunculus-type	1	2	1	1	2	2	3
Rheum	3	1	1	0	0	0	1
Sanguisorba minor-type	3	1	0	0	0	0	0
Scabiosa	0	1	0	0	0	1	4
Sparganium	0	0	0	1	0	0	14
Trilete spore	3	0	13	1	5	5	4
Veronica-type	0	0	0	3	6	0	7
Indeterminate	6	4	3	4	3	4	5

Appendix 3

Fiacconi, M., & Hunt, C. O. (2015). Pollen taphonomy at Shanidar Cave (Kurdish Iraq): An initial evaluation. Review of Palaeobotany and Palynology, 223, 87-93.

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Appendix 4

Fiacconi, M., & Hunt, C. O. (2017). Palynology of surface sediments from caves in the Zagros Mountains (Kurdish Iraq): Patterns and processes. Review of Palaeobotany and Palynology, 239, 66-76.

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