
Chapter 3

The Holocene vegetation history of the Maltese Islands

Michelle Farrell, Chris O. Hunt & Lisa Coyle McClung

3.1. Introduction

Chris O. Hunt

The history of climate and environmental change in the lands around the Mediterranean Sea is dramatic, and our still emerging understanding has changed radically over the last 60 years and is still changing. Pioneering pollen work by Bonatti (1966) first provided evidence that relative to the Holocene (the last 11,500 years) the Late Pleistocene was a time of drought and cold in the region. But for many years alternative viewpoints held currency, especially the work of Vita-Finzi (1969) who held, on the basis of widespread Late Pleistocene gravels, that this had been a period of high precipitation. This view was finally laid to rest only in the 1980s and 1990s by further pollen work on lacustrine deposits (e.g. Bertoldi 1980; Bottema & Woldring 1984; Alessio *et al.* 1986; Follieri *et al.* 1988; Bottema *et al.* 1990), and analysis of the sedimentology and biotic components of Late Pleistocene gravels (e.g. Barker & Hunt 1995).

Vita-Finzi (1969) did, however, pioneer the recognition of the scale and impact of climatic variability within the Holocene in countries bordering the Mediterranean at a time when most researchers thought of the period as extremely stable climatically. Recognition of this climatic variability and its impacts was made more complex because of very strong patterns of human impacts in some Mediterranean countries, which were difficult to disentangle unequivocally from the climatic signal (e.g. Hunt 1998; Grove & Rackham 2003). Only with the rise of isotope-based palaeoclimate studies and high-resolution dating did it become possible to separate the climatic and anthropogenic signals (e.g. Sadori *et al.* 2008).

More recent work has started to show that within the Mediterranean Basin the overall trend and timing of Holocene climate change differs from region to region (Peyron *et al.* 2011). In broad terms, the northeast and southwest of the basin seem to be in phase,

with a dry Early Holocene becoming more humid after *c.* 4000 cal. BC, while the northwest and southeast show an opposite trend with a wetter Early Holocene and progressive desiccation after *c.* 4000 cal. BC (Hunt *et al.* 2007). Within this very broad pattern there are considerable regional differences (e.g. Finné *et al.* 2011) and in the central Mediterranean, changes in seasonality are superimposed on these trends (Peyron *et al.* 2011, 2017).

Furthermore, the impact of a series of short, intense aridification phases (some of which seem to relate to events in the North Atlantic (Vellinga & Wood 2002; Wiersma & Renssen 2006) seem to have had dramatically different degrees of severity in different parts of the basin (e.g. Asioli *et al.* 1999; Peyron *et al.* 2011; Jaouadi *et al.* 2016). In some Mediterranean countries, these extreme events had significant landscape impact (e.g. di Rita & Magri 2009; Zielhofer & Faust 2008; Zielhofer *et al.* 2010). Some of these events, at *c.* 6200, 4500, and 2300 BC, disrupted the environmental foundations of human societies, leading to changes in agricultural systems, social organization and migration. The most dramatic of these was the event at *c.* 6200 BC which seems to have triggered dispersal across the Mediterranean of people carrying Neolithic technology from Anatolia (e.g. Zilhão 2001; Weninger *et al.* 2006; Berger & Guilaine 2009; Zeder 2008), although later events also had severe consequences for people in marginal situations and coincide with major technological and societal change (e.g. Carroll *et al.* 2012; Soto-Berelov *et al.* 2015).

The scale and nature of human interference with – and shaping of – landscape and the interrelationships between human activities and climate have also emerged. Patterns of vegetation modification associated with the spread of farming and later waves of extensification and intensification have been widely reported in the northern Mediterranean countries, where agriculturalists cleared landscapes of trees (e.g.

Drescher-Schneider *et al.* 2007; Tinner *et al.* 2009), but are more subtle in the southern and eastern countries which were less heavily vegetated in the early Holocene and where pastoral activity and vegetation management were more significant (Roberts 2002; Asouti *et al.* 2015; Jaouadi *et al.* 2016). Episodes during which agricultural activity expanded and/or intensified are often marked by major valley alluviation phases in the northern Mediterranean countries (Hunt *et al.* 1992; Barker & Hunt 1995; Hunt & Gilbertson 1995; Hunt 1998). The interaction between people and environment emerges particularly from landscape-scale integrated archaeological-palaeoenvironmental surveys and by combining pollen patterns with settlement data (e.g. Malone & Stoddart 1994; Barker 1996; Barker *et al.* 1996; Stoddart *et al.* 2019).

In the Maltese Islands, Pleistocene temperate stages were characterized by fairly dense shrubby or small arboreal vegetation, slope stability and marked palaeosol formation, with calcareous tufa deposits forming around springs. Blown sands accumulated rapidly at the end of temperate stages as sea level fell, exposing the sandy sea bed to wind erosion. Pleistocene cold-stage environments were mostly rather arid, with minimal, very open vegetation. Consequently, high sediment mobility led to deposition of wind-blown loessic silts, thick – often muddy – colluvial slope deposits resulting from wash and mud-flow, and gravelly alluvium of ephemeral rivers (Hunt 1997). The presence of interglacial palaeosols and the absence of interglacial beach sediments in Pleistocene deposits around the coasts of the Maltese archipelago inclined Hunt (1997) to the view that sea level during the current (Holocene) interglacial was relatively higher than during the Last Interglacial, when sea level globally was c. 6 m above present day sea levels. Carroll *et al.* (2012) also noted that some Roman portside locations at Marsa were very close to the modern sea level. Both these observations negate the suggestions of Furlani *et al.* (2013) of long-term tectonic stability and instead suggest that generally the Maltese Islands are sinking very slowly relative to modern sea levels, most probably as the result of tectonic factors.

At the beginning of the Holocene, it is likely that the Maltese landscape was rather different from today. Sea levels were much lower – probably about 80 m below present-day sea level (Lambeck *et al.* 2011), so the major islands (Malta, Gozo, Comino and Cominotto) would have been part of one larger landmass. The legacy of Pleistocene slope and aeolian sedimentation was most probably a mantle of silty loessic sediment, which has now been mostly stripped away by erosion. Deep valleys scoured out during the Last Glaciation would have been flooded by the rising sea level in

the early Holocene, giving rise to deep inlets. During the mid- to late Holocene these inlets were infilled by sediments eroded from the Maltese landscape, producing coastal plains.

Schembri and Lanfranco (1993) inferred an early Holocene landscape covered by oak-pine sclerophyll woodland on biogeographical grounds. The early Holocene vegetation prior to human colonization was otherwise completely unknown, although evidence for burning and clearance of pine-juniper woodland appears to be present before 3262–2889 cal. BC at Marsa (Carroll *et al.* 2012). Post-colonization prehistoric environments seem to be characterized by open, often steppic landscapes, some lentisk scrub and considerable arable activity and grazing (Evans 1971; Hunt 2001, 2015; Schembri *et al.* 2009; Carroll *et al.* 2012; Marriner *et al.* 2012; Djamali *et al.* 2013; Gambin *et al.* 2016). There is a suggestion of an interruption to cereal cultivation around 2300 cal. BC, probably linked with general regional aridity at this time (Carroll *et al.* 2012). The coastal deposits seem to be marked by discontinuous sedimentation and there are issues with dating as the result of recycling and most probably intrusion of material during the coring process at some sites (Carroll *et al.* 2012; Djamali *et al.* 2013; Gambin *et al.* 2016). Strong taphonomic imprints seem to be present in pollen assemblages from archaeological sites (Hunt 2001, 2015), further complicating the process of reconstructing Holocene vegetation. Charcoal analysis at Skorba provides evidence for trees including carob, hawthorn and ash in the early Neolithic and olive, perhaps cultivated, in the later Neolithic (Trump 1966).

3.2. Palynological methods

Lisa Coyle-McClung, Michelle Farrell & Chris O. Hunt

Cores were sub-sampled for palynology with slices 1 cm thick taken for analysis and bagged in self-seal polythene bags. These were stored at 4° C in cold stores at Queen's University Belfast and Liverpool John Moores University until analysed. Sub-samples of 2.5–5 cm³ volume were taken from each sample bag.

Samples were prepared for pollen analysis following standard methods (Moore *et al.* 1991), including treatment with 10 per cent hydrochloric acid to remove carbonates, hot 10 per cent potassium hydroxide to disaggregate the sediment before sieving through 120 µm mesh to remove larger mineral and organic material, and 5 per cent sodium pyrophosphate and sieving through 6 µm mesh to remove clay-sized particles. Heavy liquid separation using sodium polytungstate at a specific gravity of 1.95 (Zabenskie & Gajewski 2007) was employed to separate the remaining mineral and organic fractions. The organic residues were stained

using aqueous safranin and mounted on microscope slides in silicone oil.

Slides were counted at a magnification of $\times 400$, with $\times 1000$ magnification and oil immersion used for critical identifications. Pollen and spores were identified using the keys of Moore *et al.* (1991), Reille (1992) and Beug (2004) and the reference collections at Queen's University Belfast and Liverpool John Moores University. Wherever possible, counts of at least 300 pollen grains per sample were made (Benton & Harper 2009, 608). Non-pollen palynomorphs (NPPs) were also identified and recorded during pollen counting.

The sum used to calculate percentages consisted of all terrestrial pollen and spores (TLPS). Percentages of taxa not included within the main sum (i.e. aquatics and NPPs) were calculated using the main sum plus the sum for the taxon group.

Pollen diagrams for the *FRAGSUS* sequences were plotted using *Tilia* (Grimm 1987) and zoned according to significant changes in the proportions of major taxa. Composite diagrams were compiled for selected taxa from the *FRAGSUS* pollen counts, those of Carroll *et al.* (2012) and Djamali *et al.* (2013), and extracted from Gambin *et al.* (2016) by measuring their pollen diagrams. The data were placed into 20-year bins and calculated and graphed in *Tilia* (Grimm 1987). All pollen diagrams were put into Adobe Illustrator for final preparation.

3.3. Taxonomy and ecological classification

Chris O. Hunt

The Maltese vegetation is in many ways comparable in physiognomy and taxonomy with that of heavily human-impacted landscapes elsewhere in the lowlands of the Mediterranean Basin, although there are differences because of the high rate of endemism in the region and in the Maltese Islands in particular (Schembri 1993). Taxonomic attribution in this study follows Reille (1992, 1995, 1998), Moore *et al.* (1991), Beug (2004) and type collections at Queen's University Belfast and Liverpool John Moores University. The taxonomic level reached is not uniform: in some cases specific identification is possible, but with some taxonomic groupings, in particular the Poaceae and Asteraceae, sub-family or family is the best that could be achieved. This is unfortunate, as members of these large taxonomic groupings have more detailed environmental requirements than can be allocated at higher taxonomic levels, but quite normal in current palynological research. In addition to the pollen and spores, a small number of NPPs were recorded in the pollen diagrams. These include fungal spores and microrrhizae, some types of green algal spores,

dinoflagellate cysts and a few microfossils of uncertain affinity. Identification follows the catalogues of Bas van Geel (i.e. van Geel 1978; van Geel *et al.* 1981, 1989, 2003) and McCarthy *et al.* (2011).

A number of semi-natural habitat-specific plant groupings may be recognized in the Maltese Islands (Table 3.1). Our palynological analyses suggest a more diverse flora existed in the past, but it is likely that similar associations existed, although not present in quite the same locations, or covering the same spatial extent as at present.

Interpretation of pollen diagrams requires attribution of taxa to ecological groupings. Scrutiny of the literature and field experience amongst the *FRAGSUS* environmental team suggests that taxa encountered during pollen counting can be attributed to one or more of the semi-natural plant communities shown in Table 3.1. The attribution of palynologically recognized taxa to plant communities appropriate for the Maltese Islands is shown in Table 3.2.

3.4. Taphonomy

Chris O. Hunt & Michelle Farrell

It has long been recognized that the relationship between pollen-producing vegetation and pollen arriving at depositional settings is far from straightforward, and that further changes to assemblages occur after deposition. Taphonomy (Efremov 1940; Behrensmeyer & Kidwell 1985) is the study of this relationship between life and death assemblages – in the case of pollen and spores it includes the processes of production by the parent plants, dispersal into the environment, transportation by animal vectors, wind and water, deposition and burial by sedimentary processes, post-depositional alteration by decay and diagenetic processes, extraction from sediments and investigation by palynologists (for a recent review see Hunt & Fiacconi 2018). Most pollen taphonomic work has dealt with peat bogs and lakes – fairly simple environments with well-defined taphonomic pathways and generally good pollen preservation, but in the case of the *FRAGSUS Project*, sediments laid down in these environments were not available for study. Therefore, sediments deposited in coastal shallow marine and marginal marine settings were sampled in the *FRAGSUS* boreholes, as previous work (Carroll *et al.* 2012) shows that pollen and other palynomorphs are preserved in these waterlogged deposits. We also sampled soils and redeposited soils associated with archaeological sites where these seemed potentially viable for palynology. Such sites are widely acknowledged to be highly challenging to the palynologist since preservation is frequently poor and subject to

Table 3.1. Semi-natural plant communities in the Maltese Islands (partly after Schembri 1993).

Association	Characteristic taxa	Comments	Palynology
Sclerophyll woodland	Pine (<i>Pinus halepensis</i>), holm oaks (<i>Quercus ilex</i> , <i>Quercus</i> spp.), with oleaster (<i>Olea europaea</i>) and carob (<i>Ceratonia siliqua</i>), and understorey of lentisk (<i>Pistacia lentiscus</i>), buckthorn (<i>Rhamnus lycioides</i>), hawthorn (<i>Crataegus</i> spp.) and a ground flora including polypody fern (<i>Polypodium</i> spp.), and ivy (<i>Hedera</i> spp.)	Very small stands of probably secondary woodland, strongly impacted by human activity and mostly situated on steep rocky ground. Today there are also more-or-less recent plantations, often characterized by non-native pines	Woodland trees, most notably pines, are mainly wind-pollinated. They produce substantial quantities of pollen and their height enables them to disperse their pollen widely. Pine pollen disperses over immense distances and is highly resistant to decay
Maquis	Oleaster (<i>Olea europaea</i>), lentisk (<i>Pistacia lentiscus</i>), carob (<i>Ceratonia siliqua</i>), buckthorn (<i>Rhamnus lycioides</i>), yellow germander (<i>Teucrium flavum</i>), white hedgenettle (<i>Prasium majus</i>)	Scrub, often characterized by thorny, glaucous or aromatic shrubs. There are fairly extensive areas of maquis in rocky areas on the sides of <i>widien</i> , at the foot of inland cliffs and on abandoned farmland. Carob seems to have been a late prehistoric introduction. Today Maltese maquis is often dominated by introduced eucalypts	Many maquis species are insect-pollinated. They produce little pollen which typically is not widely dispersed
Garrigue	Conehead thyme (<i>Thymus capitatus</i>), Maltese yellow kidney-vetch (<i>Anthyllis hermanniae</i>), tree germander (<i>Teucrium fruticans</i>), erica (<i>Erica multiflora</i>), Maltese spurge (<i>Euphorbia melitensis</i>), squill (<i>Scilla</i> spp.) and other geophytes	Low scrub, often characterized by cushion-shaped low bushes and clumps of plants. It is extensive in the Maltese Islands, some natural, but some resulting from degradation of woodland or maquis	Many garrigue plants are insect-pollinated and produce little pollen which is usually not widely dispersed
Steppe	Esparto (<i>Lygeum spartum</i>), other grasses (e.g. <i>Hyparrhenia pubescens</i> , <i>Andropogon distachyos</i> , <i>Brachypodium retusum</i> , <i>Phalaris truncata</i> , <i>Stipa capensis</i> , <i>Aegilops geniculata</i>), thistles (<i>Carlina involuocrata</i> , <i>Notobasis syriaca</i> , <i>Galactites tomentosa</i>), plantains (<i>Plantago</i> spp.), sandworts and allies (Caryophyllaceae), asphodels (<i>Asphodelus aestivus</i>), and other lilies (e.g. <i>Urginea maritima</i>)	Steppe habitats are often dominated by grasses with an admixture of other herbaceous plants and bulbs. In degraded steppes, the proportion of spiky plants such as thistles, unpalatable plants like wormwood, bulbs including asphodels, rosette plants such as plantains, ephemerals such as sandworts and the lettuce group (Lactuceae) tends to rise relative to the grasses	Some steppe plants, such as grasses, are wind-pollinated and produce abundant pollen. Grass pollen is difficult to identify beyond the family level. Pollen of thistles and the lettuce group, although insect-pollinated, are particularly durable so often present in larger proportions in pollen assemblages than their parent plants are in the vegetation. Again, pollen of these taxa cannot often be identified beyond family or sub-family level
Coastal	Grasses (<i>Elymus farctus</i> , <i>Sporobolus arenarius</i> , <i>Ammophila arenaria</i>), seakale (<i>Salsola</i>), glasswort (<i>Salicornia</i>) and other Chenopods (Chenopodiaceae), sea-lavender (<i>Limonium</i> -type), thrift (<i>Armeria</i> -type), rock samphire (<i>Crithmum</i>)	Coastal habitats include saltmarshes, dunes and shallow saline rocky soils adjacent to coasts. Dunes are very rare in the Maltese Islands. They are typically characterized by specialized grasses. Saltmarshes are marked by sea-lavender and some chenopods. The saline coastal soils are characterized by rock samphire and sea-lavender	Coastal grasses and chenopods are not separable palynologically from other members of their families, but very high percentages of chenopod pollen are often associated with saltmarshes. Sea lavender and thrift are indistinguishable palynologically. Apart from the grasses, most coastal taxa are insect pollinated and are low pollen producers.
Rupestral	Caper bush (<i>Capparis spinosa</i>), Maltese rock centaury (<i>Palaeocyanus crassifolius</i> , the National Plant of Malta) and Maltese cliff orache (<i>Atriplex lanfrancoi</i>)	Rock faces and boulder scree have a highly specialized flora and provide important refuges for endemic plants	Most rupestral taxa are insect-pollinated and are low pollen producers. Their pollen is often not widely dispersed
Freshwater	Reeds (<i>Phragmites australis</i>), mints (<i>Mentha</i>), buttercups (<i>Ranunculus</i>), knotgrass (<i>Persicaria</i>), poplar (<i>Populus alba</i>), willows (<i>Salix pedicellata</i> , <i>Salix alba</i>), elm (<i>Ulmus canescens</i>), bay (<i>Laurus nobilis</i>)	Wetlands are very rare in the Maltese Islands, and perennial wetlands are vanishingly rare. There are few semi-permanently wet valley-floors, characterized by dense stands of reeds with other wetland taxa such as mints, buttercups and knotgrass. There are also a few patches of relict riverine woodland characterized by poplars, willows, elms and bay	Reeds are not distinguishable palynologically from other members of the grass family. Most of the other herbaceous water plants are insect-pollinated. The waterside woodland trees are wind-pollinated and fairly prolific pollen producers, except for the insect-pollinated bay. Poplar pollen is not durable and rarely preserves, while bay pollen is completely non-durable

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Table 3.1 (cont.).

Association	Characteristic taxa	Comments	Palynology
Disturbed	Ironwort (<i>Sideritis</i>), nettles (<i>Urtica</i>), figworts (<i>Scrophularia</i>), borage (<i>Borago officinalis</i>), mustards (Brassicaceae), honeyworts (<i>Cerinth</i>), bindweeds (<i>Convolvulus arvensis</i> -type), spurge (<i>Euphorbia</i>), bedstraws (<i>Galium</i>), purslane (<i>Portulaca oleracea</i>), corn salad (<i>Valerianella</i>)	Disturbed habitats result from human and geomorphic activity (for instance landslides). The disturbed ground species are mostly annuals which mature quickly and disperse seeds prolifically	These species are insect-pollinated and generally low pollen producers
Cultivated	Corn cockle (<i>Agrostemma githago</i>), cow wheat (<i>Melampyrum</i>), love-in-a-mist (<i>Nigella</i>), knotweed (<i>Polygonum aviculare</i>), carob (<i>Ceratonia siliqua</i>), cereals, barley (<i>Hordeum</i>), wheat (<i>Triticum</i>), eucalypts (<i>Eucalyptus</i>), vines (<i>Vitis</i>)	Agricultural weeds such as corn cockle, cow wheat, love-in-a-mist are aliens which arrived with early agricultural plants. Olives only seem to have been domesticated quite late in prehistory	Most, apart from the cereals, are insect-pollinated. All are low pollen producers, but cereal pollen is shed in quantity during threshing

Table 3.2. Attribution of pollen taxa to plant communities in the Maltese Islands and more widely in the Central Mediterranean. Taxa where the indicated ecology is followed by an asterisk are suggested not to be native to the Maltese Islands during the Holocene because of a combination of (1) absence of macrofossil evidence (2) extremely low or very sporadic pollen counts (3) incompatible ecology. Catholic = not ecologically determinate.

Pollen taxon	Ecology
<i>Abies</i>	high montane forest*
<i>Betula</i>	montane forest*
<i>Carpinus</i>	montane forest*
<i>Corylus</i> -type	montane forest*
<i>Fagus</i>	montane forest*
<i>Ostrya</i>	montane forest*
<i>Quercus</i> (deciduous type)	montane forest
<i>Tilia</i>	montane forest*
<i>Hedera</i>	woods
<i>Helleborus</i>	woods
<i>Helleborus viridis</i> -type	woods
<i>Ilex aquifolium</i>	woods
<i>Osmunda regalis</i>	woods
<i>Pinus</i>	woods
<i>Polypodium</i>	woods
<i>Pteridium aquilinum</i>	woods
<i>Quercus</i>	woods
<i>Quercus ilex</i> -type	woods
<i>Daphne</i>	maquis
<i>Ephedra</i>	maquis
<i>Erica</i>	maquis
Ericaceae	maquis
<i>Fumana</i>	maquis
<i>Juniperus</i>	maquis
<i>Ligustrum</i> -type	maquis
<i>Olea europaea</i>	maquis
<i>Origanum</i>	maquis
<i>Phillyrea</i>	maquis

Pollen taxon	Ecology
<i>Pistacia</i>	maquis
<i>Rhamnus</i> -type	maquis
Rosaceae	maquis
<i>Rosmarinus</i> -type	maquis
<i>Salvia officinalis</i> -type	maquis
<i>Scabiosa</i>	garrigue, maquis, disturbed sites
<i>Centaurium</i>	garrigue
<i>Scilla</i> -type	garrigue
<i>Spergularia media</i> -type	garrigue, rocky places, sand
<i>Tuberaria</i>	garrigue, rocky places
<i>Linum</i>	garrigue, rocky places
Rubiaceae	garrigue, rocky places
<i>Adiantum capillus-veneris</i>	rocky places
<i>Campanula</i>	rocky places
<i>Centranthus ruber</i> -type	rocky places
<i>Gladiolus</i>	rocky places
<i>Linaria</i> -type	rocky places
<i>Sedum</i> -type	rocky places
<i>Theligionum</i>	rocky places
<i>Scrophularia</i>	disturbed, rocky
<i>Borago officinalis</i>	disturbed, rocky, weed of cultivation
Brassicaceae	disturbed, rocky, weed of cultivation
<i>Cerinth</i>	disturbed, rocky, weed of cultivation
<i>Convolvulus arvensis</i> -type	disturbed, rocky, weed of cultivation

Table 3.2 (cont.).

Pollen taxon	Ecology
<i>Euphorbia</i>	disturbed, rocky, weed of cultivation
<i>Galium</i>	disturbed, rocky, weed of cultivation
<i>Portulaca oleracea</i>	disturbed, rocky, weed of cultivation
<i>Valerianella</i>	disturbed, rocky, weed of cultivation
<i>Sideritis</i>	disturbed, weed of cultivation
<i>Urtica</i>	disturbed, weed of cultivation
<i>Agrostemma githago</i>	weed of cultivation
<i>Melampyrum</i>	weed of cultivation
<i>Nigella</i>	weed of cultivation
<i>Polygonum aviculare</i> -type	weed of cultivation
<i>Centaurea cyanus</i>	weed of cultivation
<i>Cerantonia siliqua</i>	cultivated
Cereal-type	cultivated
<i>Eucalyptus</i>	cultivated
<i>Vitis</i>	cultivated
<i>Centaurea</i>	steppe, garrigue, rocky places
<i>Sanguisorba minor</i> -type	steppe, garrigue, rocky places
<i>Acacia</i>	steppe
<i>Ambrosia</i> -type	steppe
<i>Arenaria</i> -type	steppe
<i>Artemisia</i>	steppe
<i>Asphodelus</i>	steppe
<i>Botrychium</i>	steppe
<i>Carduus</i> -type	steppe
<i>Carlina/Onopordum</i> -type	steppe
<i>Hippophae</i>	steppe
<i>Limonium</i>	steppe
<i>Lygeum spartum</i>	steppe
<i>Malva sylvestris</i> -type	steppe
<i>Matricaria</i> -type	steppe
<i>Ophioglossum</i>	steppe
<i>Plantago lanceolata</i> -type	steppe
<i>Plantago major/media</i> -type	steppe
<i>Rumex obtusifolius</i>	steppe
<i>Scabiosa columbaria</i> -type	steppe
<i>Succisa</i> -type	steppe
<i>Allium</i> -type	dry catholic

Pollen taxon	Ecology
Caryophyllaceae	dry catholic
Chenopodiaceae	dry catholic
<i>Cirsium</i> -type	dry catholic
<i>Cistus</i>	dry catholic
Dipsacaceae	dry catholic
<i>Helianthemum</i>	dry catholic
Lactuceae	dry catholic
<i>Lathyrus</i>	dry catholic
<i>Polygala</i>	dry catholic
<i>Potentilla</i> -type	dry catholic
<i>Senecio</i> -type	dry catholic
<i>Acanthus</i>	catholic
Apiaceae	catholic
Asteroidae	catholic
Cyperaceae	catholic
Fabaceae	catholic
<i>Gentiana</i>	catholic
Lamiaceae	catholic
<i>Lotus</i> -type	catholic
Poaceae	catholic
Pteropsida (monoete)	catholic
Pteropsida (trilete)	catholic
<i>Ranunculus</i>	catholic
<i>Rubus</i>	catholic
<i>Rumex</i>	catholic
<i>Tamarix</i>	catholic
<i>Trifolium</i> -type	catholic
<i>Valeriana officinalis</i> -type	catholic
<i>Alnus</i>	waterside*
<i>Equisetum</i>	waterside
<i>Filipendula</i>	waterside
<i>Mentha</i> -type	waterside
<i>Littorella</i> -type	waterside
<i>Persicaria maculosa</i> -type	waterside
<i>Ranunculus acris</i> -type	waterside
<i>Sphagnum</i>	waterside
<i>Typha</i>	emergent aquatic
<i>Isoetes</i>	aquatic
<i>Potamogeton</i>	aquatic
<i>Sparganium</i> -type	aquatic

major taphonomic alteration (Edwards *et al.* 2015). It was therefore necessary to understand the taphonomic pathways associated with these depositional environments in the Maltese Islands.

Surface sediment samples were taken in the Mistra Valley on Malta, and from the shallow marine inlet into which it drains, to explore the influence of pedogenic processes and marine sedimentation on

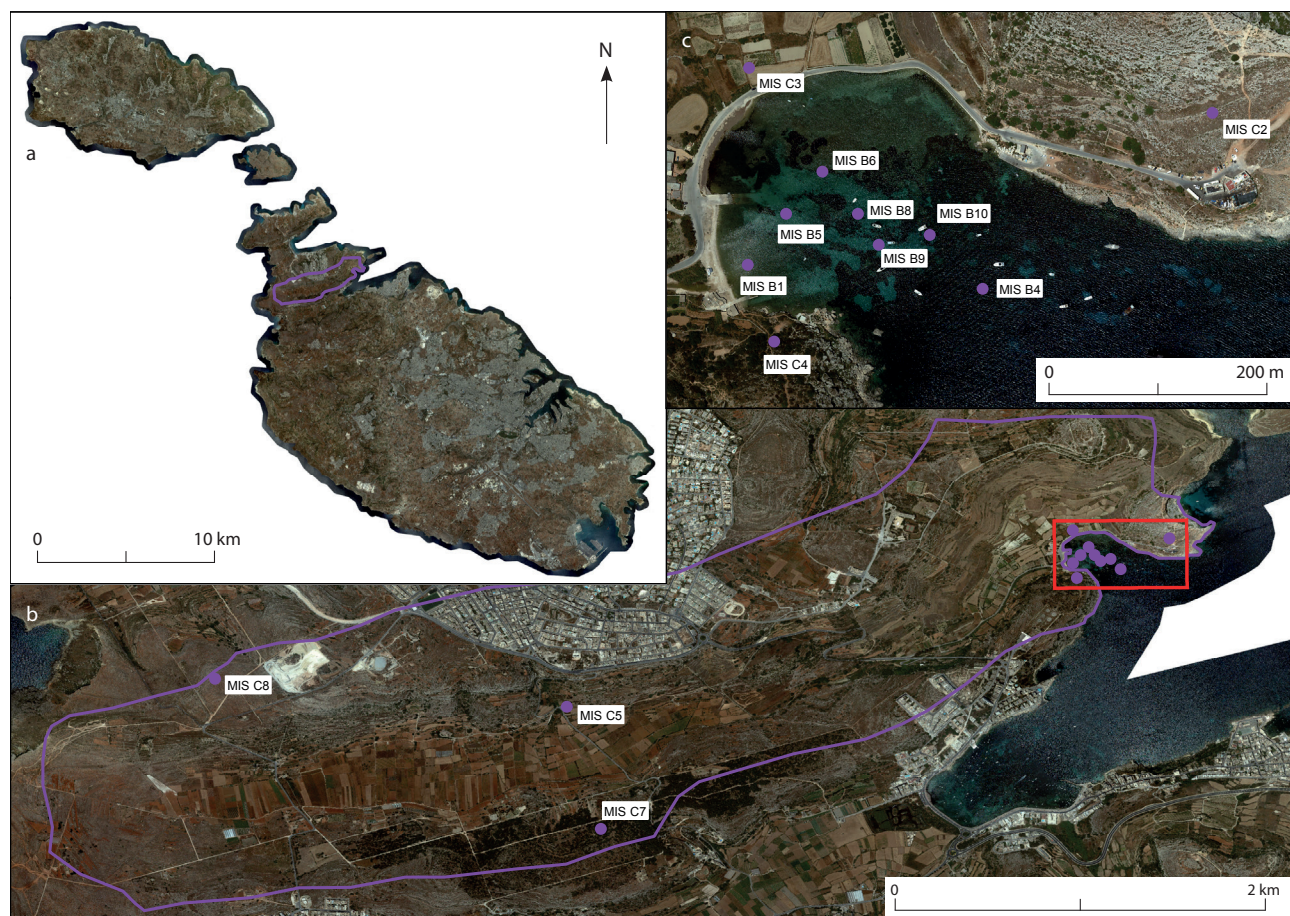


Figure 3.1. Valley catchments and core locations in the Mistra area of Malta: a) location of the Mistra catchment; b) locations of onshore surface sediment samples from the Mistra catchment; c) locations of the remaining onshore surface sediment samples from the Mistra catchment and offshore surface sediment samples from Mistra Bay (M. Farrell).

pollen assemblages within a restricted area which is likely to have had relatively uniform pollen rain (Fig. 3.1; Table 3.3). The Mistra Valley was selected because, compared with many other localities in the Maltese Islands, traditional agricultural land-uses are still present and the intensity of anthropogenic alteration of semi-natural vegetation is comparatively low. Stands of planted pines are present in the valley, mostly on higher ground, and although oak woodland is not present within the valley it is present on the slopes of the adjacent Pawles Valley. It therefore offers a reasonable, but not perfect analogue for pre-modern land-uses and the type of depositional environments sampled in this project.

Strong taphonomic biases are most probably seen in all samples (Table 3.3; Fig. 3.2). Comparing these biases is instructive for the interpretation of the *FRAGSUS* core and archaeological site assemblages. The onshore samples were obtained from microbially active, strongly oxidative environments affected by

seasonal cyclic wetting and drying and are likely analogues for samples from archaeological sites and buried soils. These environments are not suitable for long-term survival of pollen unless rapid burial occurs. In situations of rapid burial, pollen may survive because bacteria and fungi preferentially scavenge other types of organic material which are less resistant to attack than the sporopollenin from which plants make the resistant exine of pollen and spores (Moore *et al.* 1991). Here well represented taxa are widely acknowledged to be resistant to microbial attack and oxidation, principally *Pinus*, Lactuceae and various Asteraceae such as *Senecio*-type (Haviga 1964, 1967). Nevertheless, some indications of land use and vegetation are also present, for instance the cereal pollen and agricultural weeds like Chenopodiaceae in C3, derived from an arable field, maquis plants such as *Olea europaea*, *Phillyrea*, and *Ceratonia siliqua* in samples C5 and C7 where scrub is present, and the extremely high *Pinus* associated with pine scrub woodland in C7. Additionally, Florenzano

Table 3.3. Characteristics of the taphonomic samples from on-shore and off-shore Mistra Valley, Malta.

Sample code	Ecology of Location	Major palynological characteristics	Key accessory characteristics
MIS C2	Limestone pavement with low garrigue Dominant species: Poaceae, <i>Asphodelus</i> sp., <i>Psoralea bituminosa</i> , <i>Urginea maritima</i> Also present: <i>Sedum</i> sp., <i>Cirsium</i> sp., <i>Galactites tomentosa</i> , <i>Fumana</i> sp., <i>Lotus</i> sp., <i>Foeniculum vulgare</i>	<i>Pinus</i> 28%, Lactuceae 41%, <i>Senecio</i> -type 11%, Poaceae 4%	<i>Cirsium</i> -type 3%, <i>Asphodelus</i> 2%, Brassicaceae 2%, <i>Sedum</i> -type, <i>Linum</i> , <i>Carlina/Onopordum</i> -type, <i>Rumex</i> , Rosaceae, Apiaceae, <i>Acanthus</i> , Asteroideae, <i>Euphorbia</i> , <i>Mentha</i> -type present
MIS C3	Border between small arable fields close to the sea Dominant species: cultivars (wheat, beans, potatoes), Poaceae, <i>Borago officinalis</i> , Brassicaceae Also present: <i>Calendula arvensis</i> , <i>Senecio bicolor</i> , <i>Adonis microcarpa</i> , <i>Ficus carica</i>	<i>Pinus</i> 15%, Chenopodiaceae 12%, Lactuceae 42%, Poaceae 4%, Brassicaceae 11%, Cereal-type 7%	Caryophyllaceae 2%, <i>Senecio</i> -type 2%, Asteroideae 2%, <i>Sedum</i> -type, <i>Linum</i> , <i>Cirsium</i> -type, <i>Centaurea</i> , <i>Rumex</i> , Rosaceae, Apiaceae, <i>Tamarix</i> present
MIS C4	Coastal maquis Dominant species: <i>Erica</i> sp., <i>Ceratonia siliqua</i> , <i>Pistacia lentiscus</i> , <i>Prasium majus</i> , Poaceae, <i>Foeniculum vulgare</i> , <i>Rosa</i> sp., Asteraceae Also present: <i>Hedera helix</i> , <i>Asphodelus</i> sp., <i>Teucrium</i> sp., <i>Cirsium</i> sp., <i>Galium</i> sp., <i>Fumana</i> sp., <i>Psoralea bituminosa</i>	<i>Pinus</i> 57%, Ericaceae 5%, <i>Asphodelus</i> 11%, Lactuceae 14%	Poaceae 2%, <i>Ceratonia siliqua</i> 2%, <i>Quercus</i> , <i>Acacia</i> , <i>Carlina/Onopordum</i> -type, <i>Cirsium</i> -type, <i>Centaurea</i> , Caryophyllaceae, <i>Senecio</i> -type, <i>Rumex</i> , Rosaceae, Asteroideae, Poaceae, Brassicaceae, <i>Tamarix</i> present
MIS C5	Abandoned agricultural terrace with regenerating scrub Dominant species: Poaceae, <i>Ceratonia siliqua</i> , <i>Eucalyptus</i> sp., <i>Foeniculum vulgare</i> , <i>Asparagus aphyllus</i> , <i>Lotus</i> sp. Also present: <i>Cirsium</i> sp., <i>Galactites tomentosa</i> , <i>Arundo donax</i>	<i>Pinus</i> 40%, Lactuceae 35%, <i>Senecio</i> -type 10%, Poaceae 5%	<i>Cirsium</i> -type 2%, Brassicaceae 2%, <i>Linum</i> , <i>Carlina/Onopordum</i> -type, <i>Centaurea</i> , <i>Asphodelus</i> , Chenopodiaceae, <i>Helianthemum</i> , Rosaceae, Apiaceae, Asteroideae, <i>Euphorbia</i> , <i>Ceratonia siliqua</i> , Cereal-type, <i>Tamarix</i> present
MIS C7	Semi-open pine scrub/maquis Dominant species: <i>Pinus halepensis</i> , <i>Olea europaea</i> Also present: <i>Acacia</i> , <i>Asparagus aphyllus</i> , Poaceae	<i>Pinus</i> 97%	<i>Olea europaea</i> , <i>Phillyrea</i> , Poaceae, <i>Eucalyptus</i> present
MIS C8	Limestone pavement with low garrigue Dominant species: <i>Thymus capitatus</i> , Poaceae, <i>Carlina involucrata</i> , <i>Urginea maritima</i> Also present: <i>Aster squamatus</i> , <i>Atractylis gummifera</i> , <i>Euphorbia melitensis</i> , <i>Asphodelus aestivus</i> , <i>Allium</i> sp., <i>Asparagus aphyllus</i>	<i>Pinus</i> 22%, Lactuceae 40%, <i>Senecio</i> -type 12%, Poaceae 3%	<i>Carlina/Onopordum</i> -type 2%, <i>Sanguisorba minor</i> -type 2%, Chenopodiaceae 2%, <i>Euphorbia</i> 2%, Ericaceae, <i>Tuberaria</i> , <i>Scilla</i> -type, <i>Plantago lanceolata</i> -type, <i>Cirsium</i> -type, <i>Artemisia</i> , <i>Lygeum spartum</i> , <i>Asphodelus</i> , <i>Helianthemum</i> , <i>Allium</i> -type, <i>Rumex</i> , Fabaceae, <i>Eucalyptus</i> , <i>Tamarix</i> present
MIS B1	Shallow marine. Nearshore, shallow, sandy bottom	<i>Pinus</i> 15–30%, Chenopodiaceae 3–11%, Lactuceae 3–20%, Rosaceae 1–7%, Poaceae 5–14%, Brassicaceae 4–12%	<i>Quercus</i> 2–5%, <i>Ostrya</i> 0–9%, Ericaceae 0–7%, <i>Sedum</i> -type 0–9%, <i>Plantago lanceolata</i> -type 0–6%, <i>Carlina/Onopordum</i> -type 0–4%, <i>Artemisia</i> 0–2%, Caryophyllaceae 0–2%, <i>Helianthemum</i> 0–3%, <i>Senecio</i> -type 0–11%, <i>Matricaria</i> -type 0–4%, <i>Rumex</i> 0–6%, Asteroideae 0–5%, Cyperaceae 0–3%, <i>Eucalyptus</i> 0–4%, <i>Ceratonia siliqua</i> 0–4%, Cereal-type 0–5%, <i>Alnus</i> 0–2%, <i>Tamarix</i> 0–4%, <i>Mentha</i> -type 0–1%, <i>Littorella</i> -type 0–2%
MIS B4	Shallow marine. Deeper water, eelgrass meadow		
MIS B5	Shallow marine. Shallow, sandy bottom		
MIS B6	Shallow marine. Shallow, sandy bottom on edge of eelgrass meadow		
MIS B8	Shallow marine. Deeper water, eelgrass meadow		
MIS B9	Shallow marine. Deeper water, sandy bottom		
MIS B10	Shallow marine. Deeper water, eelgrass meadow		

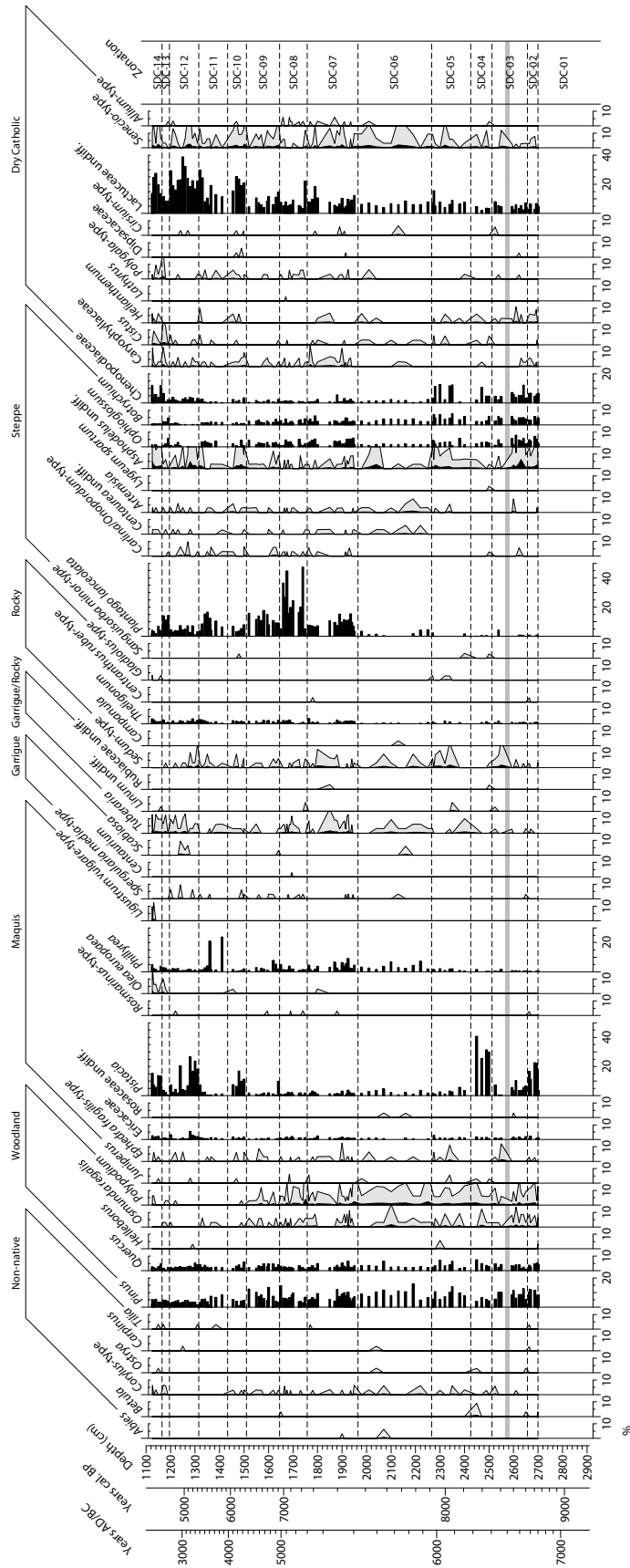


Figure 3.3. Pollen zonation for the Salina Deep Core (L. Coyle-McClung, C.O. Hunt & M. Farrell).

Table 3.4. The pollen zonation of the Salina Deep Core with modelled age-depths.

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC (BP) for zone bases (2 σ)	Characteristics	Interpretation
SDC-01	None	3000–2710		Little to no pollen present	Palaeosols and gravels virtually lacking organic matter. A few isolated grains of <i>Pistacia</i> , Poaceae, Lactuceae
SDC-02	<i>Pistacia</i> - Poaceae- <i>Pinus</i>	2710–2660	7042–6553 BC (8992–8503 BP)	<i>Pinus</i> increasing (8–10%), low <i>Quercus</i> (4%). <i>Pistacia</i> rising (5–20%), Ericaceae low (0.5–1%), <i>Phillyrea</i> present. Poaceae high but declining (20–40%). Some Asteroideae (8–15%), Lactuceae, <i>Ophioglossum</i> , <i>Botrychium</i> (2–8%), Chenopodiaceae (4–6%), <i>Asphodelus</i> , Cyperaceae (1–3%), <i>Theligonum</i> , <i>Plantago lanceolata</i> -type. <i>Persicaria maculosa</i> -type present. <i>Pseudoschizaea</i> decreasing (10–20%). Vesicular arbuscular mycorrhizae (VAMs) and <i>Tripterospora</i> -type also present	Lentisk-dominated scrub, dry grassy steppe, some pine-oak woodland, some wetland, soil disturbance declining
SDC-03	Poaceae- <i>Pistacia</i>	2660–2510	6858–6419 BC (8808–8369 BP)	<i>Pinus</i> fluctuating (5–11%), <i>Quercus</i> low (1–4%), <i>Pistacia</i> declines (4–10%), <i>Phillyrea</i> and Ericaceae present. Poaceae increase (30–48%), Asteroideae (14–20%) and Chenopodiaceae rise (3–12%), some Lactuceae, <i>Ophioglossum</i> , <i>Botrychium</i> (2–8%), and <i>Asphodelus</i> (1–5%). <i>Theligonum</i> , <i>Sedum</i> -type, <i>Helianthemum</i> , Cyperaceae present. <i>Pseudoschizaea</i> fluctuates (2–16%), <i>Tripterospora</i> -type and VAMs present. A layer at 25.75 m contains no organic material (highlighted in Fig. 3.3)	Dry grassy steppe, with some scrub and a little woodland, some wetland, episodically disturbed soils
SDC-04	<i>Pistacia</i> - Poaceae- Asteroideae	2510–2430	6489–6135 BC (8439–8085 BP)	<i>Pistacia</i> high and rising (15–40%), <i>Pinus</i> low (4–6%), <i>Quercus</i> rising (2–7%). <i>Phillyrea</i> and Ericaceae present. Poaceae (15–20%), Asteroideae high and declining (10–18%). <i>Theligonum</i> , <i>Ophioglossum</i> , <i>Botrychium</i> , Chenopodiaceae low and declining, <i>Helianthemum</i> , Lactuceae and Cyperaceae low (1–3%). Aquatics present, including <i>Potamogeton</i> . <i>Pseudoschizaea</i> and VAMs present	Steppe partly being replaced by lentisk scrub and with oak woodland expanding slightly, some wetland, soils less disturbed than previously
SDC-05	Poaceae- <i>Pistacia</i> - Asteroideae	2430–2265	6350–6037 BC (8300–7987 BP)	Low <i>Pinus</i> (6–12%), <i>Quercus</i> rising (1–6%). <i>Pistacia</i> declines (6–2%), low <i>Phillyrea</i> (0.5–2%) and Ericaceae, <i>Theligonum</i> , <i>Tuberaria</i> , <i>Helianthemum</i> present. Asteroideae high (15–38%). Poaceae high and rising (15–36%), Lactuceae (6–16%), Cyperaceae (6–8%), Chenopodiaceae (0–12%), <i>Sedum</i> (0–2%), <i>Ophioglossum</i> (3–8%), <i>Botrychium</i> (1–8%) and <i>Asphodelus</i> (1–2%) all increase. <i>Persicaria maculosa</i> -type present. <i>Pseudoschizaea</i> rises significantly (5–30%), other NPPs present include VAMs, <i>Podospora</i> -type, <i>Tripterospora</i> -type and <i>Valsaria varispora</i> -type	Steppe with a little woodland, scrub and wetland, with some eroding soils
SDC-06	Cerealia- Poaceae- <i>Pinus</i> - <i>Phillyrea</i>	2265–1965	6067–5821 BC (8017–7771 BP)	<i>Pinus</i> peaks (6–16%). <i>Quercus</i> (2–6%) and <i>Pistacia</i> (0.5–5%) both low, <i>Phillyrea</i> rises (1–8%). <i>Ephedra fragilis</i> -type, Ericaceae, <i>Tuberaria</i> , <i>Sedum</i> -type, <i>Theligonum</i> and <i>Asphodelus</i> are present. <i>Ophioglossum</i> (1–2%), <i>Botrychium</i> (2–6%) and Chenopodiaceae (0.5–3%) have low peaks in the middle of the zone. Poaceae (28–44%) and Asteroideae (15–22%) are high, and Lactuceae (4–9%) fairly high. The Cerealia-types <i>Hordeum</i> and <i>Avena/Triticum</i> are first recorded and <i>Plantago lanceolata</i> -type peaks early in the zone and rises again at the end. <i>Convolvulus arvensis</i> -type, <i>Urtica</i> , <i>Sideritis</i> , <i>Borago officinalis</i> and Brassicaceae are present. <i>Typha</i> and <i>Persicaria maculosa</i> -type are present. <i>Pseudoschizaea</i> initially increases from 15–44% before declining to 22%. <i>Diporothea rhizophila</i> -type and <i>Tripterospora</i> -type expand slightly, and <i>Sordaria</i> -type appears for the first time	Steppe with a little woodland, scrub and wetland. Initiation of cereal cultivation and livestock grazing with some indicators of disturbed ground and significant fungal indicators of disturbed ground and animal dung

The Holocene vegetation history of the Maltese Islands

Table 3.4 (cont.).

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC (BP) for zone bases (2σ)	Characteristics	Interpretation
SDC-07	<i>Plantago lanceolata</i> - <i>Cerealia</i> - <i>Poaceae</i>	1965–1755	5625–5419 BC (7575–7369 BP)	<i>Pinus</i> declines slightly (2–10%), <i>Quercus</i> and <i>Pistacia</i> low and rising slightly (2–5%), <i>Phillyrea</i> falling after a low peak (1–7%), Ericaceae, <i>Sedum</i> -type, <i>Theligionum</i> and <i>Tuberaria</i> rise slightly (0.5–3%). <i>Plantago lanceolata</i> -type increases (5–16%), <i>Ophioglossum</i> , <i>Botrychium</i> , Chenopodiaceae (1–5%), Lactuceae (6–12%) and Asteroideae (22–34%) rise slightly while Poaceae decrease (16–30%). Brassicaceae, <i>Convolvulus arvensis</i> -type, <i>Urtica</i> , <i>Hordeum</i> -type and <i>Avena/Triticum</i> -type are present. <i>Persicaria maculosa</i> -type and <i>Typha</i> are present. <i>Pseudoschizaea</i> high and fluctuating (15–45%). VAMs rise slightly (0.5–2%). <i>Diporothea rhizophila</i> -type, <i>Tripterospora</i> -type and <i>Podospora</i> -type remain low. <i>Sordaria</i> -type and <i>Valsaria varispora</i> -type are occasionally present	Steppe with slightly declining minor woodland, with scrub increasing slightly. Strong indications of grazing and the spread of short-grazed grassland, some indications of grazing pressure. Continued cereal cultivation, and strong soil erosion
SDC-08	<i>Plantago lanceolata</i> - <i>Poaceae</i> - <i>Cerealia</i> - <i>Asteroideae</i>	1755–1650	5404–5145 BC (7354–7095 BP)	<i>Pinus</i> rising (6–14%). <i>Quercus</i> (1–4%), <i>Pistacia</i> (0.5–2%), <i>Phillyrea</i> (0.5–4%), Ericaceae, <i>Tuberaria</i> , <i>Theligionum</i> are all low. <i>Plantago lanceolata</i> -type rises strongly (15–42%). <i>Ophioglossum</i> , <i>Botrychium</i> , Chenopodiaceae and Cyperaceae remain low (1–4%). Lactuceae peak and fall (5–20%). Asteroideae (12–22%) and Poaceae (14–30%) remain high. <i>Convolvulus arvensis</i> -type, Brassicaceae, <i>Borago officinalis</i> and <i>Urtica</i> increase slightly. <i>Avena/Triticum</i> -type and <i>Hordeum</i> -type are present. <i>Persicaria maculosa</i> -type and <i>Typha</i> are present. <i>Pseudoschizaea</i> highly variable (5–45%), VAMs rise slightly (1–3%), <i>Diporothea rhizophila</i> -type, <i>Podospora</i> -type and <i>Tripterospora</i> -type increase slightly. <i>Sporormiella</i> -type makes its only appearance in the profile and <i>Cercophora</i> -type, <i>Valsaria varispora</i> -type, <i>Sordaria</i> -type and <i>Chaetomium</i> -type are occasionally present	Steppe with minor scrub and woodland. Further expansion of short-grazed grassland with grazing animals indicated by dung fungi. Some cultivation of wheat and barley and marked phases of soil erosion
SDC-09	<i>Plantago lanceolata</i> - <i>Poaceae</i> - <i>Pinus</i> - <i>Cerealia</i> - <i>Asteraceae</i>	1650–1510	5202–4759 BC (7152–6709 BP)	<i>Pinus</i> (5–15%) and <i>Quercus</i> (1–5%) peak in the middle of the zone. <i>Pistacia</i> (1–9%) and <i>Phillyrea</i> (<1%–6) decline sharply near the base of the zone. Ericaceae, <i>Theligionum</i> , <i>Tuberaria</i> and <i>Spergularia media</i> -type are present. <i>Plantago lanceolata</i> -type (7–16%) declines at the beginning of the zone then rises again. <i>Ophioglossum</i> , <i>Botrychium</i> , Chenopodiaceae (1–3%) and Cyperaceae (3–6%) remain low. Asteroideae and Poaceae remain significant (20–30%). <i>Convolvulus arvensis</i> -type, Brassicaceae, <i>Galium</i> , <i>Sideritis</i> and <i>Urtica</i> are present but sporadic, and cereals are represented by <i>Hordeum</i> -type. <i>Persicaria maculosa</i> -type and <i>Typha</i> are present. <i>Pseudoschizaea</i> (6–52%) highly variable but peaks in the middle of the zone. VAMs, <i>Diporothea rhizophila</i> -type and <i>Tripterospora</i> -type present consistently. <i>Podospora</i> -type, <i>Sordaria</i> -type, <i>Chaetomium</i> -type and <i>Arniium</i> -type occasionally present	Steppe with woodland and a little scrub. There was a slight recovery of woodland, but scrub seems to have been cleared or grazed down. Grazing pressure seems to have remained strong, but cultivation may have waned locally
SDC-10	<i>Plantago lanceolata</i> - <i>Pistacia</i> - <i>Lactuceae</i>	1510–1435	4566–4177 BC (6516–6127 BP)	<i>Pinus</i> and <i>Quercus</i> low (2–6%). <i>Pistacia</i> peaks (6–18%). <i>Phillyrea</i> and Ericaceae are low (0–2%). <i>Tuberaria</i> , <i>Theligionum</i> , <i>Sedum</i> -type, <i>Asphodelus</i> , <i>Ophioglossum</i> , <i>Botrychium</i> , <i>Helianthemum</i> , <i>Polygala</i> -type and Cyperaceae are all low. <i>Plantago lanceolata</i> -type declines then rises (3–12%), Lactuceae peak (12–20%). Asteroideae (12–20%) and Poaceae (16–22%) decline slightly. <i>Convolvulus arvensis</i> -type and Brassicaceae are present. <i>Persicaria maculosa</i> -type present. <i>Pseudoschizaea</i> declines (8–13%). VAMs, <i>Diporothea rhizophila</i> -type and <i>Tripterospora</i> -type are present	Degrading steppe with encroaching scrub and a little woodland. Woodland is minor but lentisk scrub expands. Markers of degraded, perhaps rather over-grazed steppe increase but fungal spores often associated with animal dung become less frequent so it is possible that the degradation

Table 3.4 (cont.).

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC (BP) for zone bases (2σ)	Characteristics	Interpretation
					of the steppe might be climatic, or livestock were moved elsewhere. Cultivation appears to have ceased locally
SDC-11	Poaceae- <i>Plantago lanceolata</i> - <i>Phillyrea</i> - <i>Pistacia</i> - Lactuceae- Asteroideae	1435- 1320	4237-3685 BC (6187-5635 BP)	<i>Pinus</i> rises (8-10%), <i>Quercus</i> falls slightly (2-4%), <i>Pistacia</i> falls (0.5-2%). <i>Phillyrea</i> fluctuates (1-23%). <i>Tuberaria</i> , <i>Theligionum</i> , <i>Asphodelus</i> , <i>Ophioglossum</i> , <i>Botrychium</i> , Chenopodiaceae low (0-2%). <i>Plantago lanceolata</i> -type peaks (5-18%). Lactuceae (7-14%), Asteroideae (18-31%), Poaceae (12-24%) all rise then decline. Brassicaceae, <i>Convolvulus arvensis</i> -type and <i>Persicaria maculosa</i> -type all present. <i>Pseudoschizaea</i> rises, falls and rises again (12-24%) and VAMs, <i>Diporothea rhizophila</i> -type, <i>Tripterospora</i> -type and <i>Podospora</i> -type are present	Degrading steppe and scrub with a little woodland. Woodland is minor. Lentisk scrub is replaced by <i>Phillyrea</i> (false privet). Short-grazed grassland and disturbed ground indicators are present and markers for soil erosion are more prevalent than previously
SDC-12	Poaceae- <i>Pistacia</i> - <i>Plantago lanceolata</i> - Asteroideae	1320- 1195	3823-2979 BC (5773-4929 BP)	<i>Pistacia</i> rises, then declines (2-27%). <i>Quercus</i> is low and declines gently (1.5-4%). <i>Pinus</i> is low (1-5%). Ericaceae, <i>Asphodelus</i> , <i>Plantago lanceolata</i> -type (1-7%), <i>Tuberaria</i> , Chenopodiaceae, Cyperaceae and <i>Convolvulus arvensis</i> -type (0.5-2%) are all low. Lactuceae (15-37%), Asteroideae (14-27%) and Poaceae (12-26%) all fluctuate. <i>Pseudoschizaea</i> fluctuates (4-16%). VAMs (2-6%) have a low peak and <i>Diporothea rhizophila</i> -type and <i>Tripterospora</i> -type are present. <i>Valsaria varispora</i> -type is recorded at the beginning of the zone. <i>Sordaria</i> -type and <i>Arnium</i> -type appear at the end	Degrading steppe and scrub with a little woodland. Woodland is minor, lentisk replaces <i>Phillyrea</i> but then wanes. Short-grazed grassland may be replaced by taller vegetation, but there are short phases of degradation and soil erosion
SDC-13	Poaceae- <i>Pistacia</i> - Lactuceae- Asteroideae- <i>Olea</i>	1195- 1165	3047-2355 BC (4997-4305 BP)	<i>Pinus</i> , <i>Quercus</i> , <i>Pistacia</i> , <i>Phillyrea</i> , Ericaceae, <i>Tuberaria</i> , <i>Theligionum</i> , <i>Olea europaea</i> are all very low (0.5-2%). <i>Plantago lanceolata</i> -type peaks, declines then rises again (0.5-16%). <i>Botrychium</i> , <i>Ophioglossum</i> (0.5-6%), Asteroideae (12-27%) and Poaceae (15-33%) peak then decline. Lactuceae decline (8-9%). Cyperaceae (2-6%), <i>Convolvulus arvensis</i> -type and <i>Persicaria maculosa</i> -type are present. <i>Pseudoschizaea</i> declines (7-19%), while VAMs, <i>Diporothea rhizophila</i> -type, <i>Tripterospora</i> -type and <i>Podospora</i> -type all rise slightly	Steppe with very little woodland or scrub. A very open landscape characterized by grassy herbaceous vegetation with signs of grazing
SDC-14	<i>Olea</i> - <i>Ligustrum</i> - Poaceae- <i>Plantago lanceolata</i> - <i>Pistacia</i> - <i>Phillyrea</i> - Lactuceae	1165- 1125	2717-2233 BC (4667-4183 BP)	<i>Pinus</i> (4-6%), <i>Quercus</i> (1-5%), <i>Pistacia</i> (6-15%), <i>Phillyrea</i> (1-5%), <i>Olea europaea</i> , Ericaceae, <i>Tuberaria</i> , <i>Theligionum</i> , <i>Asphodelus</i> (1-2%), Chenopodiaceae (5-12%), Lactuceae (15-29%), Asteroideae (12-27%) all rise. <i>Ligustrum vulgare</i> -type appears. <i>Plantago lanceolata</i> -type (1-5%), Cyperaceae (1-6%) and Poaceae (10-14%) decline. <i>Convolvulus arvensis</i> -type and <i>Persicaria maculosa</i> -type are present. <i>Pseudoschizaea</i> (5-10%), VAMs (1-2%), <i>Diporothea rhizophila</i> -type, <i>Podospora</i> -type and <i>Tripterospora</i> -type are present	Degraded steppe and with a little scrub and woodland. The rise of scrub taxa and decline in <i>Plantago</i> may suggest declining grazing pressure, but the rise in composites and chenopods and decline in grasses might suggest a more arid landscape and/or are a sign of grazing pressure
			Top of sampled interval has an interpolated date of 2464-1979 cal. BC (4414-3929 cal. BP)		

et al. (2015) have argued that over-representation of Cichorieae, members of the Lactuceae tribe, may actually be an indicator of open habitats and grazing activity in Mediterranean landscapes, rather than the result of differential pollen preservation.

The off-shore samples provide an analogue for assemblages from shallow marine layers in the FRAGSUS cores. The assemblages are comparatively uniform (Table 3.3), characterized by lower percentages of degradation-resistant taxa (e.g. *Pinus*, Lactuceae and various Asteraceae), than are present in the onshore soil samples. These taxa are, however, still over-represented relative to their occurrence in the catchment vegetation. *Ostrya* and *Corylus*-type, which are not present in the Maltese Islands, reflect long distance dispersal by wind from Sicilian or more distant vegetation to the north. Shoreline taxa such as Chenopodiaceae and Brassicaceae are well-represented. Some anemophilous taxa, such as *Pinus*, *Quercus* and Poaceae, are over-represented relative to their occurrence in the vegetation, while several entomophilous taxa present onshore, principally maquis and garrigue species such as *Pistacia*, *Olea europaea*, *Tuberaria* and geophytes such as *Asphodelus*, are either not present or are poorly represented, although the entomophilous Asteraceae and Lactuceae are over-represented.

Although the on-shore and off-shore samples reflect the extant vegetation imperfectly as the result of these taphonomic biases, the overall aspect of that vegetation can be seen. The taphonomic biases are predictable and can therefore be allowed for in the interpretations of the palaeo-ecological sequences that follow in the next sections.

3.5. The pollen results

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Some 25 deep cores were taken from a wide selection of valley and near-shore environments on Malta and Gozo (see Chapter 2) (Fig. 2.4), but only the Salina Deep Core, Salina 4, Wied Żembaq 1 and Xemxija 1 on Malta were selected and fully analysed for their palynological records, each with an associated AMS radiocarbon chronology (Table 2.3) and age-depth models (Tables 3.4–3.7). In addition, buried soils were sampled and analysed from the Santa Verna and Ġgantija temple sites on Gozo, and the primary fill of a Bronze Age silo at In-Nuffara on Gozo.

3.5.1. The Salina cores

The results of the palynological analysis of the Salina Deep Core are shown in Figure 3.3. A total of fourteen zones, labelled SDC-01 to SDC-14, were identified and are summarized in Table 3.4. This core appears to have

a high resolution record spanning the period c. 7030–6600 cal. BC (7923 BP; UBA-34973) to 2400–2050 cal. BC (3793 BP; UBA-34970), although the coring technique caused a series of short sampling gaps. The sampled sequence was laid down during a period of rapidly rising sea level (Lambeck *et al.* 2011), so distances from the shoreline (and thus parent vegetation) to the core site will have increased during this interval. This may have impacted slightly on pollen taphonomy, although no strong trends in taphonomic indicators seem to be visible in the record. Of particular note in this core are the events in zone SDC-06 commencing at 6080–5920 cal. BC (7145 BP; UBA-35586) which appear to show the impacts of initial agricultural activity on the Maltese Islands.

The palynological results from the Salina 4 core are shown in Figure 3.4 and Table 3.5. The sampled interval in this core overlaps with the later part of the Salina Deep Core, with dates ranging from before c. 5630–5500 cal. BC (6644 BP; UBA-30090) to 1260–1050 cal. BC (2953 BP; UBA-30083) (Table 2.3).

3.5.2. Wied Żembaq

The pollen zonation for the Wied Żembaq 1 core is shown in Figure 3.5 and Table 3.6. The sampled interval runs from before c. 3630–3370 cal. BC (4707 BP; UBA-28262) to after 910–800 cal. BC at 2.15 m down-profile (2707 BP; UBA-29042). The Wied Żembaq 2 core, which was not analysed for pollen, exhibited a date range from c. 3260–2890 cal. BC (4366 BP; UBA-34969) to after 1880–1630 cal. BC at 2.95 m down-profile (3428 BP; UBA29043).

3.5.3. Xemxija

The pollen zonation for the Xemxija 1 core is shown in Figure 3.6 and Table 3.7. The sampled interval here runs from c. 8780–8460 cal. BC (9353 BP; UBA-25001) to some time in the twentieth century when natural deposition was terminated by the emplacement of quarried material (made ground) to produce a dry area for scout camping. Age control at the base of this core is, however, problematical and assemblages from the part of the core below 6.6 m show signs of significant taphonomic bias. It is also rather probable that there are major erosive discontinuities in the core, especially below pollen zone XEM-05, dated to c. 4330–4050 cal. BC (5357 BP; UBA-29041). Sedimentation above this level seems to have been more continuous, but there are significant taphonomic biases evident in pollen zones XEM-06 and XEM-10 to XEM-13.

3.5.4. In-Nuffara

The results of pollen analysis of the primary fill of a Bronze Age silo at In-Nuffara, Gozo, are shown

Table 3.5. The pollen zonation of the Salina 4 core with modelled age-depths.

Zone	Defining taxa	Depth (cm)	Date ranges cal. bc (BP) for zone bases (2 σ)	Characteristics	Interpretation
SA-01	Chenopodiaceae-Cyperaceae	1055–1040	5608–5238 BC (7558–7188 BP)	High Chenopodiaceae (30%), Cyperaceae (29%). Some Lactuceae (12%), <i>Senecio</i> -type (4%), Asteroideae (4%), Poaceae (5%), Brassicaceae (4%). A little <i>Pinus</i> , <i>Quercus</i> , Rosaceae, <i>Matricaria</i> -type, <i>Artemisia</i> , <i>Cirsium</i> -type, <i>Asphodelus</i> and <i>Rumex</i> (0.5–2%). <i>Mentha</i> -type and <i>Potamogeton</i> present. <i>Pseudoschizaea</i> and VAMs present	An extremely open, rather degraded landscape characterized by ruderals and with coastal vegetation prominent, perhaps with some woodland at a distance. Freshwater wetlands with sedges and slow-moving waters higher in the estuary
SA-02	Lactuceae- <i>Plantago</i> -Poaceae	1040–940	5566–5130 BC (7516–7080 BP)	High <i>Plantago lanceolata</i> -type (10–24%), Lactuceae (23–36%). Some <i>Senecio</i> -type (4–9%), Chenopodiaceae (7–16%), <i>Rumex</i> (2–4%), Asteroideae (2–4%), Cyperaceae (3–6%), Poaceae (6–9%), Brassicaceae (1–4%). Low <i>Pinus</i> , <i>Quercus</i> , Rosaceae, <i>Artemisia</i> , <i>Asphodelus</i> , <i>Cirsium</i> -type, <i>Lotus</i> -type, Fabaceae (0.5–2%). <i>Olea europaea</i> , <i>Centaurea</i> , <i>Theligonum</i> , <i>Malva sylvestris</i> -type, <i>Matricaria</i> -type, <i>Tamarix</i> , <i>Euphorbia</i> , <i>Hordeum</i> -type, <i>Mentha</i> -type, <i>Littorella</i> -type sometimes present. <i>Sporormiella</i> -type, <i>Sordaria</i> -type, <i>Pseudoschizaea</i> present, <i>Cercophora</i> -type, <i>Delitschia</i> -type, <i>Tripterospora</i> -type, VAMs occasionally present	An extremely open landscape. Perhaps some woodland and scrub at a distance. Decline of ruderals suggests the vegetation is less degraded in aspect than SA-01 and there is evidence for cereal cultivation and animal grazing. Declining soil fungi suggest maybe reduced soil erosion
SA-03	Lactuceae- <i>Pistacia</i> -Chenopodiaceae	940–780	5063–4670 BC (7013–6620 BP)	High Lactuceae (18–32%), <i>Pistacia</i> (2–14%), Chenopodiaceae (10–26%). Some <i>Plantago lanceolata</i> -type (4–9%), <i>Senecio</i> -type (8–12%), <i>Rumex</i> (1–9%), Asteroideae (3–6%), Cyperaceae (2–8%), Poaceae (3–9%), Brassicaceae (2–6%). A little <i>Pinus</i> , <i>Quercus</i> , <i>Daphne</i> , Ericaceae, <i>Olea europaea</i> , Rosaceae, <i>Sedum</i> -type, <i>Theligonum</i> , <i>Malva sylvestris</i> -type, <i>Carlina/Onopordum</i> -type, <i>Artemisia</i> , <i>Asphodelus</i> , <i>Helianthemum</i> , <i>Cirsium</i> -type, <i>Tamarix</i> , Fabaceae, <i>Hordeum</i> -type, <i>Mentha</i> -type, <i>Littorella</i> -type, <i>Delitschia</i> -type, <i>Sordaria</i> -type, <i>Pseudoschizaea</i> are present, <i>Coniochaeta</i> Type A, <i>Sporormiella</i> -type, <i>Tripterospora</i> -type and VAMs are occasionally present	An open, rather degraded landscape with prominent ruderals, encroaching garrigue and scrub, woodland at a distance. Some evidence for cereal cultivation and animal grazing. Some evidence for soil erosion from the soil fungi
SA-04	Brassicaceae-Lactuceae	780–690	4431–4026 BC (6381–5976 BP)	High Brassicaceae (6–24%), Lactuceae (12–20%), Chenopodiaceae (10–30%). Some <i>Plantago lanceolata</i> -type (7–8%), Caryophyllaceae (8–10%), <i>Senecio</i> -type (4–12%), <i>Rumex</i> (2–6%), Asteroideae (1–5%), Poaceae (1–5%). A little <i>Pinus</i> , <i>Quercus</i> , <i>Pistacia</i> , <i>Olea europaea</i> , Rosaceae, <i>Sedum</i> -type, <i>Theligonum</i> , <i>Matricaria</i> -type, <i>Carlina/Onopordum</i> -type, <i>Asphodelus</i> , <i>Helianthemum</i> , <i>Cirsium</i> -type, Fabaceae, <i>Euphorbia</i> , <i>Hordeum</i> -type, <i>Ranunculus acris</i> -type, <i>Convolvulus arvensis</i> -type. <i>Delitschia</i> -type, <i>Sordaria</i> -type, <i>Pseudoschizaea</i> and VAMs are present, <i>Sporormiella</i> -type is occasionally present	An open, fairly degraded landscape with prominent ruderals and with a little scrub and woodland. There is evidence for cereal cultivation and animal grazing and for some soil erosion
SA-05	Lactuceae-Caryophyllaceae- <i>Plantago</i>	690–590	4077–3716 BC (6027–5666 BP)	High Lactuceae (21–22%), Caryophyllaceae (10–28%), <i>Plantago lanceolata</i> -type (10%). Some Chenopodiaceae (2–8%), <i>Senecio</i> -type	An open, rather degraded landscape with prominent ruderals, rising ephemerals, and some scrub and

The Holocene vegetation history of the Maltese Islands

Table 3.5 (cont.).

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC (BP) for zone bases (2σ)	Characteristics	Interpretation
				(2–10%), <i>Rumex</i> (2–6%), Asteroideae (1–6%), Cyperaceae (1–12%), Poaceae (1–5%), Brassicaceae (2–11%). A little <i>Pinus</i> , <i>Quercus</i> , Rosaceae, <i>Centaurea</i> , <i>Sedum</i> -type, <i>Theligonum</i> , Rubiaceae, <i>Plantago media/major</i> -type, <i>Artemisia</i> , <i>Asphodelus</i> , <i>Cirsium</i> -type, <i>Tamarix</i> , Fabaceae, <i>Euphorbia</i> , <i>Ranunculus acris</i> -type, <i>Agrostemma githago</i> . <i>Vitis</i> and <i>Hordeum</i> -type are occasionally present. <i>Delitschia</i> -type, <i>Sordaria</i> -type, <i>Pseudoschizaea</i> and VAMs are present, <i>Sporormiella</i> -type and <i>Tripterospora</i> -type are sometimes present	woodland at a distance. There is some evidence for cereal cultivation, grazing and soil erosion
SA-06	Caryophyllaceae-Lactuceae	590–420	3386–2560 BC (5336–4510 BP)	High Caryophyllaceae (28–45%) and Lactuceae (8–16%). Some <i>Pistacia</i> (2–4%), <i>Plantago lanceolata</i> -type (1–20%), Chenopodiaceae (8–10%), <i>Senecio</i> -type (2–5%), <i>Rumex</i> (1–5%), Asteroideae (1–7%), Cyperaceae (2–8%), Poaceae (2–9%), Brassicaceae (2–8%). A little <i>Pinus</i> , <i>Quercus</i> , <i>Olea europaea</i> , Rosaceae, <i>Carlina/Onopordum</i> -type, <i>Asphodelus</i> , <i>Cirsium</i> -type, <i>Tamarix</i> , <i>Agrostemma githago</i> , <i>Hordeum</i> -type, Ericaceae, <i>Sedum</i> -type, Rubiaceae, <i>Matricaria</i> -type, <i>Polygala</i> -type, Fabaceae, Apiaceae, <i>Urtica</i> are occasionally present. <i>Sordaria</i> -type and <i>Pseudoschizaea</i> are present	An open, very degraded, probably rather dry landscape with some scrub and distant woodland. Ruderals and ephemerals prominent. Some evidence for cereal cultivation and a little animal grazing. Soil erosion was present but perhaps a little less prevalent than in earlier zones
SA-07	Lactuceae-Asteroideae	420–315	2220–1885 BC (4170–3805 BP)	High Lactuceae (15–25%), Asteroideae (6–14%). Some <i>Plantago lanceolata</i> -type (2–9%), Chenopodiaceae (3–6%), Caryophyllaceae (1–8%), <i>Senecio</i> -type (1–4%), <i>Rumex</i> (1–9%), Cyperaceae (0–11%), Poaceae (1–7%), Brassicaceae (1–3%). Some Ericaceae, Rosaceae, <i>Theligonum</i> , <i>Artemisia</i> , <i>Asphodelus</i> , <i>Cistus</i> , <i>Cirsium</i> -type, Fabaceae. <i>Pinus</i> , <i>Quercus</i> , <i>Daphne</i> , <i>Linum</i> , <i>Acacia</i> , <i>Plantago media/major</i> -type, <i>Agrostemma githago</i> , <i>Centaurea cyanus</i> -type, <i>Hordeum</i> -type, <i>Vitis</i> , <i>Ranunculus acris</i> -type, <i>Littorella</i> -type occasionally present. <i>Delitschia</i> -type, <i>Sporormiella</i> -type, <i>Sordaria</i> -type, <i>Pseudoschizaea</i> and VAMs sometimes present	An open, rather degraded landscape with ruderals and ephemerals prominent. Some scrub and garrigue and a little distant woodland. Arable agriculture and animal grazing were present and there were pulses of soil erosion at the bottom and top of the zone
SA-08	Chenopodiaceae	315–300	1326–1064 BC (3276–3014 BP)	Chenopodiaceae dominant (97%). Caryophyllaceae, Asteroideae, Brassicaceae are also present in small amounts	Probably a strong taphonomic imprint. Little can be deduced regarding the landscape, but the Chenopodiaceae include saltmarsh, coastal and exposed open ground taxa, including arable weeds
			Top of sample interval has an interpolated date of 1259–1006 cal. BC (3209–2956 cal. BP)		

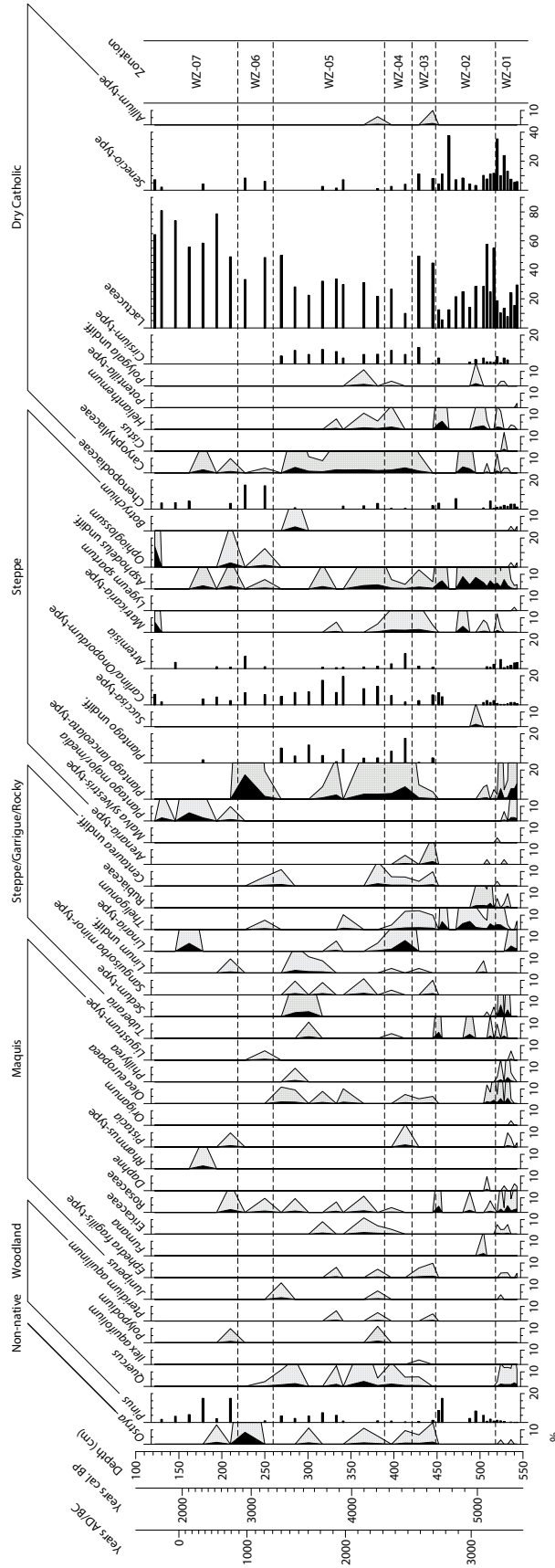


Figure 3.5. Pollen zonation for the Wied Zembra 1 core (M. Farrell).

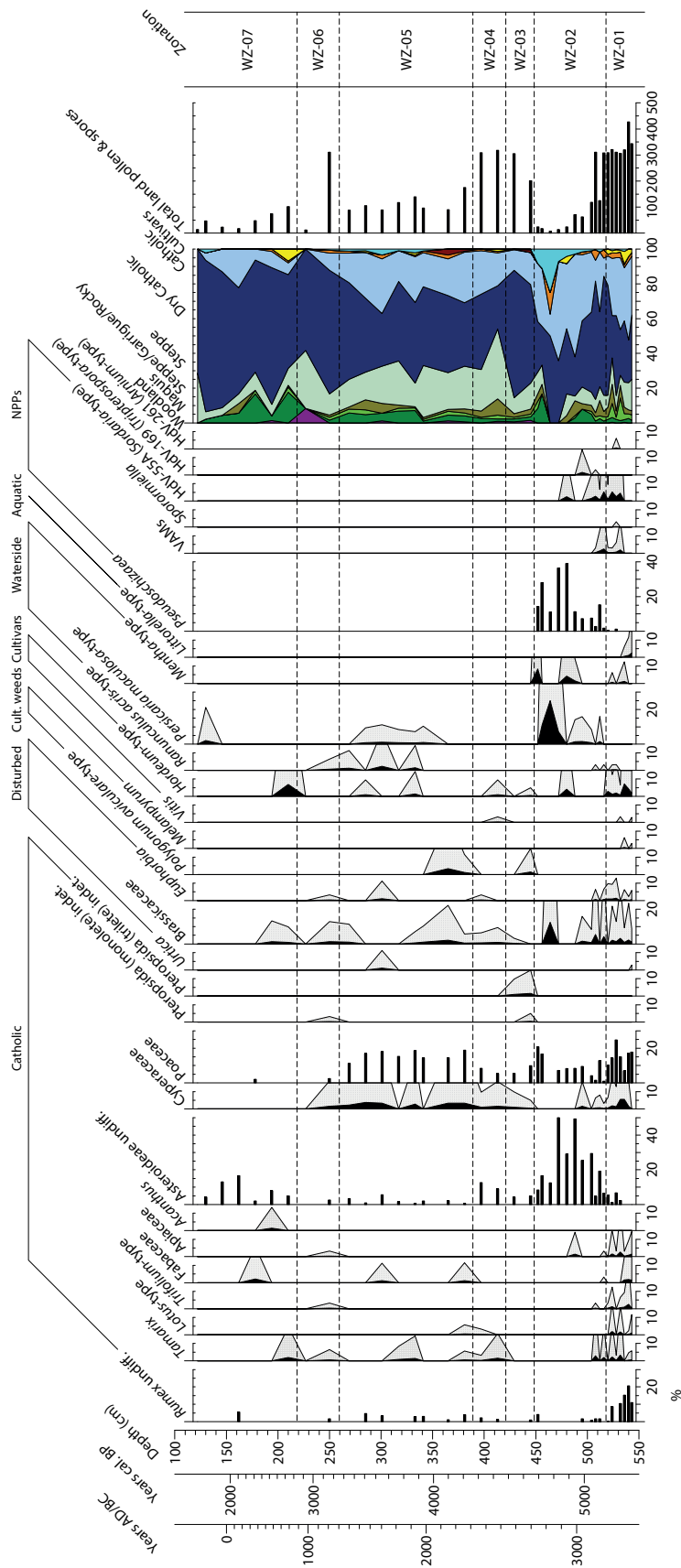


Figure 3.5 (cont.).

Table 3.6. The pollen zonation of the Wied Żembaq 1 core with modelled age-depths.

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC (BP) for zone bases (2σ)	Characteristics	Interpretation
WZ-01	Lactuceae-Poaceae-Senecio-type-Rumex	550–520	3587–3352 BC (5537–5302 BP)	High Lactuceae (9–30%), Poaceae (7–25%), <i>Senecio</i> -type (5–37%), <i>Rumex</i> (10–20%) and <i>Plantago lanceolata</i> -type (1–11%). Some <i>Pinus</i> , <i>Quercus</i> , <i>Olea europaea</i> , <i>Ephedra fragilis</i> -type, Rosaceae, <i>Phillyrea</i> , <i>Sedum</i> -type, <i>Theligonum</i> , <i>Asphodelus</i> , Chenopodiaceae, <i>Helianthemum</i> , <i>Tamarix</i> , <i>Lotus</i> -type, <i>Trifolium</i> -type, Apiaceae, Cyperaceae, Brassicaceae, <i>Euphorbia</i> , <i>Hordeum</i> -type, <i>Mentha</i> -type and <i>Littorella</i> -type (>2%). <i>Vitis</i> is occasionally present. <i>Sordaria</i> -type, <i>Arnium</i> -type, <i>Sporormiella</i> -type, VAMs and <i>Pseudoschizaea</i> are sometimes present	A predominantly open landscape mosaic with grassland indicators, ruderals and ephemerals, some taxa typical of scrub and garrigue. There are indicators of cereal cultivation and grazing animals
WZ-02	Asteroidae-Lactuceae-Senecio-type-Poaceae	520–450	3330–3047 BC (5280–4997 BP)	Some very low counts, particularly in the top half of this zone. Very high Asteroidae (6–49%), high Lactuceae (6–54%), <i>Senecio</i> -type (2–38%), Poaceae (4–22%). Some <i>Pinus</i> (0–18%), <i>Theligonum</i> (0–5%), <i>Asphodelus</i> (0–8%), Brassicaceae (0–12%), <i>Persicaria maculosa</i> -type (0–23%). <i>Pseudoschizaea</i> are very high (2–39%). <i>Sordaria</i> -type, <i>Tripterospora</i> -type and VAMs are occasionally present	A very open degraded landscape with some intermittent cereal cultivation and animal grazing and very strong soil erosion. It is likely that these assemblages bear a strong taphonomic imprint consistent with erosion and redeposition of material from soil profiles since many common grains in this zone are known to be highly resistant to degradation and preferentially preserved in soils. It may therefore reflect a cluster of significant erosion and sedimentation events
WZ-03	Lactuceae-Senecio-type-Poaceae	450–420	2922–2542 BC (4872–4492 BP)	Very high Lactuceae (45–51%) with some <i>Senecio</i> -type (8–11%), Poaceae (8–12%), <i>Cirsium</i> -type (1–12%) and Asteroidae (5–6%). A little <i>Ostrya</i> , <i>Quercus</i> , <i>Olea europaea</i> , <i>Ephedra fragilis</i> -type, <i>Theligonum</i> , <i>Centaurea</i> , <i>Plantago lanceolata</i> -type, <i>Matricaria</i> -type, <i>Asphodelus</i> , Caryophyllaceae, and Cyperaceae. <i>Ilex aquifolium</i> , <i>Sanguisorba minor</i> -type, <i>Arenaria</i> -type, Chenopodiaceae, Brassicaceae, <i>Polygonum aviculare</i> -type and <i>Hordeum</i> -type are sometimes present	A very open landscape with a little scrub and woodland at a distance. It is likely, given the high percentage of degradation-resistant grains, that soil erosion continued but this could also reflect a vegetation dominated by ruderals and ephemerals. There are indications of a little cereal cultivation but the lack of dung fungi in this zone makes it difficult to be sure that animals were grazing
WZ-04	Lactuceae- <i>Plantago</i> -Asteroidae-Poaceae	420–390	2728–2322 BC (4678–4272 BP)	High Lactuceae (10–28%), <i>Plantago</i> spp. (7–18%), Asteroidae (9–12%), Poaceae (6–9%), <i>Cirsium</i> -type (7–10%), <i>Artemisia</i> (4–10%). Some <i>Linaria</i> -type (1–7%), <i>Carlina</i> / <i>Onopordum</i> -type (1–5%), <i>Senecio</i> -type (2–4%). A little <i>Ostrya</i> , <i>Pinus</i> , <i>Quercus</i> , <i>Theligonum</i> , <i>Centaurea</i> , <i>Matricaria</i> -type, <i>Asphodelus</i> , Caryophyllaceae, <i>Tamarix</i> , Cyperaceae, Brassicaceae. <i>Pistacia</i> , <i>Olea europaea</i> , Ericaceae, <i>Tuberaria</i> , <i>Sanguisorba minor</i> -type, <i>Linum</i> , <i>Arenaria</i> -type, <i>Helianthemum</i> , <i>Vitis</i> , <i>Hordeum</i> -type are occasionally present	An open landscape with a little scrub and distant woodland. Soil erosion probably continued but at a reduced rate and parts of the landscape may have started to stabilize. Taxa such as <i>P. lanceolata</i> and <i>Artemisia</i> are consistent with animal grazing; cereal agriculture and vine cultivation were also present

Table 3.6 (cont.).

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC (BP) for zone bases (2σ)	Characteristics	Interpretation
WZ-05	Lactuceae-Poaceae- <i>Carlina</i> / <i>Onopordum</i> -type- <i>Plantago</i> - <i>Cirsium</i> -type	390–260	2529–2104 BC (4479–4054 BP)	Lactuceae (25–51%) very high. High Poaceae (15–20%), <i>Carlina</i> / <i>Onopordum</i> -type (6–20%), <i>Plantago</i> spp. (5–16%), <i>Cirsium</i> -type (4–10%). Some Asteroideae (1–6%). <i>Ostrya</i> , <i>Pinus</i> , <i>Quercus</i> , <i>Olea europaea</i> , Rosaceae, <i>Sanguisorba minor</i> -type, <i>Asphodelus</i> , Caryophyllaceae, <i>Helianthemum</i> , <i>Senecio</i> -type, <i>Rumex</i> , Cyperaceae, Brassicaceae, <i>Ranunculus acris</i> -type and <i>Persicaria maculosa</i> -type are often present	A very open steppic landscape with abundant ruderals and ephemerals. Some distant woodland but little scrub. Abundant <i>Plantago</i> suggests a great deal of animal grazing. Cereal cultivation was present at times. Areas of wetland were present. High Lactuceae and other degradation-resistant grains suggest continuing soil erosion
WZ-06	Lactuceae-Chenopodiaceae- <i>Carlina</i> / <i>Onopordum</i> -type	260–220	1501–1120 BC (3451–3070 BP)	Very low count size in uppermost sample of this zone. Very high Lactuceae (33–47%) and high Chenopodiaceae (16–17%). <i>Carlina</i> / <i>Onopordum</i> -type (9–11%), <i>Plantago lanceolata</i> -type (2–18%), <i>Senecio</i> -type (7–9%), <i>Artemisia</i> (1–8%) are present in all samples	An extremely open, eroding landscape with abundant ruderals and ephemerals. <i>Plantago</i> most probably reflects animal grazing. The high Chenopodiaceae most probably represents nearby saltmarsh vegetation in this coastal locality
WZ-07	Lactuceae- <i>Pinus</i> -Asteroideae	220–120	1021–819 BC (2971–2769 BP)	Some low counts in this zone, particularly towards the top. Very high Lactuceae (54–81%), high <i>Pinus</i> (2–17%) and Asteroideae (2–16%). <i>Plantago major/media</i> -type, <i>Carlina</i> / <i>Onopordum</i> -type, Chenopodiaceae are present in most samples	An extremely degraded steppic landscape with woodland at a distance and marked by strong soil erosion. The vegetation was characterized by ruderals and ephemerals, with nearby saltmarsh. It is possible that the relatively high <i>Pinus</i> reflects low local pollen productivity enhancing the regional pollen signal, rather than an expansion of woodland
			Top of sampled interval has an interpolated date of cal. AD 47–763 (1903–1187 cal. BP)		

in Figure 3.7 and Table 3.8. Chronological control is provided by radiocarbon dates on cereal grains recovered from the basal fills, ceramic typology and pollen biostratigraphy. The pollen analyses show significant taphonomic biases but generally suggest extremely open environments.

3.5.5. Santa Verna

Pollen analyses of the buried soil preserved below the floor sequence of the temple structure at Santa Verna, Gozo, exposed by the archaeological investigation, are summarized in Tables 3.9 and 3.11 and Figure 3.8. Pollen counts are very low and the assemblages are very small and probably taphonomically influenced, but the assemblages from the B horizon of the buried soil (contexts SV2/2, 2/3, 5/1, 5/2; see Chapter 5), which most likely dates from the earlier Neolithic,

do not show strong evidence that corrosion resistant taxa are present in percentages typical of microbially active, strongly oxidizing environments, as seen in modern soils (Fig. 3.2; Table 3.3). This, along with the very high percentages of spores of liverwort and other lower plants is perhaps consistent with a perennially humid, local sheltered location and deposition in very damp sediments. The *Peridinium* cysts are suggestive of unshaded, mildly eutrophic freshwater. The later assemblage from the buried lower organic (Ah) horizon (context SV2/1) is too small for reliable interpretations to be made.

The combination of very abundant thermally mature (charred) material, plant cell walls and cuticle and fungal hyphae is typical of middens, while the high inertinite in the upper part of Santa Verna 2 (Fig. 3.8) is very typical of seasonally wet biologically active soils.

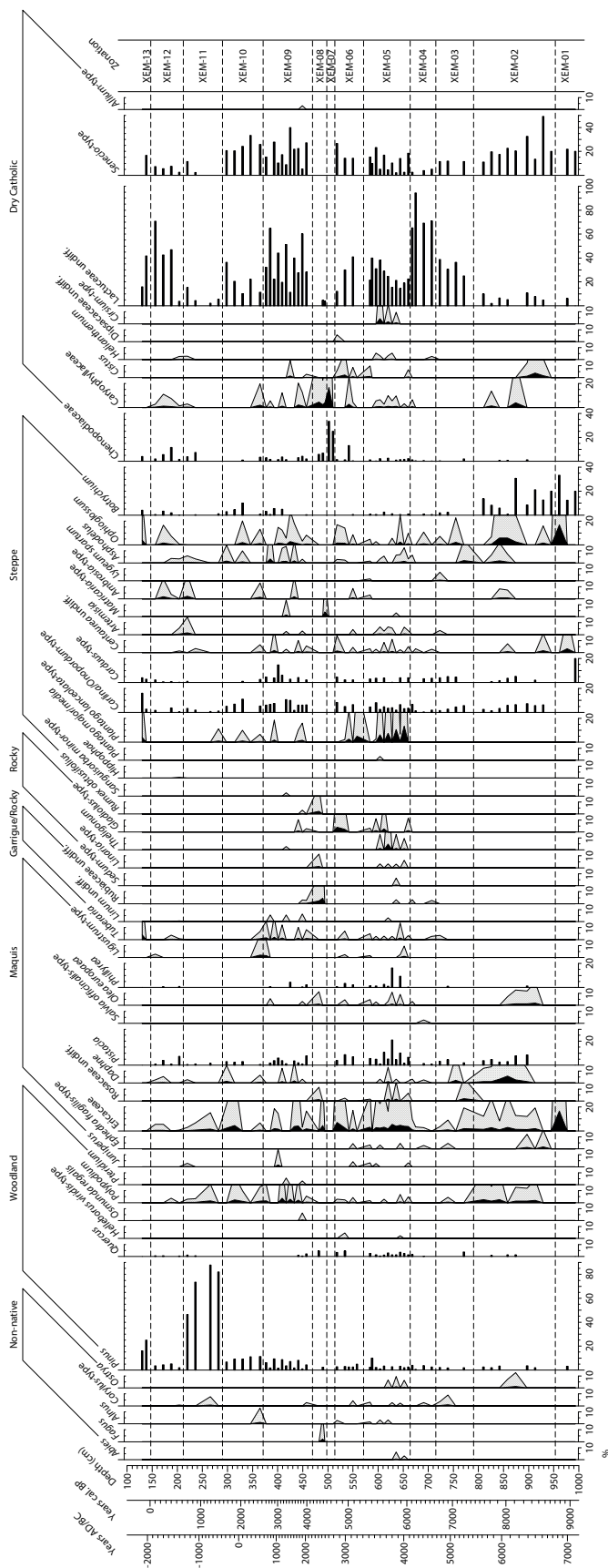


Figure 3.6. Pollen zonation for the Xemxija 1 core (M. Farrell & L. Coyle-McClung).

Table 3.7. The pollen zonation of the *Xemxija 1* core with modelled age-depths.

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC/AD (BP) for zone bases (2σ)	Characteristics	Interpretation
XEM-01	<i>Botrychium</i> - Poaceae	1000– 950	7675–6861 BC (9625–8811 BP)	Extremely low pollen counts. High <i>Botrychium</i> (11–32%) and Poaceae (6–34%) with sporadic but strong occurrences of Pteropsida (trilete) (0–38%), <i>Senecio</i> -type (0–23%), Cyperaceae (0–20%), <i>Carduus</i> -type (0–19%), <i>Ophioglossum</i> (0–16%), Ericaceae (0–15%), Lactuceae (0–6%) and the occasional presence of <i>Pinus</i> , <i>Persicaria maculosa</i> -type and <i>Sphagnum</i> . <i>Pseudoschizaea</i> is common (12–54%) and <i>Tripterospora</i> -type is present in one sample	The very limited pollen counts and the high percentages of spores and other degradation-resistant grains constrain confident interpretation but assemblages are consistent with an open, grassy, virtually treeless steppe with ephemerals and ruderals prominent and with some scrub. The high percentages of <i>Pseudoschizaea</i> may reflect eroding soils
XEM-02	<i>Senecio</i> -type- <i>Botrychium</i> - Pteropsida (Trilete)-Poaceae	950–790	7066–6444 BC (9016–8394 BP)	Low pollen counts. High <i>Senecio</i> -type (10–48%), Pteropsida (trilete) (2–39%), <i>Botrychium</i> (1–30%), Poaceae (6–11%). Some <i>Pinus</i> , <i>Quercus</i> , <i>Olea europaea</i> , Ericaceae, <i>Pistacia</i> , <i>Daphne</i> , <i>Carlina</i> / <i>Onopordum</i> -type, <i>Asphodelus</i> , <i>Ophioglossum</i> , Lactuceae, <i>Persicaria maculosa</i> -type. Very high <i>Pseudoschizaea</i> (75–87%), a few VAMs, some <i>Sordaria</i> -type, <i>Tripterospora</i> -type, <i>Podospora</i> -type and <i>Debarya</i> sp.	The low pollen counts and considerable proportion of degradation-resistant grains constrain interpretation. Nevertheless, assemblages are consistent with an open grassy steppe with some ruderals and ephemerals, some scrub and distant woodland. Locally, a wetland with standing water is suggested by the green alga <i>Debarya</i> and the wetland taxa, while the very high <i>Pseudoschizaea</i> is consistent with considerable soil erosion
XEM-03	Lactuceae- Cyperaceae- Poaceae	790–715	5722–5255 BC (7672–7205 BP)	High Lactuceae (22–35%) and Cyperaceae (22–27%), some Poaceae (5–10%), <i>Carlina</i> / <i>Onopordum</i> -type (1.5–6%), Apiaceae (0–22%), <i>Senecio</i> -type (0–12%), <i>Carduus</i> -type (0–6%). <i>Pinus</i> , <i>Pistacia</i> , <i>Ophioglossum</i> and <i>Typha</i> are often present. <i>Pseudoschizaea</i> decline rapidly; VAMs and <i>Tripterospora</i> -type are present	Rising pollen counts may point to declining sedimentation rates, but the high proportion of degradation-resistant grains is consistent with continued soil erosion and complex taphonomic pathways. The rise in ephemerals and decline in grassland indicators suggests strong degradation of steppe habitats. Some scrub and wetlands were present
XEM-04	Lactuceae- Poaceae- Cyperaceae	715–660	4923–4439 BC (6873–6389 BP)	Very high Lactuceae (66–94%). Some <i>Pinus</i> , Ericaceae, Chenopodiaceae, Cyperaceae, Poaceae. <i>Persicaria maculosa</i> -type and <i>Typha</i> are occasionally present	The very high Lactuceae most likely reflect a taphonomic bias, most probably reflecting eroding soils, but may also reflect a high incidence of ephemerals and ruderals, given that <i>Pinus</i> and other degradation-resistant taxa are not heavily represented. There are hints from the rest of the assemblage of distant woodland, some scrub and wetlands with standing water, but the dominant signal is steppe
XEM-05	Lactuceae- Cyperaceae- Poaceae- <i>Senecio</i> - type- <i>Pistacia</i>	660–570	4251–3989 BC (6201–5939 BP)	High Lactuceae (15–40%), Cyperaceae (6–25%), Poaceae (4–23%), <i>Senecio</i> -type (4–22%), <i>Pistacia</i> (4–19%). Some <i>Pinus</i> (2–10%), <i>Quercus</i> (1–4%), Ericaceae (0–6%), <i>Carlina</i> / <i>Onopordum</i> -type (2–6%), <i>Plantago lanceolata</i> -type (0–14%), Chenopodiaceae (1–3%), Brassicaceae (0–9%), <i>Hordeum</i> -type (0–9%), <i>Sparganium</i> -type (0–18%).	The assemblages show a less strong taphonomic imprint than those lower in the sequence. Assemblages are consistent with a complex landscape with a mosaic of steppe, garrigue, maquis and local wetlands with perennial pools, and a little distant woodland. Soil erosion continued. There are clear signals for arable agriculture and animal grazing

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Table 3.7 (cont.).

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC/AD (BP) for zone bases (2σ)	Characteristics	Interpretation
				<i>Olea europaea</i> , Rosaceae, <i>Phillyrea</i> , <i>Tuberaria</i> , <i>Theligonum</i> , <i>Gladiolus</i> -type, <i>Carduus</i> -type, <i>Centaurea</i> , <i>Artemisia</i> , <i>Asphodelus</i> , <i>Ophioglossum</i> , <i>Botrychium</i> , Caryophyllaceae, <i>Cirsium</i> -type, <i>Ranunculus</i> , <i>Rumex</i> , Apiaceae, <i>Tamarix</i> , Asteroideae and <i>Potamogeton</i> are often present in small amounts. <i>Pseudoschizaea</i> and VAMs are present. <i>Sordaria</i> -type, <i>Cercophora</i> -type and <i>Debarya</i> sp. are often present	
XEM-06	Poaceae-Cyperaceae-Lactuceae- <i>Senecio</i> -type	570–520	3521–3102 BC (5471–5052 BP)	Count sizes very variable. High Poaceae (3–51%), Cyperaceae (11–31%), Lactuceae (0–42%), <i>Senecio</i> -type (0–27%). Some <i>Pinus</i> (4–5%), <i>Quercus</i> (0–5%), <i>Pistacia</i> (0–8%), Ericaceae (0–6%), <i>Phillyrea</i> (0–4%), <i>Plantago lanceolata</i> -type (0–5%), <i>Carlina/Onopordum</i> -type (0–9%), <i>Carduus</i> -type (0–5%), <i>Centaurea</i> (0–2%), <i>Ophioglossum</i> (0–2%), Chenopodiaceae (0–13%), <i>Cistus</i> (0–2%), <i>Ranunculus</i> (0–6%), Apiaceae (0–3%), <i>Persicaria maculosa</i> -type (0–5%). <i>Pseudoschizaea</i> , VAMs, <i>Sordaria</i> -type, <i>Cercophora</i> -type and <i>Debarya</i> sp. are sometimes present	These samples show a variable taphonomic imprint and count sizes are very variable. There are indications of a mosaic of steppe, garrigue, maquis, local wetland with standing water and distant woodland. There are signs of animal grazing
XEM-07	Chenopodiaceae-Cyperaceae-Caryophyllaceae	520–500	3048–2686 BC (4998–4636 BP)	Extremely low pollen counts. High Chenopodiaceae (26–34%), Cyperaceae (12–75%) and Caryophyllaceae (5–17%). Some <i>Persicaria maculosa</i> -type and Poaceae (0–35%)	These assemblages have very low pollen counts, but do not show a strong taphonomic imprint. They most probably derived from a very local pollen catchment. The indications are of a wetland environment with standing water and perhaps nearby saltmarsh
XEM-08	Poaceae-Asteroideae- <i>Ranunculus</i>	500–470	2824–2503 BC (4774–4453 BP)	Some low pollen counts. Very high Poaceae (34–54%). High Asteroideae (5–31%) and <i>Ranunculus</i> (4–8%). Some Ericaceae (0–6%), Rubiaceae (0–4%), Caryophyllaceae (2–5%), Chenopodiaceae (0–8%), <i>Rumex</i> (1–5%), Pteropsida (monolete) (1–10%), <i>Equisetum</i> , <i>Littorella</i> -type, <i>Potamogeton</i> and <i>Isoetes</i>	Rather small pollen counts constrain interpretation, but there appears to be fairly strong ecological coherence, suggesting that taphonomic alteration was limited. There is a strong successional pattern, suggesting marshland taxa giving way to aquatics in the local environment. It is likely that some of the Poaceae pollen reflects reeds rather than grasses. Away from the wetland was steppe, maquis and perhaps a little distant forest
XEM-09	Lactuceae- <i>Senecio</i> -type- <i>Pinus</i> - Poaceae-Cyperaceae	470–370	2401–2092 BC (4351–4042 BP)	Some low pollen counts in this zone. High Lactuceae (11–64%) and <i>Senecio</i> -type (8–38%). Some Cyperaceae (1–22%), <i>Pinus</i> (1–10%), <i>Carlina/Onopordum</i> -type (0–11%), Poaceae (1–8%). Ericaceae, <i>Pistacia</i> , <i>Daphne</i> , <i>Tuberaria</i> , <i>Carduus</i> -type, <i>Asphodelus</i> , <i>Ophioglossum</i> , Chenopodiaceae, Caryophyllaceae and <i>Persicaria maculosa</i> -type are generally present and <i>Hordeum</i> -type is occasionally	The pollen catchment for this zone appears larger than for the previous zones. An open, strongly eroding landscape with rather degraded steppe, scrub and a little distant woodland is indicated, with the site likely a wetland containing shallow pools. There are signs of some grazing animals and occasional cereal cultivation

Table 3.7 (cont.).

Zone	Defining taxa	Depth (cm)	Date ranges cal. BC/AD (BP) for zone bases (2σ)	Characteristics	Interpretation
				present. <i>Pseudoschizaea</i> and VAMs are common, <i>Debarya</i> sp. is often present and <i>Sordaria</i> -type, <i>Tripterospora</i> -type and <i>Valsaria</i> -type are sometimes present	
XEM-10	<i>Senecio</i> -type- Lactuceae- Poaceae- Cyperaceae- <i>Pinus</i> -	370–290	736–321 BC (2686–2271 BP)	Some very low pollen counts. High <i>Senecio</i> -type (20–34%), Lactuceae (10–36%), Poaceae (5–23%), Cyperaceae (5–17%), <i>Pinus</i> (7–14%). Ericaceae, <i>Pistacia</i> , <i>Plantago lanceolata</i> -type, <i>Carlina/Onopordum</i> -type, <i>Asphodelus</i> , <i>Ophioglossum</i> , <i>Botrychium</i> , <i>Convolvulus arvensis</i> -type and <i>Persicaria maculosa</i> -type are sometimes present. <i>Pseudoschizaea</i> , VAMs, <i>Tripterospora</i> -type and <i>Sordaria</i> -type are occasionally present	Counts are very low and there appears to be a reasonably strong taphonomic imprint in this zone, with high percentages of degradation-resistant grains. Nevertheless, a vegetation mosaic with degraded steppe, some scrub and distant woodland is suggested. The wetland suggested for previous zones appears to have been drier, without permanent pools. There were disturbed soils and some soil erosion took place
XEM-11	<i>Pinus</i> -Lactuceae- Poaceae	290–215	AD 141–570 (1809–1380 BP)	Some low pollen counts in the lower half of this zone. Very high <i>Pinus</i> (47–86%). Some Lactuceae, Poaceae, Cyperaceae, <i>Carlina/Onopordum</i> -type. <i>Persicaria maculosa</i> -type is often present. VAMs, some <i>Pseudoschizaea</i> and occasional <i>Podospora</i> -type are present	The extremely high percentages of <i>Pinus</i> pollen are consistent with nearby pine woodland: in this Late Holocene Maltese context, this most likely reflects a pine plantation rather than natural vegetation. Other vegetation was likely a mosaic of degraded steppe with a little scrub with eroding soils. It is likely that the depositional site was seasonally dry
XEM-12	Lactuceae- Cyperaceae	215–150	AD 1092–1509 (858–441 BP)	Very high Lactuceae (5–71%) and Cyperaceae (5–78%). Some Chenopodiaceae (2–12%), Poaceae (3–9%), <i>Pistacia</i> (1–9%), <i>Senecio</i> -type (2–8%), <i>Pinus</i> (2–6%). A little Ericaceae, <i>Daphne</i> , <i>Phillyrea</i> , <i>Carlina/Onopordum</i> -type, <i>Carduus</i> -type, <i>Ambrosia</i> -type, <i>Ophioglossum</i> , <i>Botrychium</i> , Caryophyllaceae, <i>Persicaria maculosa</i> -type, <i>Filipendula</i> and <i>Typha</i> in some samples. Some VAMs, <i>Pseudoschizaea</i> , and a little <i>Debarya</i> sp. in one sample	A very variable taphonomic signal is present in this zone, with a major influx of degradation-resistant Lactuceae grains in the upper part. The assemblages are otherwise consistent with a mosaic landscape with grassy and degraded steppe, scrub and distant woodland. There is evidence for eroding soils and for a local wetland environment with near-permanent pools supporting emergent aquatics by the end of the zone
XEM-13	Lactuceae- <i>Pinus</i> - Cyperaceae	150–130	AD 1845–1963 (105–13 BP)	Abundant Lactuceae (16–42%), <i>Pinus</i> (15–26%), Cyperaceae (11–16%). Some <i>Carlina/Onopordum</i> -type (3–16%) and <i>Carduus</i> -type (2–4%). <i>Tuberaria</i> , <i>Plantago lanceolata</i> -type, <i>Ophioglossum</i> , <i>Botrychium</i> , Chenopodiaceae, <i>Senecio</i> -type and Poaceae are sometimes present. <i>Pseudoschizaea</i> and <i>Debarya</i> sp. are occasionally present	Counts are extremely low and the proportion of degradation-resistant grains is high, suggesting a marked taphonomic imprint. The high <i>Pinus</i> is likely consistent with the presence of pine woodland, most probably a plantation, though further away or less sizeable than that suggested for XEM-11. The other taxa are suggestive of a degraded steppeland, some grassland and some scrub or garrigue. Soils were eroding and shallow pools were present on the deposition site
			Natural sedimentation appears to have ceased during the twentieth century		The uppermost 1.3 m of this core appears to be made ground of twentieth century age.

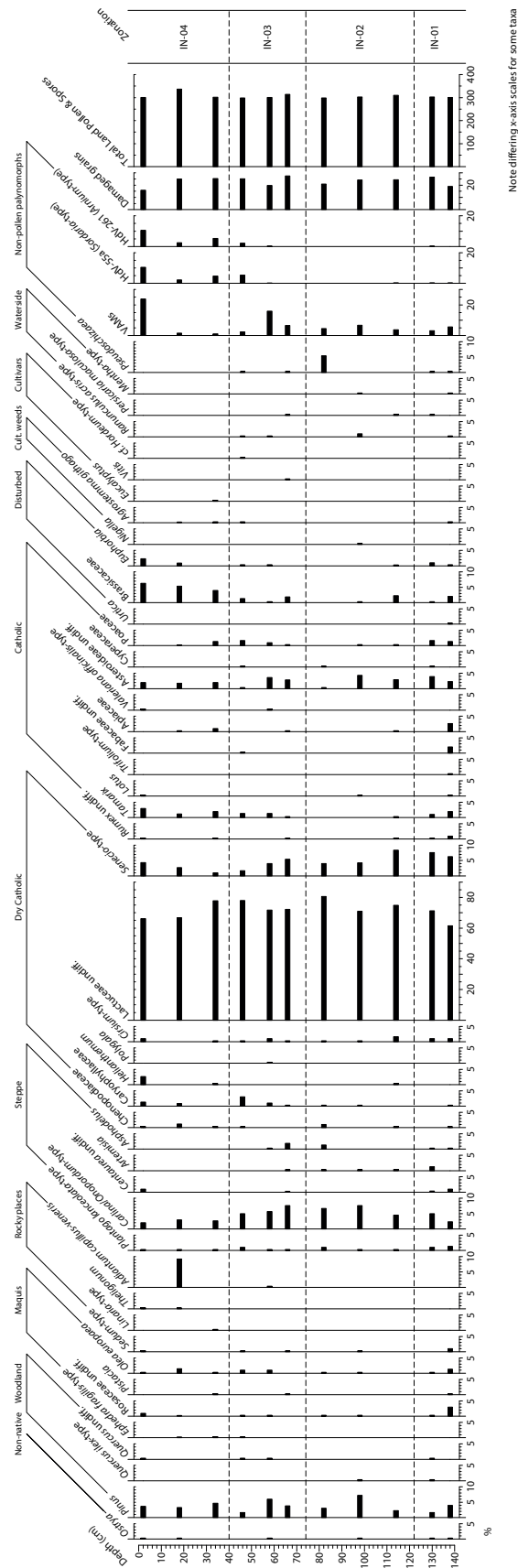


Figure 3.7. Pollen zonation for the pit fills at In-Nuffara (M. Farrell).

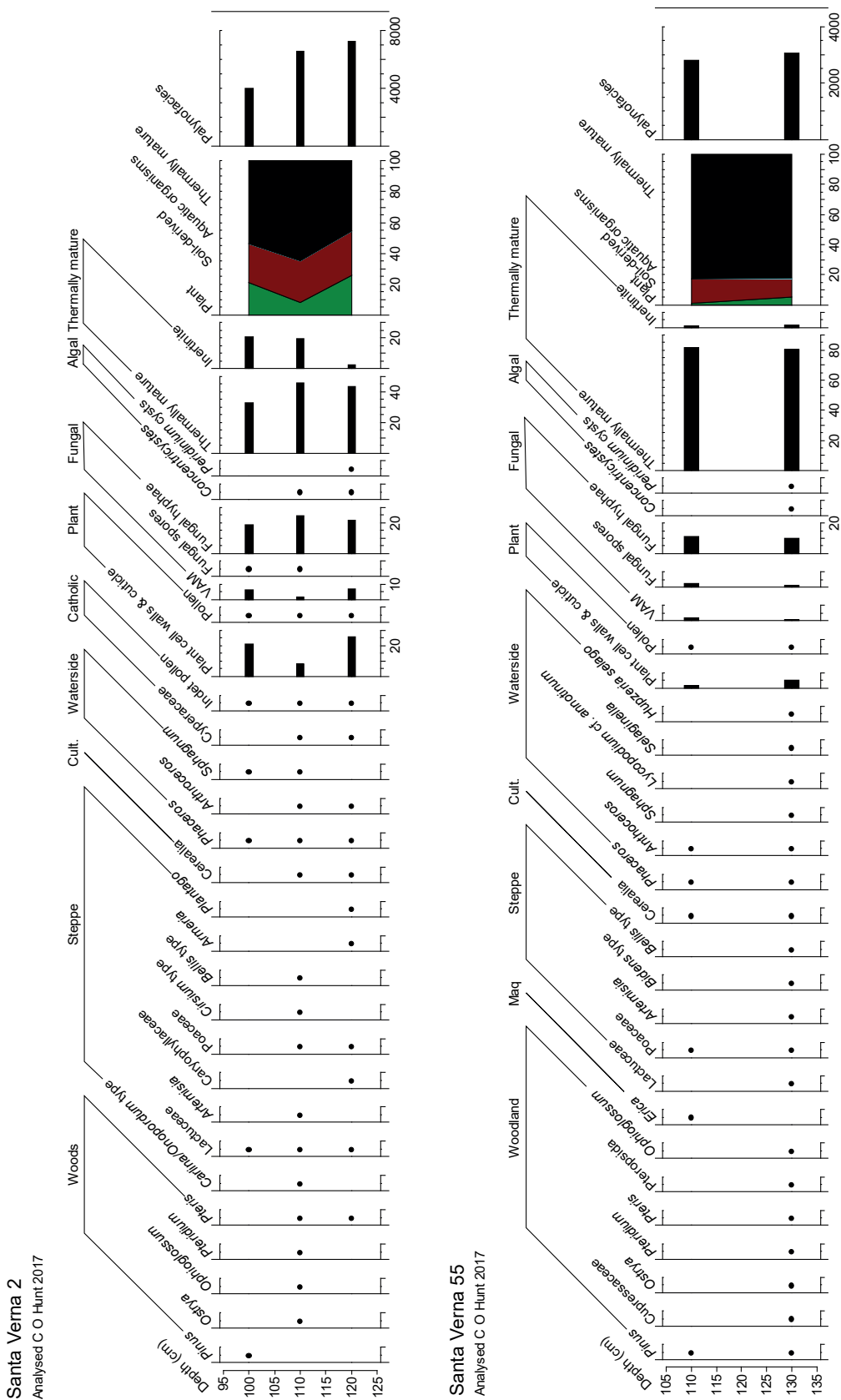


Figure 3.8. Pollen and palynofacies from the buried soils below the temple at Santa Verna, with the presence of a taxon shown by a dot (C.O. Hunt).

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Table 3.8. The pollen zonation of the fill of a Bronze Age silo at In-Nuffara, Gozo.

Zone	Contexts	Defining taxa	Depths (cm)	Period	Characteristics	Interpretation
IN-01	46, 41	Lactuceae- <i>Senecio</i>	138–125	Borg in-Nadur	Dominated by Lactuceae (62–70%). Also present are <i>Pinus</i> (2–5%), <i>Tamarix</i> (1–3%), <i>Olea</i> (1–2%), Rosaceae (0.5–4%), <i>Rumex</i> (0.5–1.5%), <i>Euphorbia</i> (0.5–1%), <i>Plantago lanceolata</i> -type (1–2%), <i>Carlina/Onopordum</i> -type (3–6%), <i>Cirsium</i> -type (1%), <i>Centaurea</i> (0.5%–1), <i>Senecio</i> -type (6–8%), Poaceae (1–3%), Asteroideae (2–4%), <i>Asphodelus</i> (1%), Brassicaceae (1–2%). VAMs (2–5%) and <i>Pseudoschizaea</i> (2%) present in small amounts	Assemblages highly biased taphonomically and showing signs of the recycling of material derived from soil profiles through erosion. Landscape predominantly open steppe, with some scrub. Considerable evidence for grazing and consequent vegetation degradation in the wider landscape
IN-02	41–40	Lactuceae- <i>Carlina/Onopordum</i> -type- <i>Senecio</i>	125–72	Punic	Dominated by Lactuceae (70–80%). Also present are <i>Pinus</i> (3–7%), <i>Plantago lanceolata</i> -type (0.5–1%), <i>Carlina/Onopordum</i> -type (5–8%), <i>Senecio</i> -type (4–9%), Asteroideae (1–4%). VAMs present (4–5%)	Assemblages highly biased, with erosional recycling of material from soil profiles. Landscape mostly very open steppe, probably heavily degraded by grazing
IN-03	39–37	Lactuceae- <i>Carlina/Onopordum</i> -type	72–42	Roman-Knights	Dominated by Lactuceae (74–79%). Also present are <i>Pinus</i> (2–6%), <i>Tamarix</i> (1–2%), Caryophyllaceae (1–3%), <i>Plantago lanceolata</i> -type (0.5–1%), <i>Carlina/Onopordum</i> -type (6–8%), <i>Senecio</i> -type (2–6%), Asteroideae (0.5–4%), Poaceae (0.5–2%), Brassicaceae (1–2%). VAMs present in all samples (2–16%). First appearance of <i>Hordeum</i> -type and spores of <i>Arnium</i> -type and <i>Sordaria</i> -type	Assemblages highly biased and with recycling of material from soil profiles. Landscape rather open grassy grazed steppe with some scrub. Minor cereal cultivation. Fungal spores provide evidence for grazing adjacent to the deposition site
IN-04	36–34	Lactuceae-Brassicaceae- <i>Pinus</i>	42–0	nineteenth–twentieth centuries AD	Dominated by Lactuceae (71–76%). Also present are <i>Pinus</i> (4–5%), <i>Olea europaea</i> (1–2%), <i>Tamarix</i> (1–2.5%), Chenopodiaceae (0.5–1%), <i>Plantago lanceolata</i> -type (0.5%), <i>Carlina/Onopordum</i> -type (2–4%), <i>Senecio</i> -type (1–5%), Asteroideae (2%), Brassicaceae (4–7%). VAMs (1–38%), <i>Arnium</i> -type (2–19%), <i>Sordaria</i> -type (2–18%) present. First appearance of <i>Eucalyptus</i>	Highly biased assemblages with evidence for recycling of material from soil profiles. Landscape rather open increasingly degraded steppe with some scrub. Possible increase in grazing pressure at top of zone

Table 3.9. Summary of the pollen analyses of the buried soil below the Santa Verna temple structure.

Contexts	Defining taxa	Depths (cm)	Period	Characteristics	Interpretation
SV2/2, 2/3, 5/1, 5/2	<i>Phaceros</i> - <i>Anthroceros</i> -Lactuceae	110–140	Earlier Neolithic pre-5500 cal. BC (pre-7500 cal. BP)	Woodland taxa 10% (<i>Pinus</i> , Cupressaceae, <i>Ostrya</i> , <i>Pteris</i> , Pteropsida, <i>Ophioglossum</i> , <i>Pteridium aquilinum</i>), maquis taxa 1% (<i>Erica</i>), steppe taxa 15% (<i>Carlina/Onopordum</i> -type, Lactuceae, <i>Artemisia</i> , Caryophyllaceae, Poaceae, <i>Cirsium</i> -type, <i>Bellis</i> -type, <i>Bidens</i> -type, <i>Armeria</i> , <i>Plantago</i>), cultivated taxa 9% (cereals), waterside taxa 61% (<i>Phaceros</i> , <i>Anthroceros</i> , <i>Sphagnum</i> , <i>Lycopodium</i> cf. <i>annotinum</i> , <i>Selaginella</i> , <i>Huperzia selago</i> , Cyperaceae, 24% <i>Peridinium</i> cysts, 8% <i>Pseudoschizaea</i>)	Very small, highly taphonomically influenced assemblages. An open steppic landscape with some woodland patches, grazed land and cereal cultivation. The abundant waterside plants and <i>Pseudoschizaea</i> are consistent with damp, sheltered soils close to water. The planktonic <i>Peridinium</i> cysts suggest the presence of mildly eutrophic fresh water
SV2/1	<i>Pinus</i> -Lactuceae- <i>Phaceros</i> - <i>Sphagnum</i>	100	Early Neolithic 5500–3800 cal. BC (7500–5800 cal. BP)	Presence of <i>Pinus</i> , Lactuceae, <i>Phaceros</i> and <i>Sphagnum</i>	Extremely small assemblage, in which all recorded taxa are known to be degradation-resistant. Suggestive perhaps of the presence of woodland, steppe and damp habitats

Table 3.10. Summary of the pollen analyses from the buried soil in Ġgantija Test Pit 1.

Defining taxa	Depths (cm)	Period	Characteristics	Interpretation
Lactuceae- <i>Hedera-Pinus</i>	110–130	Tarxien	Woodland/maquis taxa 34% (<i>Pinus</i> , <i>Quercus</i> , Cupressaceae, <i>Hedera</i> , Pteropsida), steppe taxa 43% (Lactuceae, Poaceae, <i>Carduus</i> -type, <i>Carlina/Onopordum</i> -type, <i>Artemisia</i> , <i>Helianthemum</i> , <i>Bidens</i> -type, <i>Bellis</i> -type, <i>Rumex</i>), cereals 5%, agricultural weeds 9% (Brassicaceae, <i>Sideritis</i> -type, <i>Lathyrus</i> , Chenopodiaceae), waterside taxa 5% (<i>Tamarix</i> , <i>Mentha</i> -type, <i>Anthoceros</i>). Algae 37% (mostly Type 119)	Moderately taphonomically biased assemblages, but suggestive of some woodland (the rather high <i>Hedera</i> could have been growing on stonework), open steppe, arable land, damp habitats. Algal assemblage suggestive of rather eutrophic standing water
Lactuceae	85–110	Tarxien	Woodland/maquis taxa 7% (<i>Pinus</i> , <i>Olea europaea</i> , Rosaceae aff. <i>Prunus</i> , Pteropsida, <i>Pteridium aquilinum</i>), steppe taxa 85% (<i>Centaurea scabiosa</i> -type, Lactuceae, Caryophyllaceae, Poaceae, <i>Armeria</i> -type, <i>Geranium</i> , <i>Carduus</i> -type, <i>Carlina/Onopordum</i> -type, <i>Artemisia</i> , <i>Bidens</i> -type), cereals 1%, agricultural weeds 1%, waterside taxa 1%. Algae 64% (mostly Type 119 and <i>Peridinium</i> sp.)	Strongly taphonomically biased assemblages dominated by Lactuceae. Suggestive of a little woodland/scrub, very open, dry, somewhat degraded steppe, minimal damp habitats and somewhat eutrophic standing water

Table 3.11. Activity on Temple sites and high cereal pollen in adjacent cores. Pollen data from FRAGSUS Project, Carroll et al. (2012), Djamali et al. (2013) and Gambin et al. (2016) and periods of human activity (C. Malone, pers. comm.). Grey shading indicates periods not sampled for palynology in coring or during archaeological excavation. Archaeologically attested or inferred periods of activity on megalithic sites are indicated with an 'a'. Anomalously high cereal pollen values are indicated with an 'h'.

	Tas-Siġ temple	Tas-Siġ middens	Borg in-Nadur temple	Wied Żembaq core	Tarxien/Hal Saflieni temple	Marsa core (Carroll et al. 2012)	Bugibba temple	Salina Bay (Carroll et al. 2012)	Tal Qadi temple	Burmarad BM1 and BM2 cores (Djamali et al. 2013; Gambin et al. 2016)	Xemxija temple	Xemxija core	Ġgantija temple	Ġgantija soils	Santa Verna temple	Santa Verna soils
Later Bronze Age		h	a	h		h										
Tarxien Cemetery					a											
Thermi Ware	a															
Tarxien	a	h			a		?	h					a	h		
Saflieni	a		a		a		?		a				a			
Ġgantija	a		a	h	a	h	?	h	a		a	h	a		a	
Mgarr	?		a		a	h	?	h	?			h	a		a	
Żebbuġ	?				a	h	?	h	?						a	
Earlier Neolithic						h							a		a	h

The algal microfossils suggest that the sites were in receipt of slightly eutrophic standing or slow-moving water or sediments derived therefrom. Representative material is illustrated in Figure 3.10.

3.5.6. Ġgantija

Pollen analyses of the buried soil as exposed in Test Pit 1, located immediately to the southwest of Ġgantija

temple are summarized in Tables 3.10 and 3.11 and Figure 3.9. Pollen counts are very low, but peaks in pollen occurrence and the coincident peak in vesicular arbuscular miccorhyzae (VAM) suggests episodes of soil stability around 115 and 85 cm. The combination of very abundant thermally mature (charred) material, plant cell walls and cuticle and fungal hyphae is typical of middens, while the high inertinite in the lower part

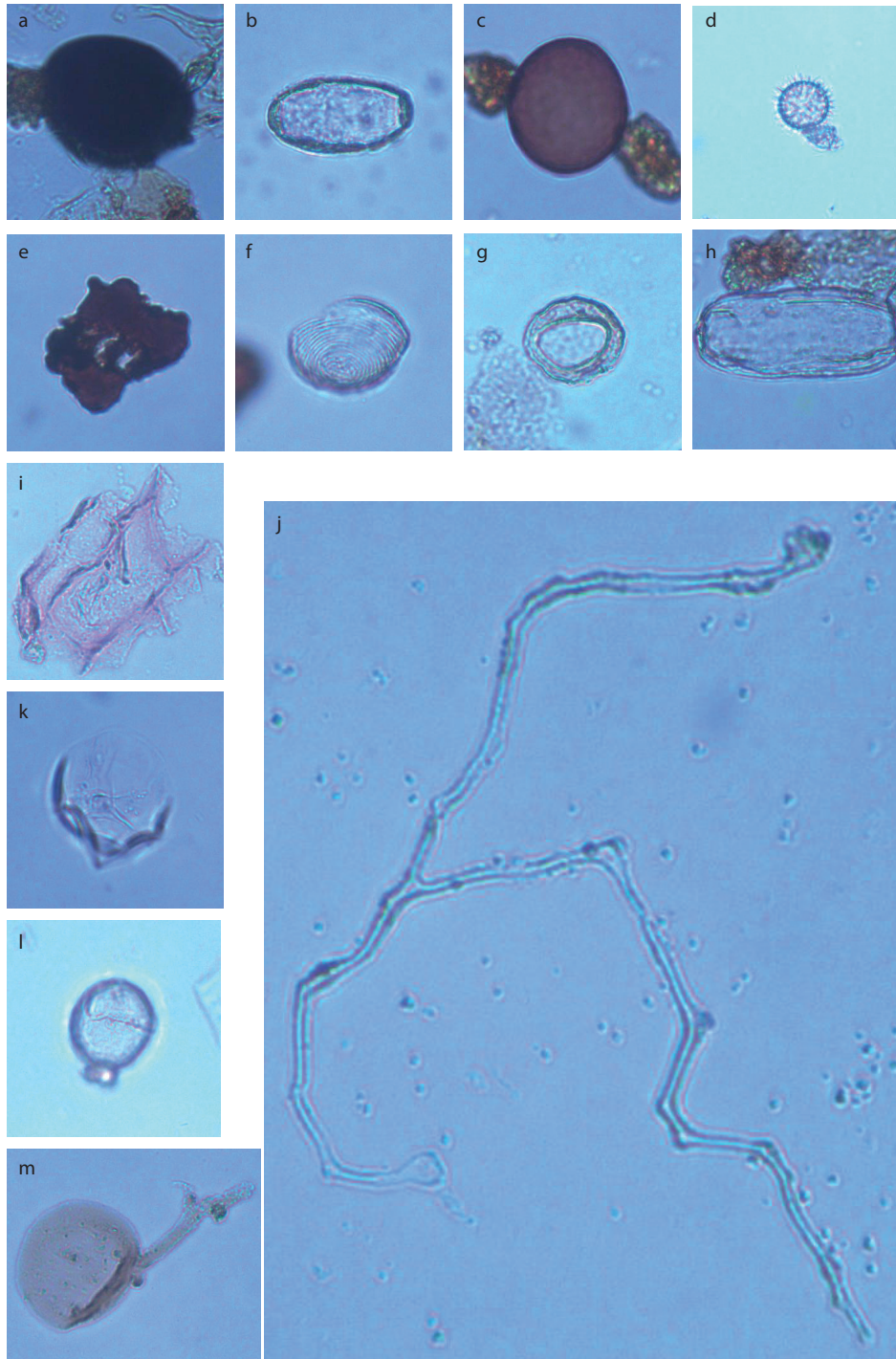


Figure 3.10. Photomicrographs ($\times 800$) of key components of the palynofacies at Santa Verna and Ggantija: a) Spherule, Ggantija 80–85 cm; b) Capillaria egg, Ggantija 95–100 cm; c) fungal spore, Santa Verna 2, 105–115 cm; d) fungal zoospore, Ggantija 95–100 cm; e) thermally mature (charred) material, Santa Verna 2, 105–115 cm; f) Concentricystes sp., Santa Verna 2, 105–115 cm; g) Type 119, Ggantija 80–85 cm; h) Spirogyra sp. aplanospore, Ggantija 80–85 cm; i) plant cuticle, Santa Verna 2, 105–115 cm; j) fungal hypha, Santa Verna 2, 105–115 cm; k) Saeptodinium sp. cyst showing large compound archaeopyle, Ggantija 95–100 cm; l) Peridinium sp. cyst showing incipient compound archaeopyle, Santa Verna 55, 120–140 cm; m) vesicular arbuscular miccorhyza, Santa Verna 2, 105–115 cm (C.O. Hunt).

of the section is very typical of seasonally wet biologically active soils. The nematode *Capillaria* gives rise to a hepatitis-like zoonotic disease causing liver failure in humans, but it can also affect a variety of animal hosts. The algal microfossils suggest that the site was in receipt of fairly eutrophic slow moving or standing water or sediments derived therefrom. Representative material is illustrated in Figure 3.10.

Two phases of sedimentation are evident, both dating to the Tarxien phase. The earlier assemblages (130–110 cm) suggest some soil erosion and a landscape with woodland, open steppe and damp habitats close to water. A rather eutrophic water body nearby is suggested by the algal microfossil assemblage. The later assemblages (110–85 cm) show rather strong soil erosion and a drier landscape with a little woodland, open steppe and less evident damp habitats. The water body had by this time become slightly less eutrophic.

3.6. Synthesis

3.6.1. Pre-agricultural landscapes (pre-5900 cal. BC)

The basal sections of the deeper cores are characterized by extremely sparse pollen assemblages, which show evidence of strong taphonomic bias. The Salina Deep Core has a basal section which predates 7042–6553 cal. BC (8992–8503 cal. BP), consisting of poorly sorted gravels interbedded with incipient palaeosol material, some of which contain pedogenic carbonates. These deposits relate to terrestrial fluvial and colluvial environments, most probably present during the Late Pleistocene and perhaps the Early Holocene, by comparison with similar deposits described by Hunt (1997). The very sparse pollen survival in these deposits may be consistent with dry terrestrial environments supporting steppe and scrub vegetation, as might be expected during interstadial episodes (Hunt 1997), but extremely low numbers of pollen grains and poor pollen preservation caution against reliance on these assemblages.

The basal 3.4 m of the Xemxija 1 core is also rather problematic as the sediments are heavily pedogenically altered. The pollen assemblages contained within are extremely small and appear to have been significantly altered by strongly oxidizing and biologically active terrestrial environments. Indeed, the micromorphological analysis of this core suggests that at least the basal c. 1.2 m of sediments are probably eroded soils from the immediate catchment, which are similar to the soils observed beneath several of the Neolithic temple sites and would have undergone some pedogenesis once re-deposited in the base of the valley bottom (see Chapter 5). The abrupt changes in pollen assemblages throughout this core may also suggest that there are

sedimentary discontinuities associated with erosion episodes. The latter point may indicate that the modeled ages could be unreliable, but the progressively consistent spread of dates over the last c. 8000 years suggests otherwise (see Chapter 2).

Some time after about 8000 cal. BC, shallow marine sedimentation became established at the Salina Deep Core site (Table 2.4). Thereafter, continuing sedimentation was off-set by rising sea level, and it may be suggested that sediment accumulation was essentially continuous. The reducing environment offered by shallow marine sediments led to preservation of sufficient pollen to recognize the biostratigraphy shown in Figure 3.3 and Table 3.4. As with the modern marine samples from the Mistra catchment discussed above, the assemblages show taphonomic biases but these can be accounted for in the interpretation (Table 3.4 and below). These are the oldest reliable data available from which to reconstruct Maltese Holocene vegetation history. Previously the earliest Holocene palynological data from Malta were from the BM1 sequence from Burmarrad, with the oldest sediments there dated to c. 5350 cal. BC (7300 cal. BP) (Marriner *et al.* 2012; Djamali *et al.* 2013; Gambin *et al.* 2016).

It is well documented that attempting to disentangle natural climatically forced events from anthropogenic impacts in the palynological record is extremely difficult (e.g. Caló *et al.* 2012; Carroll *et al.* 2012; Djamali *et al.* 2013; Gambin *et al.* 2016; Chapman 2018). Prior to the arrival of farming people in the Maltese Islands, any changes in vegetation would have most likely resulted from environmental processes. The basal pollen zones in the Salina Deep Core (SDC-02 to 05) suggest the cyclic spread of *Pistacia* (lentisk) scrub into steppe landscapes in Salina Deep Core zone SDC-02 at 7042–6553 cal. BC (8992–8503 cal. BP) and zone SDC-04 at 6489–6135 cal. BC (8439–8085 cal. BP). The repeated spread of *Pistacia* was most probably driven by periods of increasing effective humidity within a generally very dry period. *Pistacia* is generally accepted to be under-represented in modern day pollen assemblages (Wright *et al.* 1967; Collins *et al.* 2012; Djamali *et al.* 2013), and the percentages found in these zones indicate dense lentisk-dominated vegetation. Djamali *et al.* (2013) review the edaphic conditions required for *Pistacia* species – an expansion in this taxon may be indicative of high moisture availability either through humidity or increased precipitation (Tinner *et al.* 2009; Carroll *et al.* 2012; Djamali *et al.* 2013; Gambin *et al.* 2016). The very short duration of these episodes seems to have precluded significant expansion of other scrub or woodland taxa, but the substantial decline in *Pseudoschizaea* and vesicular arbuscular mycorrhizae (VAMs) in the Salina Deep Core zones SDC-02 and

SDC-04 also point to the dense vegetation canopy reducing soil erosion. Equivalent chronologically to the second *Pistacia* peak, a humid episode among general aridity is reported in Sicily and in southeastern Spain at c. 6450 cal. BC (8400 cal. BP) (e.g. Reed *et al.* 2001; Tinner *et al.* 2009).

Intervening zones in the Salina Deep Core SDC-03 at 6858–6419 cal. BC (8808–8369 cal. BP) and SDC-05 at 6350–6037 cal. BC (8300–7987 cal. BP) show an increase in herbs including grasses, Chenopodiaceae, *Asphodelus* and sporadic occurrences of *Plantago lanceolata*, *Urtica*, Brassicaceae and *Convolvulus arvensis*-type. While some species of *Asphodelus* can be favoured by nutrient-deficient soils resulting from over-grazing, it is also known to colonize rapidly newly exposed ground surfaces following fires (Pantis & Margaris 1988; Abel-Schaad & López-Sáez 2013). Fungal ascospores are also present, with *Podospora*-type (Dietre *et al.* 2012) and *Tripterospora*-type considered to be coprophilous, growing on the dung of large herbivores, while *Diporothea rhizophila* is associated with nitrogen-rich environments (van Geel *et al.* 2003). Studies of modern palynological assemblages have shown that these ascospores are not dispersed over long distances (Blackford & Innes 2006) and therefore they can be interpreted as indicative of grazing animals close to the deposition site, whether these were naturally present or introduced by people. It has been argued that navigation in the central Mediterranean Sea may have occurred as early as c. 8000 cal. BC (9950 cal. BP) (Broodbank 2013) and that temporary exploration and occupation of Malta might have occurred prior to the establishment of permanent settlements (Gambin *et al.* 2016). No archaeological evidence has been identified from this period, however, and whilst the present day mammalian fauna of Malta is relatively impoverished, comprising only around 21 species (Schembri 1993), it is possible that a dwarfed form of red deer was present in the earlier Holocene (Hunt & Schembri 1999). The presence of coprophilous fungal spores could therefore represent either native herbivores or (less likely) wild species introduced by early pioneer settlers. Regression of scrub and woodland was accompanied by rising *Pseudoschizaea* and VAMs, indicating increased erosion in the catchment area (Argant *et al.* 2006; Ejarque *et al.* 2011; Estiarte *et al.* 2008; Gambin *et al.* 2016; van Geel *et al.* 1989). This is likely to have been related to the decline in vegetation cover, as the exposed soil surface would have been more vulnerable to removal via surface run-off.

The expansion of steppe habitats in Salina Deep Core zones SDC-03 and SDC-05 may be consistent with periods of general precipitation decline in Malta. The second of these events (in zone SDC-05) coincides

chronologically with the widely reported 8.2 ka BP event which led to cooling in the North Atlantic and aridification in the Mediterranean coastlands (e.g. Barber *et al.* 1999; Wenginger *et al.* 2006; Bini *et al.* 2018; Chapman 2018), although the second part of this zone shows a small increase in *Quercus* (oak) pollen, suggesting perhaps the end of climate severity.

3.6.2. First agricultural colonization (5900–5400 cal. BC)

A key point in the Salina Deep Core is at 22.65 m, where pollen zone SDC-06, commencing at 6067–5821 cal. BC (8017–7771 cal. BP), is marked by assemblages containing pollen of cereals. These include both *Avena/Triticum* type (oats/wheat) and *Hordeum*-type (barley) and a ruderal flora including *Convolvulus*, *Borago*, *Scrophularia* and *Sideritis*, all of which are often associated with arable farming (Fig. 3.3). It is very likely that arable agriculture was established in the vicinity of the present-day Salina salt pans, since cereal pollen is produced in low quantities and is not well-dispersed (Edwards & McIntosh 1988). Pollen of *Plantago lanceolata*-type (ribwort plantain) and *Urtica* (nettle) may indicate grazing. The presence of a range of fungal ascospores, including the coprophilous taxa *Podospora*-type, *Tripterospora*-type, *Sordaria*-type and *Arnium imitans*-type and the nitrophilous *Diporothea rhizophila*-type is strongly suggestive of the presence of grazing animals locally. The assemblages also show very high incidences of *Pseudoschizaea*, which is of likely fungal origin (Milanesi *et al.* 2006) and associated with damp calcareous soils. Large numbers of this palynomorph deposited in a marine environment are likely to reflect enhanced soil erosion. All these indicators suggest that the base of this zone may reflect the initial colonization of this area by people using cereals and domestic animals, and thus also reflect the beginning of the Neolithic in the Maltese Islands, suggesting that it occurred at 6067–5821 cal. BC (8017–7921 cal. BP). Such an early date was not expected on archaeological grounds, but is broadly consistent with other first Neolithic dates in the central and western Mediterranean (e.g. de Vareilles *et al.* 2020; Zeder 2008; Zilhao 2001), and strengthens the hypothesis for a seaborne Neolithic diaspora from the eastern Mediterranean in response to instability caused by the 8.2 ka BP climate event (i.e. Wenginger *et al.* 2006; Zeder 2008).

The vegetation suggested by assemblages in Salina Deep Core zone SDC-06 otherwise comprises a very grassy steppe with some maquis and garrigue and very minor woodland, suggesting a relatively dry seasonal Mediterranean climate. The rise of the drought-resistant but frost-sensitive *Phillyrea* (false privet) might suggest strengthening summer droughts and relatively warm winters at this time.

3.6.3. Early Neolithic (5400–3900 cal. BC)

Plantago lanceolata-type (ribwort plantain, very often associated with grazed pasture) rises strongly in the Salina Deep Core zone SDC-07 at 5625–5419 cal. BC (7575–7369 cal. BP) shortly after the date of the first known archaeological evidence for human activity in the Maltese Islands (Fig. 3.4). Coincident with this, pollen of Lactuceae rises. High percentages of Lactuceae are generally accepted to be indicative of poor pollen preservation as the pollen is relatively resistant to decay (Havinga 1967; Mercuri *et al.* 2006). The pollen assemblages from the Salina Deep Core, however, also contain many other taxa and the condition of the pollen was generally good, so this does not necessarily appear to be a preservation issue. It is possible that this rise reflects the liberation of the resistant Lactuceae pollen grains from the soil, caused by over-grazing of vegetation exposing the soils to erosion. Other taxa resistant to corrosion, oxidation and microbial attack – including *Pinus* and fern spores – do not, however, rise at this time. Alternatively, Florenzano *et al.* (2015) have argued that an abundance of Lactuceae pollen in Mediterranean contexts is related to intensively grazed pasture, and given the abundance of other pastoral indicators, this is a plausible explanation for some of the high percentages seen in the Salina Deep Core and at other sites. Cereal pollen is low in this period, suggesting either low intensity cultivation or cultivation relatively distant from the core site.

In Salina Deep Core pollen zone SDC-08 at 5404–5145 cal. BC (7354–7095 cal. BP) *P. lanceolata*-type rises further and the nitrophilous *Urtica* (nettles), *Rumex* (docks), ruderals including Brassicaceae and *Convolvulus arvensis*-type and rising coprophilous fungal spores (with *Sporormiella*-type now present in addition to those taxa discussed earlier) are consistent with major expansions of pastoral agriculture close to this site. Relatively high *P. lanceolata*-type and Lactuceae are visible in the basal zone of the Salina 4 core (Fig. 3.4), but are not present in the Burmarrad BM1 and BM2 cores (Djamali 2014; Djamali *et al.* 2013; Gambin *et al.* 2016), or at Xemxija (Fig. 3.6) (where, however, pollen preservation is poor in sediments of this age). The signal is probably localized, suggesting that areas of intensive grazing were restricted in size at this time. Cereal pollen shows a short-lived peak in the two FRAGSUS Salina cores and at Burmarrad, synchronous with the rise in *P. lanceolata*-type, suggesting that arable farming became more extensive, for a while (Fig. 11.2).

A slight increase in *Theligonum* pollen accompanies other evidence for increased agricultural activity, and the taxon is consistently present throughout the remainder of the Salina Deep Core sequence (Fig. 3.3). *Theligonum* is found in dry, rocky environments and

it has been suggested that an increase in this taxon seen in the Burmarrad sequence at c. 4650 cal. BC (6600 cal. BP) may reflect the establishment and development of terraces in the landscape (Djamali *et al.* 2013). Climatically, there appears to have been very little change through these events, which thus probably reflect cultural processes and variously successful experiments with agriculture. Broadly contemporary early cereal cultivation in a landscape characterized by steppe with some woodland is also evident on Gozo at this time, in the soils underlying the Santa Verna Temple (Table 3.9). The palynological evidence for early cereal cultivation in Malta is supported by the recovery during FRAGSUS excavations at Santa Verna and Skorba of archaeobotanical remains of barley, wheat and lentils dating from c. 5400–4900 cal. BC (7350–6850 cal. BP). This period of intensive and extensive arable and pastoral agriculture occurs during the Għar Dalam and Skorba cultural phases.

From about 7000 years ago (5050 cal. BC) there may have been significant changes in effective moisture. It seems highly probable that, at Burmarrad and in other localities where land-use was not intensive in Malta, as in Sicily and southern Spain (Tinner *et al.* 2009; Reed *et al.* 2001), *Pistacia* and other vegetation was responding to an episode of relatively high effective moisture, with widespread major increases in precipitation at this time. The presence of *Pistacia* pollen does seem, however, to have been extremely localized, for instance in the BM1 core it was rising strongly by 5050 cal. BC (7000 cal. BP), while in the nearby BM2 core it was still a relatively minor component of assemblages at that time (Fig. 11.1) (Djamali *et al.* 2013; Gambin *et al.* 2016).

Although high tree pollen is present, a different pattern is visible in the Marsa 1 core, where the basal zone, with an interpolated age of c. 5050 to 4850 cal. BC (7000 to 6800 cal. BP) is characterized by pollen suggestive of scrub dominated by *Pinus* (pine) and *Juniperus* or *Tetraclinis* (juniper or sandarac gum), with very little *Pistacia*. There is also pollen indicative of a little steppe and cereal agriculture and there is much microscopic charred wood, suggestive of significant and repeated fire (Carroll *et al.* 2012). Thereafter the landscape at Marsa appears to have become significantly more open and shortly after c. 4550 cal. BC (6500 cal. BP) cereal and *P. lanceolata*-type pollen had become more common, suggesting an expansion of arable and pastoral agriculture. This most probably points toward patches of pine-juniper/sandarac gum scrub woodland being cleared. These findings may point to development of a different flora on the dry Globigerina Limestone plateau in southern Malta, in contrast to the lentisk-dominated vegetation associated with the better water-retaining properties and hill-side

springs from the perched Upper Coralline Limestone aquifer associated with the Blue Clay lowlands and muddy colluvial cover of hillsides in northern Malta (Hunt 1997).

Areas of intense arable agriculture and grazing seem to have shifted during the interval between c. 5050 and 4550 cal. BC (7000–6500 cal. BP), whether in response to climatic or to socio-cultural factors. In both the Salina Deep and Salina 4 cores, *P. lanceolata*-type and cereals reach minima and peaks of *Pistacia* suggest patches of lentisk scrub around 4550 cal. BC (6500 cal. BP) (Figs. 3.3 & 3.4). The patchiness of vegetation at Salina is indicated by the contrasting record from the Salina Bay core of Carroll *et al.* (2012), which shows an opposite trend, with a maximum of *Plantago* and very little *Pistacia* or other woodland or maquis taxa at the same time. In the Burmarrad BM1 pollen diagram, *P. lanceolata*-type peaks at c. 4900 cal. BC (6850 cal. BP), then declines to a minimum at c. 4600 cal. BP (6550 cal. BP), while *Pistacia* rises strongly from c. 4950 cal. BC (6900 cal. BP), peaking at over 60 per cent at c. 4750 cal. BC (6700 cal. BP) before declining to c. 45 per cent at c. 4550 cal. BC (6500 cal. BP). There are peaks of *Pistacia* and *Phillyrea* around 3850 cal. BC (5800 cal. BP) at Xemxija (Fig. 3.6).

Vitis (vine) appears at c. 4750 cal. BC (6700 cal. BP) at Burmarrad (Djamali *et al.* 2013), perhaps reflecting the introduction of grapes. It is also possible, because vines are extremely low producers of pollen, that these were native plants under-represented in the pollen rain (Pagnoux *et al.* 2015). The Burmarrad BM2 pollen diagram (Gambin *et al.* 2016) has an interval with no pollen preservation at this time.

There is evidence for a general decline in agricultural activity around 4550 cal. BC (6500 cal. BP) in many of the Maltese records. Arboreal and scrub pollen expands at several sites, and cereal pollen percentages generally decline apart from at Marsa 1 where they rise sharply (Carroll *et al.* 2012) (Figs. 11.1 & 11.2). The rise in arboreal and scrub pollen might suggest that climatic wetness was rather high at this time. Although this may in part reflect a relaxation of grazing pressure associated with agricultural decline, percentages of tree and shrub pollen are higher at 4550 cal. BC (6500 cal. BP) than during humid episodes before the 8.2 ka BP event when grazing livestock were most likely absent. This suggestion of possible higher effective humidity contrasts with many areas around the Mediterranean (e.g. Magny *et al.* 2011; Sadori *et al.* 2016; Jaouadi *et al.* 2016; Bini *et al.* 2018), which show evidence of climatic disruption and rainfall decline around 4550 cal. BC (6500 cal. BP). It is thus possible to infer that in Malta, the widespread, although not universal decline in agriculture at this time may perhaps

reflect social and/or cultural rather than climatic factors. Archaeological excavations by the FRAGSUS Project at Skorba and Santa Verna have identified a hiatus in the cultural record between c. 4800–3800 cal. BC (6750–5750 cal. BP), which corresponds broadly with the reduced agricultural activity in the palynological record (see Volume 2). The continuation of cereal agriculture at some sites suggests, however, that there might have been some sort of re-organization of the locations preferred by the population and/or changes in social structures and economic activities at this time, rather than a substantial de-population of the islands. This view is supported by the very small number of excavated Neolithic sites.

3.6.4. The later Neolithic Temple period (3900–2350 cal. BC)

After 6000 years ago (4050 cal. BC), Maltese landscapes generally remained extremely open, with cereal cultivation increasing and grazing evident at most core sites. Spores of soil fungi suggest continued soil erosion, while rising values of corrosion-resistant pollen such as Lactuceae and various Asteraceae may suggest that soil erosion was accelerating, perhaps because of agricultural intensification, or expansion of arable activity into more geomorphologically marginal areas. At the same time, the percentages and diversity of pollen of agricultural weed taxa both start to increase, suggesting that farmers may have been losing productivity as weeds proliferated and soils degraded and continued to erode. All of this is consistent with the island being relatively intensively used for agriculture during the later Neolithic (see Chapter 6 and Volume 2).

There are, however, some distinct elements of spatial and chronological patterning. The Salina Deep Core shows three episodes when *Pistacia* (lentisk) scrub regenerated, between c. 4450 cal. BC (6400 cal. BP) and 3850 cal. BC (5800 cal. BP), between c. 3450 cal. BC (5400 cal. BP) and c. 2700 cal. BC (4650 cal. BP) and c. 2400 cal. BC (4350 cal. BP) and c. 2300 cal. BC (4250 cal. BP) (Fig. 3.3). The second peak in *Pistacia* is also recorded at the Burmarrad BM2 core, where it forms over 60 per cent of the pollen assemblages deposited during the Ġgantija and early Saflieni phases (Fig. 11.1) (Djamali *et al.* 2013; Gambin *et al.* 2016). The first and second peaks seem to be visible at Xemxija, but records further away seem to be out of phase. This therefore suggests the presence of very localized stands of lentisk scrub in an area close to the Burmarrad core sites which was not used heavily for arable agriculture or grazing. It has been hypothesized that *Pistacia* spp. were managed for food, fuel and fodder in the Levant during the pre-pottery Neolithic (Asouti *et al.* 2015) and it is conceivable that something similar occurred

on Malta during the later Neolithic. That management was occurring might be inferred from the Burmarrad BM1 and BM2 diagrams (Djamali *et al.* 2013; Gambin *et al.* 2016), because the expansion of *Pistacia* is not followed by substantive successional expansion of other maquis or woodland taxa for about 2000 years, until after c. 3050 cal. BC (5000 cal. BP) when *Pistacia* declines and short-lived peaks of *Olea* and *Quercus* are observed. Substantiating this suggestion further would require intensive investigations of macro-fossil wood and charcoal on Maltese archaeological sites.

During the later Neolithic period, from the Żebbuġ phase (3900–3600 cal. BC) onward, cereal percentages are remarkably high at some sites (Tables 2.1 & 3.11). In the Salina Bay core of Carroll *et al.* (2012), from c. 3850–2350 cal. BC (5800 to 4300 cal. BP), there are at times very high values (over 10 per cent) for cereal pollen. This especially occurred during the Ġgantija phase (3450–3200 cal. BC), when there are cereal pollen percentages of the same order at Wied Żembaq and one very high value at Xemxija, and again during the Tarxien phase (2850–2350 cal. BC), when there are very high cereal pollen percentages at Tas-Silġ (Fig. 11.2). There are also some very high values in the segment of the Marsa core assigned to the Żebbuġ to Ġgantija phases (3900–3200 cal. BC), but unfortunately these sediments are followed by a depositional hiatus. The percentages at all these sites are greater than would be expected in a landscape devoted to cereal growing and perhaps reflect threshing on cereal-processing sites rather than cultivation *per se*. Even in the middle of a field of cereals, it is rare for their pollen to form more than 8 per cent of the assemblage (Faegri & Iversen 1975), but threshing releases into the environment abundant cereal pollen, which would otherwise remain trapped within the husks, so sites where threshing occurred are often marked by very high cereal pollen values (e.g. O'Brien *et al.* 2005). This perhaps raises the possibility of cereal processing, or the handling of processed cereals, adjacent to temple sites such as Tas-Silġ, Borg in-Nadur (close to the Wied Żembaq core site), the Tarxien Ħal Saflieni complex (near the Marsa core sites), Xemxija (adjacent to the Xemxija core site), and Buġibba (close to the Salina core sites). Only the Burmarrad cores, which are not far from the Tal-Qadi temple, do not conform to this pattern, but this area was not cultivated and instead appears to have been covered with dense lentisk scrub. Dispersal of cereal pollen within this environment would likely have been minimal.

The occurrence of pollen of vines in the later Neolithic Żebbuġ phase at Salina 4, and in the Ġgantija and Tarxien phases at Wied Żembaq, and of carob in the Tarxien phase at Salina 4 is possibly of significance

(Figs. 3.4 & 11.1; Table 2.1). Both vines and carob have extremely poor dispersal so the very low percentages recovered may indicate that these were actually fairly abundant in the vegetation when first recorded, and absence in the pollen diagrams prior to this cannot be taken as conclusive evidence that they were not present in the Maltese Islands. Indeed, carob charcoal was recovered from the early Neolithic site at Skorba (Metcalf 1966), suggesting that it was present in Malta from well before the first appearance of the pollen. Carob was thought to be an eastern Mediterranean species domesticated during the Chalcolithic (Ramón-Laca & Maberley 2004), although recent genetic work suggests populations of wild carob spreading from several glacial refugia such as in Morocco, Iberia, Sicily, Greece and southern Turkey during the early Holocene (Viruel *et al.* 2016). Traditionally, carob pods have been used as animal fodder and famine food in Mediterranean countries (Forbes 1998) and could have been used in Maltese prehistory, wild or domesticated. On the other hand, grape pips first appear at Tas-Silġ in the Early Bronze Age (Fiorentino *et al.* 2012), significantly after the first appearance of the pollen. Nevertheless, the appearance of pollen grains of these species may perhaps indicate rising numbers of the plants and possible widening of the subsistence base during this time.

3.6.5. The late Neolithic–Early Bronze Age transition (2350–2000 cal. BC)

During the Tarxien phase (2850–2350 cal. BC), there is possible evidence for aridification at Ġgantija (Table 3.10), Tas-Silġ (Hunt 2015) and Wied Żembaq (Fig. 3.5), in the form of woodland contraction, steppe vegetation apparently taking on a drier aspect and diminished clear evidence for areas of damp vegetation. Cereal pollen also declines markedly at this time at many sites. Woodland decline occurs during the Tarxien Period at Xemxija, Burmarrad (Gambin *et al.* 2016), Salina 4, Salina Bay (Carroll *et al.* 2012) and in the Salina Deep Core, but trends in other indicators are less clear. Nevertheless, it can be argued that effective precipitation may have declined during the Tarxien Period (cf. Gambin *et al.* 2016), with the corollary that socio-economic systems may have come under increasing stress through declining agricultural productivity and perhaps the drying of some karst water sources.

In the Salina 4 core (Fig. 3.4), Carroll's (2012) Salina Bay core, the Wied Żembaq core (Fig. 3.5) and in the Tas-Silġ middens, there is a short episode around 2350 to 2050 cal. BC (4300 to 4000 cal. BP) during which cereal pollen disappears or becomes very rare and pollen of trees and shrubs increases. The only contrary trend is at Burmarrad BM2 (Gambin *et al.* 2016) where

cereal pollen rises at this time. The behaviour of *P. lanceolata*-type (which may be taken to reflect grazed land) through this episode varies: at Salina 4 it declines markedly and at Wied Żembaq it declines more gently, whereas at Burmarrad BM2 (Gambin *et al.* 2016) and Salina Bay it rises sharply (Carroll *et al.* 2012). This episode is known elsewhere around the Mediterranean as the culmination of a time of climatic stress (e.g. Magny *et al.* 2009, 2011; Jaouadi *et al.* 2016; Ruan *et al.* 2016), but there seems to be no strong climatic evidence from the Maltese pollen records at this point.

When considering all the available records, the decline of cereal pollen at Salina 4 and Salina Bay (Carroll *et al.* 2012), Tas-Silġ and Wied Żembaq and the rising trend of tree and shrub pollen at Salina (Deep Core & Salina 4), Xemxija, and Wied Żembaq close to 2350 cal. BC (4300 cal. BP) may reflect abandonment of agricultural land and regeneration of woody vegetation rather than a climatic signal *per se*. It is worth noting that in Malta during the early Holocene, only times of climatic wetness seem to have supported abundant woody vegetation, so alternatively the rise of woody vegetation at this time may conceivably reflect a rise in effective moisture.

On the other hand, archaeological evidence suggests that there was most probably some form of societal disruption close to 2350 cal. BC (4300 cal. BP), reflected in the apparent abandonment of temple sites and short-lived appearance of the Thermi ware, followed later after c. 2000 cal. BC by the Tarxien Cemetery culture (e.g. Malone *et al.* 2009b; Fiorentino *et al.* 2012; Malone & Stoddart 2013) (see Chapters 6 & 7). The pollen evidence suggests that as part of this disruption, cereal cultivation and pastoral activity were abandoned in coastal localities such as Salina, Xemxija and Wied Żembaq. The decline in pollen of woody plants and rise in cereal pollen at Burmarrad counters this trend and would be consistent with relocation of agriculture, and perhaps human populations, toward the interior of the island (see Chapter 7). This may be consistent with an element of population continuity at the end of the Temple Period and into the Bronze Age. The redistribution of agricultural activity and perhaps population away from the coast seems a consistent response to the well-known rise of maritime raiders in the Early Bronze Age (Grima 2007; Wiener 2013) since at this point coastal localities would have become very vulnerable.

3.6.6. *The Bronze Age (2000–1000 cal. BC)*

After the decline in cereal pollen around the end of the Temple Period (2350 cal. BC), which may reflect partial population decline, by c. 2050 cal. BC (4000 cal. BP) there is evidence from the pollen of cereals,

agricultural weeds, pasture land taxa and coprophilous fungal spores for widespread cereal cultivation and pastoral agriculture. This coincides with evidence for extensive arable agriculture at this time in the macrofossil record at Tas-Silġ (Fiorentino *et al.* 2012). The number of sites of Later Bronze Age date sampled during this and previous research is rather small and there are marked taphonomic biases to assemblages at Wied Żembaq, Tas-Silġ (Hunt 2015) and Xemxija. Nevertheless, the relatively uniform percentages for tree and shrub pollen are suggestive of there being no major climatic change at this time, while relatively high cereal pollen percentages can be used to infer that cereals were grown and quite probably processed at Tas-Silġ.

3.6.7. *Late Bronze Age, Punic and Classical periods (c. 1000 cal. BC to AD 1000)*

By the start of the Classical Period, pollen assemblages from Marsa (Carroll *et al.* 2012) are marked by relatively high incidences of Caryophyllaceae, Chenopodiaceae, spiny Asteraceae, *Arabis*, *Spergula*-type, and rather low Poaceae and tree/shrub pollen. This is likely to reflect a highly degraded landscape (Carroll *et al.* 2012). There is ample evidence for eroding soils (e.g. at Xemxija), with relatively high counts for corrosion-resistant taxa, such as *Pinus*, Lactuceae and various Asteraceae, and often very strong representation of soil organisms such as VAMs and *Pseudoschizaea*.

Tree and shrub pollen persisted relatively unchanged from the Late Bronze Age and throughout the Punic period at Xemxija and Marsa (Carroll *et al.* 2012). In contrast, arboreal pollen values are higher at Wied Żembaq and at Tas-Silġ, mostly because of high percentages of *Pinus*, which could be taphonomic or reflecting overall lower pollen productivity locally rather than reflecting changes to the vegetation.

Cereal pollen remains high and rises in the latest Punic period, peaking in the Roman Period at Marsa (Carroll *et al.* 2012). Cereal pollen also appears at In-Nuffara, but declines slightly at Tas-Silġ and disappears at Wied Żembaq (Hunt 2015) at the same time. The long record from Xemxija shows very strong evidence for possible discontinuities and often has very low pollen counts, but nonetheless reflects a degraded steppe landscape adjacent to a drying former marshy area.

It is not possible to separate the pollen of cultivated and wild or feral (descended from cultivated forms) olives, but since *Olea* pollen is recorded prior to the Neolithic at Xemxija, it is almost certainly a native species and therefore likely derives from oleaster (wild olive) for most of the Holocene. Its behaviour prior to the Punic Period is in-phase with the rise and fall

of tree and shrub pollen and out of phase with the pollen of cereals, supporting its likely derivation from oleaster. Only in the later Punic and Roman periods, from c. 400 cal. BC (2450 cal. BP) onwards at Burmarrad and Marsa, is *Olea* pollen in phase with cereal pollen, perhaps suggesting that it derives from the cultivation of domesticated olive trees. This corresponds with finds of olive stones at Marsa and Tas-Silġ (Fiorentino *et al.* 2012). Recent investigations have shown that the pollen productivity and dispersal of modern *Olea europaea* are very limited, with pollen percentages in surface samples declining by 60–90 per cent within 100 m of the cultivation site (Florenzano *et al.* 2017). Values of olive pollen as high as 8 per cent at Burmarrad (Gambin *et al.* 2016) and 5 per cent at Marsa (Carroll *et al.* 2012) during the Roman period may therefore reflect extensive olive groves (Anastasi & Vella 2018; Vella *et al.* 2017). Elsewhere in the Mediterranean, such as at Kouremenos in Crete, there is certainly evidence of intensifying olive tree presence from the later Neolithic at about 3600 cal. BC onwards (Langgut *et al.* 2019), coincident with the opening-up of the landscape and intensification of grazing (Stoddart *et al.* 2019), although the early stages of olive tree management may not necessarily imply domestication and cultivation of the tree (Canellas-Bolta *et al.* 2018, 73, & references therein). A recent review of the evidence for olive growing in Puglia, southeast Italy, shows that wild olives have been cultivated there since the early Neolithic, and selective cultivation culminated in the first appearance of the domestic type during the Middle Bronze Age or mid-second millennium BC (Caracuta 2020).

At Xemxija the very high peak of *Pinus* pollen during the period c. 150 cal. BC to cal. AD 1150 (1800 to 800 cal. BP) is notable, and can probably be best interpreted as evidence for a Roman period pine plantation that persisted through the Arab period and into Norman times. Supporting evidence for this interpretation may be provided by the observation of al-Idrisi, made around AD 1150, incorporated in a later text by al-Himyari (Brincat 1995) that good timber for ship repair had been available on Malta.

3.6.8. Medieval to modern (post-AD 1000)

All assemblages of Medieval to early Modern age show a very strong taphonomic imprint, being dominated by corrosion-resistant taxa such as Lactuceae. All other evidence points towards very degraded environments, mostly degraded steppe, although most records have

poor chronological resolution. Pollen indicative of degraded steppe vegetation is particularly evident in the basal half of the core from Santa Marija Bay on Comino with very low percentages of Poaceae and high percentages of *Centaurea* and *Gladiolus*, taxa which are today associated with degraded steppe environments on the islands (Carroll *et al.* 2012).

Around AD 1600–1650 (assuming constant sedimentation rates), there is a sharp change in the Santa Marija Bay core, with a decline in *Gladiolus* and rise in Poaceae and *Plantago* (Carroll *et al.* 2012). At In-Nuffara, there is a minor increase in Poaceae which is undated, but predates the appearance of the exotic *Eucalyptus* and thus is probably earlier than the British Period (or pre-nineteenth century). At Ġhajj il-Kbira on Gozo, molluscan assemblages relating to the nineteenth century or earlier are marked by a rise in the grassland species *Truncatellina callicratis* (Hunt & Schembri 2018). These changes were most likely caused by the policy of the Knights, who encouraged the creation of terrace systems (see Chapters 7 & 8) and improvement or manufacture of soils and the development of sheep runs (Blouet 1997), but may also reflect a phase of higher effective humidity during the Little Ice Age (Sadori *et al.* 2016).

Finally, the most recent parts of the In-Nuffara deposit, and the cores from Xemxija, Santa Marija Bay, Salina Bay and Marsa (Carroll *et al.* 2012) all show a strong rise in *Pinus*, consistent with the widespread planting of pines as ornamentals during the British Period. The Australian exotic *Eucalyptus*, was also planted during British times and was present at In-Nuffara and in the Mistra Valley (Hunt & Vella 2004/2005). Maize and cotton were also present in the field-fill in the Mistra Valley (Hunt & Vella 2004/2005). The wider landscape generally remained extremely degraded.

3.7. Conclusions

The work done by the FRAGSUS Project has significantly changed our understanding of the sequence and causes of Holocene vegetation change in the Maltese Islands, as well as some aspects of the relationship between the environment and the human population. For the first time, analysis of multiple sediment sequences and archaeological sites has allowed us to differentiate between climatic and anthropogenic signals at times during the Holocene. These entwined issues will be returned to in the concluding Chapter 11.