

HOLOCENE ENVIRONMENTAL CHANGE THROUGH NATURAL
PROCESSES AND HUMAN INFLUENCE IN SALENTO, SOUTH-EAST ITALY:
AN INTEGRATED GEOMORPHOLOGICAL
AND PALYNOLOGICAL INVESTIGATION

(In two volumes)

by

Jenny Lynne Harding

Volume 1

Thesis submitted for the degree of Doctor of Philosophy,
Department of Archaeology and Prehistory, University of Sheffield,
July 1992

For my parents

CONTENTS - VOLUME 1

Acknowledgements - page XVI

Summary - page XVII

Part 1**Chapter 1 (pages 1-7)****INTRODUCTION**

1.1 Grounds for research and the research aims

1.2 Research approach.

1.3 Research strategy.

1.3.1 Field survey of the study-area.

1.3.2 Selection of sampling locations.

1.3.3 Modern surface-samples.

1.3.4 Analysis of sediment cores for environmental reconstruction.

Chapter 2 (pages 8-25)**PUGLIA: THE PRESENT ENVIRONMENT**

2.1 Introduction

2.2 The morphological regions of Puglia.

2.2.1 The Gargano promontory.

2.2.2 The Tavoliere Plain.

2.2.3 The Murge.

2.2.4 The Bradano Trench and Monte Vulture.

2.2.5 The Salento Peninsula.

2.3 Karst development in Puglia.

2.4 Unconsolidated deposits.

2.4.1 Red earth.

2.4.2 Alluvium and Holocene soils.

2.4.3 Calcrete.

2.4.4 Holocene sands, silts and clays.

2.4.5 Coastal dunes.

2.5 Surface drainage and water supply.

- 2.5.1 Surface drainage.
- 2.5.2 Groundwater
- 2.5.3 Springs
- 2.6 Climate
- 2.7 Vegetation and landuse
 - 2.7.1 Woodland
 - 2.7.2 Macchia
 - 2.7.3 Stony pastures or Murgia
 - 2.7.4 Marsh vegetation
 - 2.7.5 Coastal dune vegetation
- 2.8 Landuse
- 2.9 Aspects of population distribution, present and past, in relation to the physical environment

Chapter 3 (pages 26-44)

THE PRESENT ENVIRONMENT OF THE STUDY AREA

- 3.1 Introduction
- 3.2 Geology
- 3.3 The tectonic situation
- 3.4 Karst morphology
- 3.5 Surface drainage and water supply
 - 3.5.1 Surface drainage
 - 3.5.2 Groundwater
 - 3.5.3 Springs and the distribution of marsh
- 3.6 Unconsolidated deposits
 - 3.6.1 Red earths
 - 3.6.2 Calcrete
 - 3.6.3 Water-lain deposits and deposits of wet ground
 - 3.6.4 Soils and soil erosion
 - 3.6.5 Aeolian deposits
 - 3.6.6 Coastal dunes and coastline dynamics
- 3.7 Semi-natural vegetation and landuse
 - 3.7.1 Woodland
 - 3.7.2 Isolated trees in the landscape
 - 3.7.3 Macchia
 - 3.7.4 Garigue and herbaceous vegetation
 - 3.7.5 Freshwater marsh

- 3.7.6 Saltmarsh
- 3.7.7 Coastal dune vegetation
- 3.7.8 Modern landuse
- 3.8 Summary of environmental attributes in the study-area

Chapter 4 (pages 45-55)

ENVIRONMENTAL CHANGE WITHIN THE STUDY-AREA: OBSERVATIONS AND EXISTING IDEAS

- 4.1 Introduction
- 4.2 Relative sea-level change
- 4.3 Areas of marsh
- 4.4 Past vegetation
- 4.5 Population distribution in the study-area; present and past

Chapter 5 (pages 56-74)

THE SEDIMENT SAMPLING LOCATIONS

- 5.1 The selection of sediment-core sampling locations for palynological analysis
 - 5.1.1 Alimini Piccolo, marginal lacustrine and marsh sediments
 - 5.1.2 Marsh basin sediments north of Alimini Grande
 - 5.1.3 Marsh basin sediments north-west of San Foca
 - 5.1.4 Cesine lagoon margin sediments and marsh sediments
- 5.2 The sediment-core locations
 - 5.2.1 Alimini Piccolo
 - 5.2.2 Marsh basin at the northern end of Alimini Grande
 - 5.2.3 Paludi Pozzelle
 - 5.2.4 Depression west of Roca Vecchia
 - 5.2.5 Marsh basin 2 km to the north-west of San Foca
 - 5.2.6 Cesine marshes and lagoons
- 5.3 Surface-sample locations
 - 5.3.1 Surface-sampling strategy
- 5.4 Modern waterlain sediment-samples
- 5.5 Sediment sampling from archaeological deposits

Chapter 6 (part 1) (pages 75-78)**SEDIMENT SAMPLING AND PREPARATION METHODS****6.1 Field procedure**

6.1.1 Sediment cores

6.1.2 Surface-samples

6.2 Laboratory procedure

6.2.1 Core stratigraphy

6.2.2 X-ray radiography

6.2.3 Sampling for palynological analysis

6.2.4 Sample preparation

6.2.5 Slide preparation

(part 2) (pages 79-84)**RECORDING PROCEDURES FOR POLLEN AND OTHER MICROFOSSILS****6.3 Pollen and Spores**

6.3.1 Counting

6.3.2 Identification

6.4 Non-pollen microfossils

6.4.1 Counting

6.4.2 Identification

6.5 The presentation of quantitative pollen and microfossil data

6.5.1 Pollen data

6.5.2 Non-pollen microfossil data

Chapter 7 (part 1) (pages 85-89)**FOSSIL POLLEN****7.1 Points on the identification of pollen types of special interest in this study**7.1.1 Quercus

7.1.2 Oleaceae

7.1.3 Tamarix7.1.4 Ostrya carpinifolia and Carpinus orientalis7.1.5 Cynoglossum type

7.1.6 Compositae

7.1.7 Gramineae

7.2 Morphological descriptions of pollen from specific exotic plants in the study-area

(part 2) (pages 90-101)

THE NON-POLLEN MICROFOSSILS

7.3 Introduction

7.4 Plant remains

7.4.1 Cell walls

7.4.2 Charcoal

7.4.3 Other plant remains

7.5 Fungal remains

7.5.1 Fungal hyphae

7.5.2 Vesicular arbuscular mycorrhizae

7.5.3 Fungal spores

7.6 Invertebrate animal remains

7.6.1 Cladocera

7.6.2 Sponges (Porifera)

7.6.3 Foraminifera

7.6.4 Other animal remains

7.7 Algal remains

7.7.1 Diatoms (Chrysophyta)

7.7.2 Dinoflagellates (Pyrrhophyta)

7.7.3 Cyanophyceae (Cyanophyta/blue-green algae)

7.7.4 Botryococcus (Chlorophyta/green algae)

7.7.5 Pediastrum (Chlorophyta/green algae)

7.7.6 Zygnemataceae (Chlorophyta/green algae)

7.7.7 Desmids (Chlorophyta/green algae)

7.8 Microfossils of uncertain affinity found in the present study

7.8.1 Concentricystes cf. Circulus

7.8.2 Type A

7.9 Mineral remains

7.9.1 Pyrite

(part 3) (pages 102-104)**MACROFOSSILS**

- 7.10 Coarse residue contents**
- 7.11 Plant remains**
 - 7.11.1 Cellular material**
 - 7.11.2 Charophyte oogonia**
- 7.12 Animal remains**
 - 7.12.1 Mollusc shells**
 - 7.12.2 Ostracods**
 - 7.12.3 Foraminifera**
- 7.13 Mineral residue**

PART 2**Chapter 8 (pages 105-141)****SURFACE-SAMPLES AND MODERN MUD-SAMPLES: RESULTS OF FIELD SURVEY AND PALYNOLOGICAL ANALYSES**

- 8.1 Introduction**
- 8.2 The spot surface-samples**
 - 8.2.1 Data presentation**
 - 8.2.2 Spot surface-sample results**
 - 8.2.3 The representation of vegetation zones by pollen assemblages in the spot surface-samples**
 - 8.2.4 Notes on the distribution of certain plant types and pollen types in the different vegetation zones**
 - 8.2.5 The representation of surface-sediment conditions by non-pollen microfo in the spot surface-samples**
- 8.3 The transect surface-samples**
 - 8.3.1 Data presentation**
 - 8.3.2 The Cesine transect results**
 - 8.3.3 The representation of vegetation zones by pollen assemblages along the Cesine transect**
 - 8.3.4 Notes on the distribution of certain plant types and pollen types in the vegetation zones traversed by the transect**
 - 8.3.5 The representation of surface-sediment conditions by non-pollen microfo**

- along the Cesine transect
- 8.3.6 The north-west Alimini Piccolo transect results
- 8.3.7 The representation of the two marsh-zones by pollen assemblages along the transect
- 8.3.8 The representation of the two marsh-zones by non-pollen microfossils along the transect
- 8.4 Conclusions on the palynological analyses of the surface-samples
 - 8.4.1 Pollen analyses
 - 8.4.1 Non-pollen microfossil analyses
- 8.5 Modern mud-sample results

Chapter 9 (pages 142-254)

THE SEDIMENT CORES: STRATIGRAPHY AND RESULTS OF PALYNOLOGICAL ANALYSES

- 9.1 Introduction
- 9.2 Core AP88
 - 9.2.1 Core stratigraphy and macrofossils
 - 9.2.2 Discussion of stratigraphy and macrofossil content
 - 9.2.3 Non-pollen microfossils
 - 9.2.4 Evidence for local environmental conditions from spores and pollen of aquatic plants
 - 9.2.5 Fossil pollen
 - 9.2.6 Radiocarbon dates
 - 9.2.7 A chronology for environmental change, interpreted from core AP88
- 9.3 Core 1AP
 - 9.3.1 Core stratigraphy and macrofossils
 - 9.3.2 Discussion of stratigraphy and macrofossil content
 - 9.3.3 Non-pollen microfossils
 - 9.3.4 Evidence of local environmental conditions from spores and pollen of aquatic plants and marsh plants
 - 9.3.5 Fossil pollen
 - 9.3.6 Summary of environmental change at the north-eastern end of Alimini Piccolo, represented by core 1AP
 - 9.3.7 Comparison of core 1AP with core AP88
- 9.4 Cores 2AP and 3AP
 - 9.4.1 Core 2AP stratigraphy
 - 9.4.2 Core 3AP stratigraphy

- 9.4.3 Discussion of stratigraphy in cores 2AP and 3AP
- 9.5 Core 1AG
 - 9.5.1 Core stratigraphy and macrofossils
 - 9.5.2 Discussion of core stratigraphy and macrofossils
 - 9.5.3 Non-pollen microfossils
 - 9.5.4 Evidence for past local environmental conditions from plant spores and from pollen of marsh plants
 - 9.5.5 Fossil pollen
 - 9.5.6 Synthesis of environmental information from core 1AG
 - 9.5.7 A discussion of chronology for environmental change represented by core 1AG
 - 9.5.8 Chronological interpretation of environmental change represented by core 1AG
- 9.6 Core PP1
 - 9.6.1 Core stratigraphy
- 9.7 Core RV88
 - 9.7.1 Core stratigraphy
- 9.8 Core SF88 and SF1
 - 9.8.1 Core SF88: stratigraphy
 - 9.8.2 Core SF1: stratigraphy
 - 9.8.3 Discussion of stratigraphy and macrofossil content
 - 9.8.4 Non-pollen microfossils in core SF1
 - 9.8.5 Fossil pollen
 - 9.8.6 Summary of local environmental conditions
- 9.9 Cores C1 and PG
 - 9.9.1 Core C1: stratigraphy and macrofossils
 - 9.9.2 Core PG: stratigraphy and macrofossils
 - 9.9.3 Discussion of stratigraphy and macrofossil content in core PG
 - 9.9.4 Non-pollen microfossils
 - 9.9.5 Interpretation of local environmental change represented by core PG
- 9.10 Core C2
 - 9.10.1 Core stratigraphy and macrofossils
 - 9.10.2 Discussion of stratigraphy and macrofossil content
 - 9.10.3 Non-pollen microfossils
 - 9.10.4 Evidence for local environmental conditions from spores and pollen of aquatic plants and marsh plants
 - 9.10.5 Interpretation of local environmental change represented by core C2
 - 9.10.6 Fossil pollen
- 9.11 Core CS1

- 9.11.1 Core stratigraphy and macrofossils
- 9.11.2 Discussion of core stratigraphy and macrofossils
- 9.11.3 Non-pollen microfossils
- 9.11.4 Evidence for local environmental conditions from spores and pollen of aquatic plants and marsh plants
- 9.11.5 Interpretation of local environmental change represented by core CS1
- 9.11.6 Fossil Pollen
- 9.11.7 Comparison of cores C2 and CS1
- 9.11.8 Chronology for environmental change represented by cores C2 and CS1
- 9.12 Core CS2
 - 9.12.1 Core stratigraphy and macrofossils
 - 9.12.2 Discussion of core stratigraphy and macrofossil content
 - 9.12.3 Non-pollen microfossils
 - 9.12.4 Interpretation of environmental change represented by core CS2
- 9.13 Cores C3 and C4
 - 9.13.1 Core C3: stratigraphy
 - 9.13.2 Core C4: stratigraphy
 - 9.13.3 Discussion of stratigraphy and macrofossils in core C4
- 9.14 Core CM
 - 9.14.1 Core stratigraphy
 - 9.14.2 Discussion of core stratigraphy
- 9.15 Synopsis of environmental change represented by cores from the Cesine region
 - 9.15.1 Sedimentary environments
 - 9.15.2 Vegetation patterns

Chapter 10 (pages 255-259)

RESULTS OF SAMPLE ANALYSES FROM ARCHAEOLOGICAL CONTEXTS

- 10.1 Roca Vecchia
 - 10.1.1 Principal features of the site
 - 10.1.2 Sample locations and archaeological context
 - 10.1.3 Summary results of the chemical analyses
 - 10.1.4 Pollen analyses
- 10.2 Archaeological feature in the Cesine reserve

PART 3

Chapter 11 (pages 260-271)**SUMMARY OF THE GEOMORPHOLOGICAL AND PALYNOLOGICAL RESULTS AND CONCLUSIONS ON LATE QUATERNARY ENVIRONMENTAL CHANGE IN THE STUDY-AREA****11.1** late Quaternary sedimentary environments

- 11.1.1 Early mineral deposits
- 11.1.2 Organic sediments
- 11.1.3 Lacustrine sediments
- 11.1.4 The absence of volcanic ash layers

11.2 Vegetation change in the study-area

- 11.2.1 The interpreted pollen record of core 1AG
- 11.2.2 Correlation between cores of the study-area
- 11.2.3 Human impact on the study-area landscape

Chapter 12 (pages 272-295)**PRESENT RESEARCH CONCLUSIONS IN THE CONTEXT OF HOLOCENE ENVIRONMENTAL CHANGE IN CENTRAL-SOUTHERN EUROPE****12.1** Introduction**12.2** Late Quaternary vegetation change in the central Mediterranean

- 12.2.1 Southern Italy
- 12.2.2 Central Italy
- 12.2.3 Sea core studies
- 12.2.4 How does the record of environmental change in the study-area compare with pollen records from southern and central Italy?
- 12.2.5 Vegetation development in the study-area compared with other parts of the central Mediterranean

12.3 Conclusions on Holocene vegetation history in the central Mediterranean**12.4** Climatic change and human impact during the Holocene in south-east Italy: a review of the evidence

- 12.4.1 Holocene climatic change in the central and southern Mediterranean region
- 12.4.2 The nature and chronology of human impact on the environment of Puglia
- 12.4.3 Concluding remarks on Holocene climate and subsistence economies in south-east Italy, with respect to environmental change in the study-area

- 12.5 The impact of Holocene sea-level rise in the study-area**
 - 12.5.1 Holocene sea-level change
 - 12.5.2 Adriatic bathymetry and relative sea-level change
 - 12.5.3 The submergence of land off-shore from the study-area

Chapter 13 (pages 296-303)

CONCLUSION

13.1 Completion of the research aims

- 13.1.1 Holocene vegetation change in the study-area
- 13.1.2 Mechanisms for vegetation and environmental change
- 13.1.3 The effect of changing vegetation patterns on soils and drainage
- 13.1.4 The impact of Holocene sea-level rise on the coastline and on ground conditions in the coastal margin

13.2 Significance of the present research

- 13.2.1 Palaeoenvironmental contributions
- 13.2.2 Methodological contributions

13.3 Limitations of the present research

13.4 Further work

Appendix A (pages 304-307)

Appendix B (pages 308-309)

Bibliography (pages 310-333)

CONTENTS - VOLUME 2

LIST OF FIGURES

Figure/table titles followed by page numbers

- 1.1: Map of Italy showing the locations of Puglia and the study-area, 1.
- 2.1: The morphological regions of Puglia, 2.
- 3.1: The study-area, between San Cataldo and Otranto, 3.
- 3.2: Geological map of the study-area, 4.
- 3.3: Map of geomorphological and structural features in the study-area, 5.
- 3.4: Diagram of channel section through the archaeological feature in the Cesine reserve, 6.
- 3.5: The distribution of woodland in the study-area, 7.
- 4.1: The distribution of existing and former marsh areas in the study-area, 8.
- 4.2: The distribution of known prehistoric sites around the Alimini lakes, 9.
- 4.3: Archaeological sites/locations in Salento, mentioned in chapter 4, 10.
- 5.1: Plan of core locations around the Alimini lakes, and in the Paludi Pozzelle, 11.
- 5.2: Plan of core locations in depressions near San Foca and Roca Vecchia, 12.
- 5.3: Plan of core locations in the Cesine reserve, 13.
- 5.4: Plan of surface-sample and modern mud-sample locations around the Alimini lakes, 14.
- 5.5: Plan of surface-sample and modern mud-sample locations in the Cesine reserve, 15.
- 8.1: Pollen frequencies along the Cesine transect, 16.
- 8.2: Non-pollen microfossil frequencies along the Cesine transect, 17.
- 8.3: Pollen frequencies along the transect on the north-west side of Alimini Piccolo, 18.
- 9.1: Core AP88. Sediment stratigraphy, 19.
- 9.2: Core AP88: Non-pollen microfossil diagram, 20.
- 9.3: Core AP88: Pollen diagram (%), 21.
- 9.4: Core AP88: Pollen diagram (absolute), 22.
- 9.5: Core 1AP. Sediment stratigraphy, 23.
- 9.6: Core 1AP: Non-pollen microfossil diagram, 24.
- 9.7: Core 1AP: Pollen diagram (%), 25.
- 9.8: Core 1AP: Pollen diagram (absolute), 26.
- 9.9: Cores 2AP & 3AP. Sediment stratigraphy, 27.

- 9.10: Particle size distributions of sands from the north-west side of Alimini Piccolo, core 3AP and core 1AG, 28.
- 9.11: Particle size distributions of dune sand samples from the study-area, 29.
- 9.12: Core 1AG. Sediment stratigraphy, 30.
- 9.13: Core 1AG: Non-pollen microfossil diagram, 31.
- 9.14: Core 1AG: Pollen diagram (%), 32.
- 9.15: Core 1AG: Pollen diagram (absolute), 33.
- 9.16: Particle size distributions of the sand fraction of red-earth samples from the study-area, 34.
- 9.17: Cores PP1 & RV88. Sediment stratigraphy, 35.
- 9.18: Cores SF88 & SF1. Sediment stratigraphy, 36.
- 9.19: Core SF1: Non-pollen microfossil diagram, 37.
- 9.20: Core SF1: Pollen diagram (%), 38.
- 9.21: Cores C1 & PG: Sediment stratigraphy, 39.
- 9.22: Particle size distributions of sands from cores PG and CM from the Cesine, and cores 1AG and 3AP near the Alimini, 40.
- 9.23: Core PG: Non-pollen microfossil diagram, 41.
- 9.24: Core C2: Sediment stratigraphy, 42.
- 9.25: Core C2: Non-pollen microfossil diagram, 43.
- 9.26: Core C2: Pollen diagram (%), 44.
- 9.27: Core C2: Pollen diagram (absolute), 45.
- 9.28: Core CS1: Sediment stratigraphy, 46.
- 9.29: Core CS1: Non-pollen microfossil diagram, 47.
- 9.30: Core CS1: Pollen diagram (%), 48.
- 9.31: Core CS1: Pollen diagram (absolute), 49.
- 9.32: Diagram showing the suggested correlation between pollen assemblage-zones in cores C2, CS1, 1AG and AP88, 50.
- 9.33: Core CS2: Sediment stratigraphy, 51.
- 9.34: Core CS2: Non-pollen microfossil diagram, 52.
- 9.35: Cores C3 & C4: Sediment stratigraphy, 53.
- 9.36: Core CM: Sediment stratigraphy, 54.
- 10.1: The archaeological site of Roca Vecchia, 55.
- 10.2: Sketch plan of the sampling area within the excavated area at Roca Vecchia, 56.
- 12.1: Schematic distribution of vegetation belts along a north- south transect of the Apennines, 57.
- 12.2: Map of Italy showing core-site locations mentioned in section 12.1, 58.
- 12.3: Map of the central Mediterranean region showing core-site locations mentioned in section 12.2, 59.

- 12.4: Map of Mediterranean sea-surface topography (geoid), 60.
- 12.5: Bathymetric map of the Adriatic Sea (to -150 m), 61.
- 12.6: Bathymetric map of the southern Adriatic, 62.
- 12.7: Map of the study-area showing nearshore bathymetry to -50 m, 63.

LIST OF TABLES

- 7.1: Summary of microfossil occurrence in the sediment cores, 64.
- 8.1-8.15: Spot surface-sample results, 65-79.
- 8.16: Summary of microfossil occurrence in the spot surface-samples, 80.
- 8.17: Composite list of plants and pollen taxa, showing the presence/absence of plants recorded in the field and pollen recorded from the surface-samples, 81.
- 8.18-8.28: Cesine transect surface-sample results, 82-92.
- 8.29: Summary of microfossil occurrence in surface-samples along the Cesine transect, 93.
- 8.30: Composite list of plants and pollen taxa along the Cesine transect, showing the presence/absence of plants recorded in the field and pollen recorded from the surface-samples, 94.
- 8.31-8.32: Alimini Piccoo transect, quadrat descriptions, 95-96.
- 8.33: Summary of microfossil occurrence in surface-samples along the Alimini Piccolo transect, 97.
- 8.34: Summary of microfossil occurrence in the modern-mud samples, 98.
- 9.1: Summary of the sediment-cores and analyses, 99.
- 9.2: Macrofossil distribution in core AP88, 100.
- 9.3: Macrofossil and mineral distribution in core 1AP, 101.
- 9.4: Macrofossil and mineral distribution in core 1AG, 102.
- 9.5: Macrofossil and mineral distribution in core SF1, 103.
- 9.6: Macrofossil and mineral distribution in core PG, 104.
- 9.7: Macrofossil and mineral distribution in core C2, 42.
- 9.8: Macrofossil and mineral distribution in core CS1, 105.
- 9.9: Macrofossil and mineral distribution in core CS2, 106.
- 9.10: Macrofossil and mineral distribution in core C4, 107.
- 10.1: Pollen-assemblage of sediment from the 3rd/4th century well B.C; Roca Vecchia, Vol.1, 258.
- 12.1: Studies of late Quaternary vegetation history in southern Italy, the Adriatic Sea and the Gulf of Taranto, 108.
- 12.2: Studies of late Quaternary vegetation history in central Italy, 109.
- 12.3: Summary of Holocene environmental change at crater-lake locations in southern Italy, 110.
- PLATES 1 to 12, 111-122.

ACKNOWLEDGEMENTS

I thank my supervisor, Professor David D. Gilbertson, for his sound advice and encouragement. I also thank Dr. Chris O. Hunt and Ken J. Dorning for palynological and technical advice. I thank the following people for academic and technical consultation: Dr. E. Cox, Dr. C. Braithwaite, Dr. L. Barfield, Mrs. J. Ulmanis and Ms. S. College.

In Italy I wish to thank Professor C. Pagliara of the Dipartimento di Scienze dell'Antichita, Universita di Lecce, for introducing me to the archaeology and landscape of the study-area, and for valuable assistance in making study and fieldwork arrangements. Thanks are also due to personnel of the Corpo Forestale, Lecce, and wardens of the WWF for access to the Cesine reserve. I am grateful to the following people for their assistance in the field: Jim Hansom and David Thomas in 1988, Andrew Hanasz in 1989, and Ken Dorning, Simon Lewis, Chris Hunt and Anne Jones in 1990. I am also grateful to the British School at Rome for assistance in 1989, and to the Royal Botanic Gardens, Kew, for supplying samples of modern flower anthers.

I further thank Ken Dorning, Ian Brooks, Chris Hunt and Anne Jones for their interest and encouragement throughout the research. Most of all, I thank my parents who have been tremendous support always.

I thank the S.E.R.C for funding this research with an Instant Award.

SUMMARY

South-east Italy is a region of distinct archaeological importance in which environmental factors have clearly played a major role in settlement site selection and economic development throughout the Holocene. Little is known, however, of how the environment has changed during this period. This research focuses on the Adriatic coastal margin of Salento between San Cataldo and Otranto, an important area of prehistoric and historic settlement. The research principally determines how and at what rate the environment of the study-area has changed during the Holocene as a result of the interaction between natural processes and human influence. For the first time, detailed scientific analysis is provided on Holocene environmental change in south-east Italy.

Specifically, the impact of natural processes and human influence on vegetation patterns are investigated, together with the impact of Holocene relative sea-level rise on this low-lying, semi-arid coastal zone. The research aims are tackled by geomorphological and palynological investigations of the sedimentary record within the study-area in order to derive evidence for past environmental conditions. Analyses of the sediments, macrofossils, incorporated pollen and non-pollen microfossils including dinoflagellate cysts, diatoms and algal cysts within lacustrine, freshwater marsh and marine lagoon environments are integrated to maximise the palaeoenvironmental information obtained. These analyses are interpreted together with archaeological data to reconstruct spatial differences in Holocene environmental change in the study-area.

Holocene sedimentary sequences are determined and a record of vegetation change since the mid-Holocene in the study-area is interpreted from palynological analyses. In contrast to most studies of Holocene vegetation history in Italy, the sharp decline in woodland vegetation in the middle to late Holocene, is primarily attributed to human activities rather than climatic change. Palynological and archaeological evidence point to continuing relative sea-level rise in the past two millennia, an important factor in the development of coastal marsh in the study-area.

Part 1

Background
Methodology

Chapter 1

INTRODUCTION

1.1 Grounds for research and the research aims

Throughout prehistory and until the present day, regional differences in the environment of Puglia, south-east Italy (Fig. 1.1), have presented varied opportunities and constraints to human settlement and economy. These differences, principally concerning morphology and drainage, are manifest in the distribution pattern of known archaeological sites of different ages (see chapter 2).

Evidence for human settlement in Puglia extends back to the early Palaeolithic. Particularly well known are the Upper Palaeolithic cave sites of Grotta Romanelli and Grotta Zinzulusa in Salento, and the dense distribution of Neolithic sites on the Tavoliere Plain. In both cases, site selection reflects, at least in part, a distinct preference for particular environmental attributes, given the economic, cultural and technological basis of the population. The proximity of Puglia to Greece and the approachability of the Adriatic coastline, particularly along parts of the Salento littoral, have also greatly influenced settlement distribution, economy and cultural development in this part of southern Italy.

That the prehistoric and historic development of Puglia are inextricably linked with inland and coastal environmental attributes is clear, but very little is known of how the Puglian environment has changed during its long history of human occupation. The varied and largely impoverished modern landscapes have evolved through millennia of interaction between natural processes of geomorphological and vegetation change, and human landuse practices.

Sedimentological analyses have been carried out within the Tavoliere Plain in association with studies of Neolithic sites and Roman coastal developments (see Delano-Smith 1976, 1978, 1981, 1987). Information on late Pleistocene climatic conditions in Salento has been interpreted from the sediment stratigraphy and faunal remains of Grotta Romanelli (see Blanc 1921, 1928). Of the few existing studies on past vegetation patterns in Puglia, only two limited studies on the Gargano promontory involve pollen analysis (see Satta & Renault-Miskovsky 1985; Pasa & Pasa Durante 1962). The remaining studies are largely speculative, drawing on palynological investigations from locations in central Italy (see Biancofiore 1957) or based upon historical documentation (see Novembre 1965, 1979).

Biancofiore (1957) recognised that the environment was a fundamental factor in the economic development of prehistoric Puglia. His tentative reconstruction of vegetation zones in the Neolithic and Bronze Age of Puglia, based upon limited faunal remains and extra-regional vegetation histories, was intended as a stimulus for future research.

The principal objective of the present research is to provide, for the first time, detailed scientific analysis of Holocene environmental change in south-eastern Italy. The research is focussed on a section of the Adriatic coastal margin of Salento, stretching 30 km northwards from Otranto to San Cataldo (see chapter 3). Remains of Upper Palaeolithic, Bronze Age, Messapian (Iron Age), Roman and medieval age testify to the importance of the study-area to human settlement throughout the Holocene.

Salento is environmentally distinct from other regions of Puglia (see chapter 2). Two environmental attributes of the study-area have been especially attractive to prehistoric and historic populations; all environmental attributes are assessed fully in chapter 3. Firstly, the hydrogeology of the area is such that freshwater is readily accessible, unlike in many parts of Puglia. Secondly, the coastline affords many natural harbours and landing places. Since this coastline is more accessible than that south of Otranto, it is effectively the closest point of contact between Italy and Greece - a key factor in the cultural evolution of Salento.

This research aims to determine how and at what rate the environment of the study-area has changed in the presence of prehistoric and historic populations. How have natural processes of environmental change affected the study-area during the Holocene? In what ways have environmental conditions influenced patterns of human settlement and economy, and to what extent have landuse practices influenced the environmental evolution of the study-area? The following specific questions are targeted for investigation:

- i) How has the vegetation of the study-area changed in composition and spatial pattern throughout the Holocene?
- ii) What are the mechanisms for change? Is climatic change detectable in the changing environmental conditions and vegetation pattern, and how have human activities influenced the vegetation history?
- iii) What has been the effect of changing vegetation patterns on soils and drainage?
- iv) What has been the impact of Holocene sea-level rise on the coastline and on ground conditions in the coastal margin?

These investigations also have broader significance. The research aims to show how the nature and chronology of environmental change in this part of south-eastern Italy

compare with or differ from Holocene records in other parts of the central Mediterranean region.

1.2 Research approach

The research aims are tackled by a thorough geomorphological and palynological investigation of the sedimentary record within the study-area in order to derive evidence for past environmental conditions and the sequence of Holocene environmental change. This empirically derived evidence is complemented wherever possible by information from historical documentary sources concerning past landscapes of the study-area. Integrated analyses of the sediments and incorporated pollen, non-pollen microfossils and macrofossils within the sediment sequences are carried out to maximize the palaeoenvironmental information obtained and consolidate the palaeoenvironmental interpretations made to satisfy the research aims.

Pollen analysis is a technique commonly applied in the research of past vegetation histories, but few Quaternary palynological studies record and analyse the numerous other microfossils which appear with pollen in palynological preparations. Many of these microfossils are readily identifiable to family, genus or even species level. When habitat restrictions or tolerances of the living organism are known, they provide evidence for local environmental conditions in the past. In this research the term 'microfossil' is used to denote all non-pollen organic and silicified remains or organisms observed within the palynological preparations; general use of the term 'pollen' in this research includes Cryptogam spores.

Individual microfossil forms recorded in this research and their specific environmental tolerances are detailed in chapter 7(part 2), but their collective interpretive value is summarised here. Some microfossils are from predominantly soil-dwelling organisms, while others in life occupy aquatic niches constrained by environmental variables including water depth, salinity, nutrient levels, temperature and light. In this way, microfossils potentially provide indications for the following:

- a) the nature of a deposit e.g. terrestrial or water lain
- b) soil or sediment dryness/moisture levels
- c) marine, brackish or freshwater conditions
- d) trophic levels of a water body
- e) input of soil or allochthonous sediment to a water body

Thus other non-pollen microfossils may provide information on local environmental conditions that pollen cannot. Their analysis is especially informative in marginal

marine areas, at the interface between freshwater, estuarine, lagoonal and marine conditions where differences in the environment are represented by different microfossil assemblages. Such is the situation in the coastal margin zone constituting the study-area. Human practices in the local landscape will have further impact on the organic forms deposited and living in both terrestrial and water lain deposits. Deforestation, artificial drainage, agricultural practices and high inputs of dung for example, may lead to intolerable conditions for some organisms, whilst others may thrive. Such disturbance will influence stratigraphic changes in microfossil assemblages. It follows that these changes could correspond to changes in local vegetation type, interpreted from the pollen diagrams.

By ignoring non-pollen microfossils, potentially pertinent information to various palaeoenvironmental studies has been missed. Whilst many palaeolimnological studies exist focussing on one or several specific microfossils, for example diatoms, few examine a broader range of microfossils together with pollen and archaeological information. Perhaps the most integrated study to date is that of Lago di Monterosi, central Italy (Hutchinson *et al.* 1970). Archaeologists in association with specialists in pollen analysis, lake sediments, invertebrates and specific algae, produced a history of the lake and its surroundings since the last Wurm glacial maximum. Combined analyses pointed to changes in the lake and its catchment following nearby construction of the Via Cassia in the 2nd century B.C., and reflected major cultural disturbance in the catchment during the 10th and 11th centuries A.D.

Microfossil assemblages have been interpreted in several palaeolimnological studies in North America to assess the impact of indigenous and European populations in lake catchments (see for example: Brugam 1978; Carney 1982; Burden *et al.* 1986). Lake sediments have been the focus for microfossil studies in late Quaternary environmental research, but microfossil analyses in association with pollen and archaeological data from terrestrial deposits are also highly informative, as shown by the work of van Geel and others, referred to in chapter 7(part 2).

In the present research, microfossil analyses in terrestrial, lacustrine and coastal lagoon environments are integrated with sediment and pollen analyses and archaeological data to reconstruct spatial differences in Holocene environmental change in the study-area.

1.3 Research Strategy

1.3.1 Field survey of the study-area

Geomorphological and geological survey was carried out to:

- i) establish the morphological and hydrological basis of the environment, and identify geomorphological processes affecting the coastal and inland environments;
- ii) identify sediment types, their spatial distribution and the relationship between vegetation zones and sediment type;
- iii) identify zones of sediment deposition and areas which have potentially accumulated sediment throughout the Holocene. These areas are the focus for the integrated sedimentological and palynological investigations into past environmental conditions in the study-area, and the nature, rate and mechanisms for change;
- iv) locate deposits associated with datable archaeological contexts, upon which palynological and/or chemical analyses may provide an insight into local environmental conditions at a determined point in prehistoric or historic time.

1.3.2 Selection of sampling locations

Both regional and local elements of environmental change are of importance to this research. Sediment-core samples were required from zones of sediment deposition representative of each depositional environment in the study-area, at locations well distributed throughout the study-area. Inland locations were selected to detect changes in sediment flux, surface moisture and vegetation patterns in terrestrial catchments. Coastal locations were selected to detect change in these parameters in the coastal environment, and importantly, to detect the influence of Holocene sea-level rise on environmental evolution in the coastal margin.

1.3.3 Modern surface-sample analysis

Before interpreting past environmental conditions from the fossil pollen and microfossil assemblages in the Holocene sediment sequences, it is necessary to establish relationships between modern vegetation zones and pollen deposited in surface sediments, and between modern depositional environments and microfossil assemblages in the study-area.

Surface-sample analyses greatly assist in differentiating between local and regional elements of fossil pollen assemblages (Wright 1967). Pollen dispersal is a function of the dispersal properties of pollen types, agents of transport and catchment size (Jacobson & Bradshaw 1981; Prentice 1985). Pollen types differ in their resistance to decay (see Havinga 1964, 1967) and a number of experimental studies have shown that pollen taphonomy is affected by the sedimentary environment (see Sangster & Dale 1964; Havinga 1971). It is necessary therefore, to examine the relationships between pollen and microfossil assemblages with respect to specific vegetation zones and environmental conditions in the study-area. The few existing palynological studies of modern surface-samples in the Mediterranean region are useful for reference, but are not from regions directly comparable to the environmental conditions of the study-area (see chapter 8).

The approach adopted in this research combines the 'indicator species' approach, whereby the ecological preferences of existing taxa in the study-area are extended back in time, with the 'comparative' approach, assuming that vegetation or environmental types may be 'characterised' by contemporary pollen or microfossil spectra (see Birks & Birks 1980). Both approaches are based on the principle of uniformitarianism, assuming that present day associations between taxa and the habitat preferences of specific taxa have not changed throughout the Holocene (see Maguire 1983).

Present vegetation patterns and communities in the study-area are clearly modified by human landuse practices over probably several millennia (see chapters 3 and 4), such that no natural vegetation communities remain as analogues for early vegetation prior to human disturbance. Much valuable information is however obtainable from the analysis of modern surface-samples. The objectives in the present research are to:

- i) assess the representation of different vegetation zones in the study-area by modern pollen assemblages;
- ii) assess how accurately specific plant types are represented in modern pollen assemblages;
- iii) determine differences in the microfossil assemblages of the different depositional environments of the study-area.

1.3.4 Analysis of sediment cores for environmental reconstruction

i) Sediment analyses:

Sediment stratigraphy and the mineral and organic matter content of sedimentary units within the cores are examined to determine the origins of the sediments, where possible, including their source and agents of transport and deposition. These analyses provide useful information on past processes and local ground surface conditions. As pointed out by Rybničková & Rybniček (1971), more reliable interpretations of fossil pollen assemblages may be achieved when the origin of the incorporating sediment is taken into account.

ii) Pollen analyses:

As described in 1.3.2, sampling locations for palynological analysis were selected in diverse depositional zones, distributed throughout the study-area. The objective of palynological analyses in this research is to detect regional patterns of vegetation change, affecting the study-area as a whole, together with local variations in vegetation communities associated with localised environmental differences in the study-area. Site location within the landscape determines which spatial component of pollen influx, regional or local, predominates in the sediments at the site (Jacobson & Bradshaw 1981). The field survey of morphology and modern geomorphological processes, together with the core-sediment analyses, provide essential ancillary information for the interpretation of regional and local vegetation change from the pollen data.

iii) Non-pollen microfossil analyses:

Analyses of non-pollen microfossil assemblages are complementary to pollen analyses in this research, providing information on local environmental conditions which cannot be inferred from pollen, as well as information supportive of pollen analytical interpretation. They contribute to this study by:

- a) distinguishing between dry, moist and aquatic depositional environments;
- b) detecting marine water influence in otherwise freshwater bodies, providing information on the effects of late Holocene sea-level rise on the coastal margin of the study-area;
- c) detecting change in ground surface conditions or water quality, associated with vegetation change and soil erosion.

Chapter 2

PUGLIA: THE PRESENT ENVIRONMENT

2.1 Introduction

A synopsis is given here of the present environment of Puglia. Although the Puglian landscape has been profoundly modified by both natural processes and human activities during the Holocene, an understanding of present environmental conditions above and below ground is a necessary basis for investigating those of past millennia.

Puglia encompasses a number of morphologically distinct regions with associated differences in soils, hydrology, climate and flora. These regional differences continue to influence population distribution and economic opportunities in the province. In the past certain environmental factors had higher significance for human settlement and subsistence, until technological advance enabled groups to become less constrained by the natural environment. Aspects of each region's environment may thus be perceived as advantageous or problematic to different groups. Before examining environmental attributes of the study-area in detail (chapter 3), it is essential to consider its regional environmental context.

2.2 The morphological regions of Puglia

Puglia is clearly distinguished from neighbouring peninsular Italy by geological and geomorphological characteristics. The Bradano Trench, extending north-westwards from the Gulf of Taranto to the mouth of the Fortore River on the Adriatic coast, effectively delimits the interior extent of the province. This fault controlled depression is a manifestation of the tectonic situation in southern Italy, separating the stratigraphic and tectonic unit of Puglia from the Apennines to the west (Sestini 1984).

In lithological terms, Puglia is a carbonate platform formed by a sequence of limestones and dolomites, mostly attributed to Cretaceous neritic facies. Intermittent deposition of calcareous rocks of Tertiary and Quaternary age were superimposed on parts of this platform during successive phases of marine submergence. Detailed consideration of the geological development and palaeogeography of Puglia until the late Pleistocene, is given by Pasa (1953) and Reina (1957).

Though it is now a relatively stable sector of southern Italy, tectonic movements continuing into the early Pleistocene have affected areas differently, producing a number of morphologically distinct regions (Fig. 2.1). These regions have significance in terms of prehistoric settlement distribution (Whitehouse 1968), and are as follows.

2.2.1 The Gargano promontory

This sector of the carbonate platform is a horst block defined by major fault systems and formed from Jurassic dolomitic limestones and Cretaceous limestones (Belloni *et al.* 1972). A tensional stress regime causes continuing uplift, albeit at very slow rates compared to the Apennines (Cristofolini *et al.* 1985). The gently folded block reaches a maximum height of 1055 m above sea level, rising abruptly above the Tavoliere Plain which skirts its western and southern sides. High limestone cliffs form most of the coastline, but spit development across two embayments on the north-western Gargano coast has enclosed two large marine lagoons. Exposed chert seams within the limestones provided a valuable material source for prehistoric lithic industries in south-east Italy; some seams were mined during the Neolithic (Galiberti *et al.* 1991).

2.2.2 The Tavoliere Plain

The Tavoliere is the largest plain in southern Italy. Bounded by the Gargano, the southern Apennine foothills to the west and the Murge hills to the south, the low lying plain extends from the Fortore River to the Adriatic Sea in the Gulf of Manfredonia. Marine clays and silts infilled the underlying Mesozoic carbonate basin to form the basis of the plain (Ciaranfi 1983), upon which terrestrial Pleistocene deposits and Holocene alluvium contribute to the present morphology. Along the low eastern Tavoliere coastline, many watercourses reach coastal marshes and lagoons after draining across the plain from the southern Apennines. Low interfluves in the west and a series of marine terraces descending gently from west to east interrupt the plain's apparently flat relief. The physical environment of the Tavoliere is described in detail by Delano-Smith (1987), and has received much attention associated with archaeological research into the high concentration of Neolithic settlement in the region (see 12.4.2).

2.2.3 The Murge

Gently folded Cretaceous limestones outcrop to the south of the Tavoliere, forming low hills between the Bradano Trench in the west and the Adriatic in the east. Sometimes known as 'Puglia pietrosa', the sparsely vegetated relief of the Murge appears undulating in the north-west and tabular in the south-east, reaching a maximum height of 686 m. The western side of this higher ground is particularly dissected by faults, whilst the eastern side descends from an escarpment to the Adriatic in a series of terraces. Between the limestone hills and the coast, a narrow zone of alluvial soils extends southwards from the Tavoliere to the coast east of Ostuni. The low coastline is fringed for much of its length by dune cordons.

2.2.4 The Bradano Trench and Monte Vulture

The Bradano Trench forms a morphologically depressed area between the Murge and Lucanian Apennines, partially filled with Late Quaternary clays, sands and alluvium. Within the tectonically active Apennine margin lies Monte Vulture, an active volcano in the middle to late Pleistocene; eruptions may have occurred during the last glacial (Keller *et al.* 1978). Volcanic minerals from this zone are transported by the Ofanto River across the southern margin of the Tavoliere to the Adriatic. Longshore currents then redistribute these heavy minerals along much of the Adriatic coast south of the Gargano, contributing distinct black sands to dune and beach deposits.

2.2.5 The Salento Peninsula

The carbonate platform of the Murge extends southwards to form Salento, the peninsular part of Puglia. Inland and coastal morphology is controlled by calcareous rocks of Palaeocene to Pleistocene age overlying Cretaceous limestones, which themselves outcrop in the western and southern parts of the peninsula. These outcropping older limestones form the higher ground adjacent to the Murge and higher ground in the south known as the 'Serre of Salento'. Where Cretaceous to Miocene rocks outcrop, they are characterised by narrow asymmetrical anticlines separated by broad synclines, oriented in a NW-SE or NNW-SSE direction. Height above sea-level rarely exceeds 150 m. Flatter land, mostly lying below 50 m above sea-level, forms the central part of Salento and much of its coastal margin. This morphologically depressed area is largely formed at the surface by Miocene, Pliocene and Pleistocene calcareous marine deposits.

Tectonic movement at normal faults, which are prevalently aligned parallel to the anticline axes, evidently continued into the Pleistocene (Zezza 1969a; Largaiolli *et al.* 1969). In fact, elevated Pleistocene shelf sediments in the region point to the occurrence of uplift since the early Pleistocene, according to Hearty & Dai Pra (1985), who also suggest downwarping is evident in isolated areas.

The geology and morphology of the study-area, located on a section of the low Adriatic coastal margin of Salento, is considered in more detail in chapter 3.

2.3 Karst development in Puglia

Extensive karst systems have developed in the Cretaceous limestone, influencing surface morphology in the Gargano, Murge and Serre of Salento. Modest karst phenomena also occur in the region's Miocene, Pliocene and Quaternary calcarenites (Belloni *et al.* 1972). The effects of karst upon surface morphology has significant implications for human settlement and economic opportunities in the landscape. Of principal concern is the influence on surface drainage and water supply.

Surface drainage is extremely limited in the intensely karsified Gargano promontory, where much of the surface water is conducted below ground through dolines, or sink hole plains. In the Murge and Salento regions surface drainage is virtually absent. Karst features are numerous in the land surface of Salento (see Guerrichio & Zezza 1982). Dolines, poljes, sink holes and fault lines enlarged by karst processes have created shallow depressions in the landscape, through which surface water may pass into the groundwater system. Elsewhere, water readily infiltrates through the permeable carbonate rocks. Springs issuing from the karst systems therefore provide vital sources of freshwater and are likely to have strongly influenced prehistoric settlement distribution. In fact the present availability of freshwater around the Gargano promontory has assisted in locating prehistoric and classical sites (Jones 1987).

Caves and rock shelters formed by karst processes can also influence settlement distribution. Such features are exposed in cliff sections along parts of the Gargano and Salento coasts, often with associated tufa and travertine deposits attesting to their karst origin. Certain caves could therefore offer shelter and a fresh water supply. Archaeological evidence has shown that some of these caves attracted human usage beginning in Palaeolithic times. For example, Grotta Zinzulusa on the south-east coast of Salento contained Upper Palaeolithic industries. Animal bones are incorporated in travertines at the cave entrance.

Many other caves of marine or karst origin around the present coast and inland along former Quaternary shorelines, have similarly been utilised by human groups. These include Grotta di Paglicci (Gargano) and Grotta dell'Alto on the Ionian coast of Salento, used in early Palaeolithic times (Franco 1981).

2.4 Unconsolidated deposits

Geographic position and drainage characteristics largely determine the nature of unconsolidated deposits overlying the Cretaceous to early Pleistocene, marine carbonates. They are mostly postglacial deposits which have been continually subject to natural processes and, since Neolithic times, human action in the landscape. Today soils are thin and discontinuous over much of the province, especially on higher land and slopes, whilst some marsh and coastal areas continue to accumulate sediment. The major types of unconsolidated deposits are quite distinct and have clearly influenced settlement distribution and economic opportunities.

2.4.1 Red earths

Strikingly red deposits are frequently exposed in many parts of the Puglian landscape, particularly in areas of net soil loss. For example, red earths are often visible on coastal cliff tops and on inland limestone surfaces, where erosional processes continue to remove unconsolidated deposits which are inadequately protected by vegetation. Only the deeper and more extensive of these deposits, commonly termed 'terra rossa', are shown on geological maps for the region. Although 'terra rossa' and 'red earth' are literally equivalent, the latter term will be used here because 'terra rossa' can have more specific pedological meaning (Butzer 1964).

In some places, where surface deposits are virtually stripped to bedrock, pockets of red earth filling surface fissures and hollows may be all that remains. Small surficial karst features such as solution pipes invariably contain red earth. This association of red earths with limestone areas exists in many areas around the Mediterranean and has advanced the commonly held, but controversial, view that they are residual weathering products of the underlying limestone. Convincing argument now exists for a primarily aeolian origin of Mediterranean red earths, a view favoured by the present author and discussed in the light of observations on red earths within the study-area, in 9.5.7ii.

It is possible that red earths lie below Holocene alluvial and eluvial deposits in localised areas of Puglia. Red earths are likely to have formed deeper and more

extensive deposits over the Puglian land surface in the late Pleistocene, consequently surface drainage could have been more extensive than it is today, particularly in karst areas.

2.4.2 Alluvium and Holocene soils

Since large areas of Puglia lack surface drainage, extensive alluvial deposits are confined to the Tavoliere and Bradano Trench. All unconsolidated deposits of the Tavoliere are attributed to the Holocene by Ciaranfi (1983), who distinguishes a pre-Neolithic and a post-Neolithic alluvium in the river valley bottoms and coastal area. Soils of the Tavoliere have been closely examined with respect to Neolithic arable practices in the region (Delano-Smith 1987).

Colmate alluvium, deposited in areas of standing water, may be found in localised areas of impeded drainage, such as coastal marshlands and karst depressions floored by impermeable silts and clays. Areas of coastal marsh exist today along many low lying parts of the Puglian coast, often associated with lagoons. Extensive areas have been artificially reclaimed, including the Fontanelle area on the southern Ionian coast, and localities of the Lago Salso and Lago Salpi in the Tavoliere.

Soils outside alluvial areas are today generally thin and calcareous, often with a high sand content. On the sparsely vegetated higher land, degraded shallow soils are dispersed among outcropping bedrock and contain little humic material.

2.4.3 Calcrete

Calcretes have developed extensively in Puglia, where warm, semi-arid climatic conditions and the availability of calcium carbonate in substrates and phreatic water favour their formation (Carnicelli *et al.* 1989). The term calcrete, or caliche, is most frequently used to describe a calcareous hardpan or crust within a soil profile; the term can also apply to a complete soil profile where soil products have become lithified, with or without a hardpan (Esteban & Klappa 1983).

Six groups of models for calcrete formation have been identified by Goudie (1973), covering the varied geomorphological situations in which they occur. Calcretes in Puglia are likely to have formed differently in disparate regions, and at different times during the Quaternary when climatic conditions were suitable. In Spain, Goudie (1973) notes that calcretes are rare where average annual precipitation exceeds 400 mm, but generally the 500 mm isohyet is a significant limit to calcrete formation. Average

annual rainfall figures today in Puglia only significantly exceed 500 mm in the Gargano (see 2.6).

As the calcrete crust is a hard and relatively impermeable layer, its presence within a sediment profile can have significant local environmental effects in terms of drainage, water availability and soil workability. In this way, great importance has been attached to the apparent relationship between calcrete and Neolithic settlement distribution in the Tavoliere. Calcrete has developed extensively within the plain in association with all the marine terraces (Delano-Smith 1987); the hardpan layer is known as 'crosta'.

In the north-eastern part of the Tavoliere, Cassano & Manfredini (1983) observe that all known Neolithic sites are located either where crosta outcrops or where it is present in the sub-soil. It is not clear, however, whether this is a causal relationship or rather an unavoidable one due to the virtual ubiquity of crosta in the plain. Having said this, the presence of crosta could benefit early agricultural settlement in several distinct ways, as identified by Ciaranfi (1983). At or near the surface, crosta provides a firm foundation for settlement construction, and by virtue of its limited permeability provides a surface upon which rainwater can collect. Beneath the soil surface, crosta impedes evaporation from phreatic water below in parts of the alluvial terraces and calcareous sands. Freshwater could be drawn from these localised phreatic layers by perforating the crosta, as practised in parts of the modern Tavoliere (Ciaranfi 1983). An additional attribute of potential benefit to prehistoric farming, is the relatively easy workability of the light, calcareous crosta soils.

2.4.4 Holocene sands, silts and clays

In the wet areas of coastal marsh, lagoons and inland marshy depressions, calcareous sands and silt or clay muds have accumulated during the Holocene; siltation of these areas is a continuing process. These deposits are of low permeability, impeding the infiltration of surface water (Largaiolli *et al.* 1969). Their present distribution is confined to areas near the coast where perched groundwater bodies intersect the ground surface. Given that these deposits are closely linked with sea-level and groundwater levels, areas of similar deposits probably existed on land now submerged, associated with former Holocene sea-levels (see 12.5) and spring issues.

2.4.5 Coastal dunes

Dune cordons have developed along morphologically depressed parts of the Puglian coastline, where rock elevations above sea-level are insufficient to form cliffs. The dunes form an effective barrier to drainage from land to sea, thereby contributing to coastal marsh development.

In both the Adriatic and the Ionian littoral areas of Puglia, three dune deposits of different age and composition have been identified (Magri & Zezza 1970; Cotecchia *et al.* 1969). The youngest dune cordon lies adjacent to the present shoreline, and is usually fixed by dune vegetation. Remains of the gastropod, *Helix* sp., sampled from red earths underlying these dunes near Torre Canne, on the Adriatic littoral, yielded a radiocarbon age of 2110 ± 90 BP (Magri & Zezza 1970) providing an earliest date for most recent dune formation. Comparable dates were determined from corresponding dunes on the Ionian coast (Cotecchia *et al.* 1969). Given the likelihood that 'old' carbon from calcareous dune sands or pedogenic carbonates may have entered the shell matrix, these dates must be interpreted with caution.

In places, the younger dunes are underlain by older dunes containing *Helix* sp., dated to between 6780 and 3900 BP by radiocarbon (Magri & Zezza 1969). These relate to a former sea-level and have largely been eroded or submerged due to later relative sea-level rise.

The third and oldest dune deposit is identifiable in some localities, for example along a 6 km stretch of the Adriatic coast south-east of Torre Canne. Ancient beach deposits occur along the seaward base of these dunes, at three to four metres above present sea-level (Magri & Zezza 1970). This beach material corresponds with shoreline deposits containing the gastropod, *Strombus*, at three to four metres above sea-level on the Ionian coast of Salento, thought to be between 37000 and 23750 years old and therefore pre-dating the last glacial maximum (Cotecchia *et al.* 1969).

A distinct layer of pumice at a height of 2 m above sea-level within the base of modern dunes between Taranto and Capo S. Maria di Leuca, has been associated with an explosive volcanic centre in the Aegean sea (Ricchetti & De Fino 1969). The authors suggest that the pumice was deposited by sea during the Versilian (postglacial) transgression to a level 2 m above present sea-level; its absence from the Adriatic littoral is explained by surface current patterns in the Mediterranean Sea. Patterns of postglacial sea-level change are discussed in 12.5.

2.5 Surface drainage and water supply

2.5.1 Surface drainage

The surface drainage pattern of Puglia clearly reflects regional geomorphological differences. Perennial rivers are largely confined to impervious catchments in the Tavoliere and Bradano Trench. A number of major rivers flow across the Tavoliere from southern Apennine sources, frequently flooding in their lower reaches to produce coastal marsh and lagoons. Much of the coastal wetlands have been reclaimed in the past two centuries (Delano-Smith 1987), or artificially controlled to create for example the 'Saline', an area of salt pans occupying part of the former Lago Salpi. The coastal margin is still, however, predominantly an area of wetlands.

On the carbonate and karst morphology of the Gargano, Murge and Salento Peninsula, surface drainage is limited and often controlled by faults and fractures. Stream flow is characteristically ephemeral and intermittent, following intense or prolonged rainfall. Enclosed depressions such as karst dolines and poljes often retain detrital materials and clays, creating a partial impervious lining. As a consequence, marshy areas or surficial water bodies may develop within them. In parts of Salento, some doline bottoms appear thickly vegetated with reeds and other marsh vegetation, while others have been reclaimed and cultivated. These perennially wet areas, however, may be sustained primarily by springs and phreatic waters, rather than by surface drainage waters.

Inland freshwater bodies are rare today in Puglia. The freshwater lake of 'Alimini Piccolo', encompassed by the study-area, is exceptional. Seasonal water bodies probably existed in some marshy depressions previous to works of 'bonifica' or reclamation in the past century. Reclamation of these, and extensive marshlands in low-lying areas of the Puglian coast, has been necessary owing to prevalence of malaria in the province in historic times (see 2.9).

2.5.2 Groundwater

A deep, extensive aquifer in the Cretaceous limestones, known as the 'falda di base', is the most important hydrological feature of Puglia. Today it is a valuable economic resource requiring careful management, due to problems of sea water intrusion to the aquifer through coastal karst systems; a problem exacerbated by large demands through the many wells of the province. Water requirements in the Salento Peninsula are

particularly acute, and partially provided for by the 'Aquadotto Pugliese' bringing water from outside Puglia.

The Murge and Salento are hydrogeologically dissimilar, in that low permeability of the Murgian aquifer produces low discharge and requires wells of greater depth than in Salento (Cotecchia *et al.* 1983), but problems of contamination by saline water are far more extensive in Salento. The intruding Adriatic and Ionian Seas meet in places beneath the Salento peninsula; freshwater of the deep aquifer floats upon the intruded sea water (Largaioli *et al.* 1969). Waters from this aquifer are only naturally accessible where springs issue from the Cretaceous limestones, otherwise wells are necessary.

Without the capability to excavate deep wells, discontinuous bodies of perched groundwater are potentially a significant resource. Use of phreatic waters below the crosta in the Tavoliere has already been mentioned (2.4.3). In parts of Salento, perched groundwater exists within Quaternary deposits, above discontinuous impermeable layers. Springs issuing from these layers are largely responsible for inland and coastal marshy areas, and most notably supply the Alimini lakes, located within the study-area.

As in the Tavoliere, the relatively easy accessibility of perched groundwater in parts of Salento must have been attractive to prehistoric as well as historic populations. It has been suggested by Congedo (1984) that some of the megalithic monuments of Salento, comprising dolmen, menhirs and specchie, may have marked the presence of water in the sub-soil.

2.5.3 Springs

In a region where perennial water courses and ponds or lakes are scarce, natural springs would provide vital sources of freshwater prior to the development of suitable technology for excavating wells. Settlement distributions may thus be influenced by spring location. Present spring distribution, however, does not necessarily reflect their situation at other times during the Holocene. Sea-level change and artificial water extraction for example, affect the water table and spring location.

As stratigraphy, morphology and surface drainage vary in different regions of Puglia, so does the incidence of springs. In the Tavoliere today, springs are absent from the plain possibly due to recent lowering of the water table (Sargent 1983). In the carbonate areas springs are mostly located in coastal zones, often producing marshy localities such as the Cesine area of coastal marsh and lagoons in the study-area.

Fractures and karst passages within the carbonate rocks largely control the emergence of freshwater, both on land and frequently offshore. Relatively cold water issuing from coastal and submarine springs, is detectable around the nearshore marine zone of Salento by Meteosat infra-red imagery (Guerricchio & Zezza 1982). At times of lower sea-level, these submarine springs could have existed on land, providing water sources in more extensive low-lying coastal areas.

2.6 Climate

Puglia broadly experiences a Mediterranean type climate of warm, dry summers and cool, humid winters. Most of the annual precipitation falls from October to May, with usually little or no rainfall during the summer months. Locally, however, climate is modified according to topographic position. Average monthly temperatures and rainfall figures are particularly variable in relation to regional topographic differences. The north-facing highland of the Gargano, for example, receives an average annual rainfall of 1000 mm, the highest in Puglia, and experiences a cool temperate climate. By contrast, the climate of the adjacent Tavoliere Plain has a marked continental aspect, being effectively enclosed to the north, west and south by higher land (Delano-Smith 1987); average annual rainfall at Foggia is 454 mm, and the average annual temperature range is high at 20°C.

Coastal areas are influenced by maritime air masses. Brindisi on the Adriatic coast has a mean annual rainfall of 627 mm, and Santa Maria di Leuca at the southern most point of Salento has a mean annual rainfall of 710 mm (U.S. Dept. of Commerce 1987 & 1979). Rainfall figures inland are lower. The Adriatic coastal area is particularly affected by cold, strong 'Bora' winds which blow down the Adriatic from central Europe, most frequently in the cool season, producing heavy showers. More common in the southern Adriatic is the Scirocco, a moist southerly wind frequently reaching gale force in winter and spring (Meteorological Office 1962).

2.7 Vegetation

Little remains of the truly natural plant communities of Puglia or elsewhere in the Mediterranean region, due to the long and widespread history of human disturbance. As a complex product of the interactions of Mediterranean climatic, edaphic and historical factors, Mediterranean vegetation communities are semi-natural; a term describing plant communities which have been affected by human activities but which

retain many of the natural species (Polunin & Walters 1985). In Puglia, agricultural practices have transformed much of the landscape, but areas remain with distinctive Mediterranean type vegetation. Some areas, especially in the Salento Peninsula, show floristic affinities with the Balkan Peninsula, resulting in part from both natural and human agencies of species dispersal across the Adriatic.

Despite extensive land reclamation and irrigation works in Puglia this century, increasing the expanse of cultivated land still further, areas remain which are inaccessible to or unsuitable for agricultural use. In these areas the rich semi-natural flora of Puglia survives with varying degrees of human modification. Some areas of semi-natural vegetation are protected by small private enclosures or by reserves in a few cases, including the Cesine World Wildlife Fund Reserve in Salento and the Foresta Umbra nature reserve in the Gargano.

Within areas of semi-natural vegetation, a number of principal vegetation communities are identifiable, strongly related to local environmental parameters including soil quality, drainage, altitude and climate. The essence of these communities is described by Carano (1934).

2.7.1 Woodland

With the exception of the protected Foresta Umbra of the Gargano, only small remnants of formerly extensive woodland exist in Puglia today. Woodland areas are usually privately owned, often enclosed by dry stone walls and used for hunting. Other wooded areas remain on land of poor agricultural potential and on rocky slopes.

Numerous tree species make up these mixed woodlands. Fagus (beech) predominates in those of the high Gargano, accompanied by other deciduous trees including species of Acer and Quercus, Fraxinus ornus, Ostrya carpinifolia, Tilia platyphylla and evergreen trees including Taxus baccata and Quercus ilex. The shrub and field layer include many elements of montane, sub-montane and Mediterranean type vegetation. A remnant of deciduous woodland in the Tavoliere, protected since the Middle Ages, is described by Delano-Smith (1987).

Elsewhere in Puglia, species of Quercus (oak) are predominant in residual woodlands. All principal oak species occurring in Italy today are present in Puglia, a fact urging Carano (1934) to call Puglia 'la terra delle querce', land of oaks. In a survey of the distribution of Quercus species in Puglia, Crivellari (1950) identifies the following species in descending order of frequency: Quercus ilex, Q. pubescens, Q. cerris, Q. trojana, Q. coccifera, Q. frainetto, Q. pedunculata, Q. suber and Q. aegilops. The distribution of individual species are described in relation to regional environmental

differences in Puglia, by Carano (1934) and Crivellari (1950). Biogeographic points of particular relevance to the present study are summarised below.

Quercus ilex (Holm Oak) is an evergreen species found throughout the province and is particularly numerous in the Salento Peninsula. Its distribution appears to be linked to areas of relatively moist sub-soil, as in much of Salento and in gorges elsewhere, and to areas of higher rainfall, namely the Gargano Promontory. Despite being a highly resistant species to drought, it requires a more humid habitat than other Mediterranean evergreen oaks (Crivellari 1950). Mixed woods dominated by shade giving Q. ilex may be regarded as the natural climax vegetation in most of Puglia, and probably extended over much of the province prior to deforestation by man. According to De Philippis (1937), the removal of such woodlands for agricultural purposes alters the local climate and soil, making conditions more difficult for Q. ilex to re-establish, whilst creating more favourable conditions for Quercus pubescens.

Quercus pubescens (White/Downy Oak) is a deciduous species widespread in Puglia though notably lacking from the Foggia Plain in the Tavoliere and from the high Murge (Crivellari 1950). It favours open woodland, grows well on arid terrain and tolerates temperature extremes (De Philippis 1937).

Quercus cerris (Turkey Oak) is deciduous. Since it prefers non-calcareous soils, this species is rare in Puglia and only occurs in numbers in the Gargano forests, where it generally mixes with Q. pubescens.

Quercus trojana (Macedonian Oak) is a semi-evergreen oak whose natural range is mostly confined to the Balkan Peninsula. In Puglia this species is prevalent in parts of the Murge within the Province of Bari, where it represents the south-western limit of its European distribution. It must have crossed the Adriatic by natural or human agency. According to Crivellari (1950), the distribution of this species in the Murge is related to areas of relatively high rainfall and low temperatures.

Quercus coccifera (Kermes Oak) is a widespread evergreen oak which usually appears today in bushy shrub form, but also forms mixed woodland with Q. trojana. It occurs most commonly in the Murge and in Salento, where it is frequent among macchia vegetation (2.7.2) and in dry stone walls. It should be noted, however, that in Salento Q. coccifera is easily confused with Quercus pseudo-coccifera, which is the more common of the two species in this region (Congedo 1974).

Quercus frainetto (Hungarian Oak) and Quercus pedunculata are deciduous oaks found in limited areas of northern Puglia.

Quercus suber (Cork Oak) is an evergreen species requiring a moist climate with a minimum of 500 mm annual rainfall. In Puglia it is found only around Brindisi, mixed with Q. ilex and Pinus halepensis (Aleppo Pine) in woods near the coast.

Quercus macrolepis or Quercus aegilops (Valonia Oak) is a semi-evergreen oak, whose distribution in Puglia is mainly confined to the vicinity of Tricase in Salento. Although this oak is principally found in Greece, Carano (1934) believes it could also be a native Puglian species. Several varieties of Valonia Oak, locally known as 'Vallonea', have been recognised in this region, of which two are believed to be indigenous to Salento and a third from Epirus (Congedo 1974). The Valonia Oak was certainly cultivated around Tricase since before 1700 AD (Congedo 1974). Its acorn cups have a high tannin content and have long been used to produce a black dye for tanning leather. This practice was introduced to Salento by Arabs during the late first millennium A.D. (Congedo 1974) and tanning industries subsequently developed around Tricase.

Other arboreal species forming principal woodland elements in Puglia, are Pinus halepensis (Aleppo Pine) and in a few places Fraxinus ornus (Manna Ash) and Fraxinus excelsior. In his "Flora Salentina", Marinosci (1870) notes substantial numbers of Fraxinus excelsior in the Bosco di Belvedere in Salento, a woodland of which little now remains. Aleppo Pine woods are most common in coastal regions where they are usually planted to protect adjacent agricultural land from offshore winds, as for example along the low Salento coast between San Cataldo and Otranto in the study-area.

Diverse woody plants, including evergreen shrubs characteristic of Mediterranean type vegetation, form the shrub layer beneath wooded areas. The composition of which varies according to the location and nature of the wood. Many are elements of macchia type vegetation described below.

2.7.2 Macchia

Macchia, or maquis, is defined by Polunin and Walters (1985) as 'a dense shrub community of 1 m or more in height, consisting of evergreen sclerophyllous shrubs'. Such communities of bushes and dwarf shrubs form a distinctive Mediterranean vegetation type. Some authors maintain that macchia is not a natural climax vegetation, but represents a degraded vegetation type following deforestation. Though

many areas of macchia around the Mediterranean originated in this way, certain restricted areas are of natural origin. It particularly develops naturally on dry forest margins in the southern Mediterranean region and on exposed rocky coasts (Schönfelder & Schönfelder 1990), where tree growth is limited notwithstanding human disturbance or grazing animals. In Puglia, areas of macchia have developed both in place of former woodland and independently of woodland disturbance.

The composition of macchia varies according to local climate and soil characteristics. Common elements in Puglia are *Pistacia lentiscus*, *Phillyrea latifolia*, *Quercus coccifera*, *Arbutus unedo*, *Rhamnus alaternus*, *Cistus monspeliensis* and many more. These species frequently occur inland on dry red earths and shallow carbonate soils. Other species may predominate in coastal areas bordering dunes and marshes, and on cliff tops. These typically include *Juniperus* species, *Myrtus communis*, olive species and others (Carano 1934).

In some areas, macchia vegetation has itself been subject to degradation by clearing, fire and grazing, such that the dense shrub cover is reduced to a lower shrub community known as garigue. Garigue is extremely varied in composition, including many herbaceous plants among the largely evergreen and aromatic shrubs. In places, degradation proceeds further to produce stony pastures and ultimately sparsely vegetated ground with attendant loss of soil.

2.7.3 Stony pasture or Murgia

In Puglia, the term 'Murgia' is used to describe an elevated, rocky, impoverished area unsuitable for cultivation (Carano 1934). The term 'Serre' has similar meaning, and both relate to the geographic distribution of stony pastures in Puglia, in the Murge and Serre of Salento. Herbaceous vegetation grows amongst the exposed rock and rubble, creating stony pasture in which the following families are usually represented: Gramineae, Liliaceae, Orchidaceae, Ranunculaceae, Cruciferae, Leguminosae, Umbelliferae, Labiatae and Compositae.

Grazing is largely responsible for the creation of these areas, and usually prevents trees and shrubs from developing. Whilst most of Puglia's stony pastures represent an ultimate stage of degradation from former wooded and macchia areas, some may originate from natural steppe-type vegetation in the region. The total lack of oak species in some areas, even in a very immature state, suggests to Carano (1934) that some such areas have never been wooded.

2.7.4 Marsh vegetation

Rich marsh and aquatic vegetation has developed in localities where groundwater and surface sediment conditions give rise to waterlogged land and surface water. Dense Phragmites reed beds with Typha often dominate in these restricted areas of hygrophilous vegetation.

Saltmarsh exists around lagoons and on the landward side of dune cordons in parts of the low coastal areas. Salt tolerant plants, among them glassworts, grasses and Chenopodiaceae, grow in the wet areas whilst on the drier fringe Juncus acutus (Sharp-pointed Rush) can predominate. Phragmites reeds are often conspicuous in these areas also, as freshwater springs commonly emerge in the coastal zone.

2.7.5 Coastal dune vegetation

Halophilous plant communities are established on the present littoral dune cordons, and include species such as Elymus farctus (Sand Couch), Eryngium maritimum (Sea Holly), Otanthus maritimus (Cottonweed) and Calystegia soldanella (Sea Bindweed).

2.8 Landuse

Most cultivable land in Puglia is today used for crop production whilst remaining areas are left to semi-natural vegetation, some of which is grazed by goats and sheep. Extensive areas of cultivated olive trees are most prominent in the landscape. Olive and almond trees are well adapted to the warm, semi-arid climate and thin soil conditions characteristic of the province. Together with vines, these constitute the most important agricultural products of the province. Many other fruits and vegetables are cultivated in the region. Cereals are also cultivated on both large and small scales; Puglia is one of the largest cereal producing areas in Italy, with most production in the Tavoliere.

2.9 Aspects of population distribution, present and past, in relation to the physical environment

An examination of population distribution in the Murge and Salento by Colamonico (1916), showed that settlement location in these regions is closely linked to surface geology and associated water availability. Where the Cretaceous limestones outcrop, forming the high Murge and the Serre of Salento, freshwater from the deep aquifer is difficult to reach and therefore scarcely available. Soils are generally of poor agricultural productivity and doubtless impoverished by woodland and macchia destruction. Owing to these physical problems, population density in these areas is among the lowest in Italy, according to Colamonico (1916); most inhabitants are concentrated in few large urban centres.

The most densely populated areas in central and southern Puglia are situated on the sandy calcarenites. In areas where relatively impermeable clay or sandy clay layers exist within these rocks, a perched aquifer may be present and accessible from the ground surface (2.5.2), providing a source of drinking water and water for irrigating the relatively fertile soils. This water source is more widely available in Salento than in the Murge. In southern Salento, where outcropping Cretaceous rocks form the high ground, most centres of population are situated on lower lying Neogene and Pliocene calcarenites, as illustrated by Colamonico (1916).

The sandy calcareous rocks thus offer more favourable conditions to human settlement than do the outcropping Cretaceous limestones, where lack of water has probably always hindered settlement expansion. A further advantage of these rocks to settlement establishment is their easy workability. Blocks can be readily cut from bedrock for use in construction. Conversely, suitably sloping areas may be easily excavated to produce rock shelters, for example in steep sided valleys and coastal inlets.

In Puglia, excavated cave settlements were particularly common in medieval times, as they were elsewhere in southern Italy with suitable geological and geomorphological conditions. Most are located in Quaternary calcarenites where scarp slopes have been produced by faults or former coastlines. Natural caves had been used for shelter in Puglia since Palaeolithic times, but social and cultural conditions in the medieval period were such that some groups sought refuge in artificial rock shelters and cave dwellings. Medieval troglodyte dwellings in Puglia appear to be most concentrated in the Salento Peninsula, particularly west of Otranto (Uggeri 1974). Artificial cave sites occurring within the study-area include those excavated from the Pliocene calcarenites at Roca Vecchia. Quadrangular cuts mark the cliff tops here, where rock has also been quarried for building stone (see chapter 10).

Whilst population distribution in Puglia is clearly associated with freshwater availability, in some parts an abundance of freshwater has indirectly repelled settlement development. Malaria has infested many of the low-lying marshy areas around spring issues and water bodies near the coast. Hippocrates maintained that malaria was imported to southern Europe from Africa and Asia in the 5th century B.C. (Novembre 1964). Historical documents suggest that malaria first arrived in southern Italy in the 2nd century B.C. (Shaw-Briggs 1910), and the problem persisted until it was eradicated in the 1940's.

A map of malaria distribution in Italy, published in 1882 by the Istituto Geografico Militare (De Magistris 1942), shows the entire coastal margin of Puglia to be affected. At the time of publication, the problem was particularly grave beside the Tavoliere coast and in the coastal margin from San Cataldo to Taranto; the study-area lies entirely within this zone. Settlement has consequently been sparse in seriously affected low-lying coastal areas while unhygienic conditions prevailed. It appears, however, that this environmental problem did not exist in Puglia before the 2nd century B.C., and so did not detract from the value of springs and areas of standing water to prehistoric populations.

Low-lying coastal morphology has presented other problems. Sea vessels could easily land along low coastal stretches, exposing local peoples to attack. During the medieval period, frequent raids by Saracens and pirates forced the population outside ports to centralise in walled settlements away from the coast (Colamonico 1916).

The physical environment of Puglia thus presents spatial limitations and advantages to settlement, which have strongly influenced population distribution and economy in the province. The extent and significance of such environmental factors will have changed to some degree, however, throughout the Holocene in relation to processes of environmental change and cultural change.

Chapter 3

THE PRESENT ENVIRONMENT OF THE STUDY AREA

3.1 Introduction

The original research in this study was carried out on sediments in part of the Adriatic coastal margin of Salento. The study-area extends for 30 km along the Adriatic coast from San Cataldo southwards to Otranto, and encompasses adjacent land in a 5 km wide strip parallel to the coast (Fig. 3.1). All sediment sampling and environmental observations were made within this area, which includes the most extensive area of wetlands remaining in Salento.

Details of present spatial differences in the geology, morphology, hydrology and vegetation within the study-area are given here. In addition, the principal geomorphological processes operative within the area are identified. The information is derived from geological and topographic maps, together with the author's field observations. On the basis of this information, an insight is provided into past environmental conditions during the Late Quaternary, and specific areas are identified for sampling and research.

3.2 Geology

Surface geology in Salento forms generally elongate units parallel to the Ionian and Adriatic coasts. In the study-area, surface morphology is almost entirely formed from rocks of Pliocene age and younger. As shown on the geological plan of the study-area (Fig. 3.2), Miocene calcarenites only occur on the north-western edge of the area.

Much of the study-area is underlain by Pleistocene calcarenites known as the 'Calcareniti del Salento'. These yellow to grey calcareous rocks form a broad, morphologically depressed zone extending from Alimini Piccolo north-eastwards to the coast between San Foca and Roca Vecchia. The calcarenites are exposed along the coast northwards of San Foca to San Cataldo, forming low, near vertical cliffs of up to 5 m a.s.l. as far as Torre Specchia Ruggeri. Beyond this point their elevation declines gradually to sea level, and they form a low undulating surface upon which the Cesine lagoons and marshlands have developed. The coastline between Torre Specchia

Ruggeri and San Cataldo is dominated by a dune cordon, but in places along the beach, limited areas of the Pleistocene calcarenite are exposed.

Inland morphology appears gently undulating and generally increases in altitude away from the coast, though never exceeding 31 m a.s.l. A low escarpment marks the western boundary of these calcarenites with relatively higher land formed by Upper Pliocene calcarenites, known as the 'Sabbie di Uggiano'. To the east, the lower Pleistocene rocks are bounded by middle to Upper Pliocene calcarenites, also known as 'Calcareniti del Salento'. These yellowish, lithified calcarenites form usually vertical cliffs along the coastline southwards from Roca Vecchia to Otranto, varying in height up to 16 m a.s.l.

There are, however, two major breaks in this cliff coastline. An ancient channel occupied today by the Canale del Brunese, cuts through the Pliocene rocks at Torre dell'Orso and reaches the Adriatic in a wide embayment backed by dunes. Cliffs continue from the south side of the bay to a point 2 km to the south of San Andrea, in the vicinity of the Alimini. Here the dipping calcarenite morphology reaches sea-level, and the coastline continues as a sandy beach backed by dunes as far as a point 2 km to the north of Torre San Stefano. Cliffs span the coast from here to the natural harbour of Otranto.

To the south of Otranto, outside the study-area, the coastline has a very different aspect. Limestones mainly of Eocene and Oligocene age outcrop along the coast, producing steep, high cliffs. Just 5 km south of Otranto, at Capo d'Otranto for example, the cliff top reaches 82 m a.s.l.

3.3 The Tectonic situation

Along the indented, rocky parts of the coast between San Cataldo and Otranto, bedding planes exposed in cliff sections generally dip gently towards the NNE, at between 0° and 4°. This seawards dip could correspond to gradual uplift inland to the SSW which, according to Rossi (1969), took place at the end of the Pliocene or beginning of the Pleistocene period.

The occurrence of middle to late Pleistocene marine deposits at elevations exceeding 100 m a.s.l. in the south-western part of Salento, suggests to Hearty & Dai Pra (1985) that uplift has continued later than the early Pleistocene. According to Palmentola and Vignola (1980) some raised abrasion levels on the Adriatic coast south of Santa Cesarea Terme point to possible uplift in the past 18000 years; the geology south of Otranto is, however, very different to that of the study-area. Hearty & Dai Pra (1985) suggest that

some isolated areas of the peninsula have experienced down-warping during the Quaternary.

It is possible that neotectonic subsidence has affected parts of the Adriatic coast of Salento during the Holocene, but to date little, if any, research has tackled this question. Changes in sea-level relative to coastal lands have important implications for human groups occupying or frequenting these areas, and thus present an important question to be addressed by this research (see 12.5).

Fractures are evident in the Pliocene and Pleistocene calcarenites of southern Salento (Zezza 1969a) and in the study-area. A series of normal faults are clearly visible, for example, on the exposed Pliocene beach platform near Torre San Stefano. At other places in the study-area, dislocated Pliocene and Pleistocene rocks provide evidence for activity along faults, into the Quaternary. According to Ciaranfi *et al.* (1981), the Salento peninsula is seismically stable, but De Simone (1875) documented earthquakes of sufficient magnitude to damage buildings in the Province of Lecce in the 13th, 14th, 15th and 19th centuries. Such movements could have originated from faults within the Salento Peninsula; however, tremors from earthquakes in the southern Apennines are sometimes felt in Lecce.

A dense network of faults and fractures in Salento was mapped by Guerrichio & Zezza (1982) from Landsat imagery and aerial photographs. Within the study-area, a zone to the west of the Alimini lakes is among the most densely fractured parts of Salento (Fig. 3.3). In many locations, grouped and intersecting fractures have developed into morphologically depressed areas of doline form. According to Guerrichio & Zezza (1982), the elongate depressions occupied by the Alimini lakes have resulted from such intersecting fractures and their enlargement by sub-surface karst processes.

The predominant NNW-SSE orientation of the two lakes is probably fault controlled. This alignment is continued by narrow, depressed areas further north at the junction between the Pleistocene and Pliocene calcarenites, stretching from 1 km west of San Andrea to the coast 1 km south of San Foca. It is likely that these depressions are similarly the product of doline type development (see 3.4). In the case of the Alimini lakes, the notion that they are fault controlled helps explain the existence of the narrow channel connecting the two lakes, named 'Strittu', and the channel linking Alimini Grande to the Adriatic Sea. It has been suggested that Alimini Grande was more open to the sea in the late Pliocene and early Pleistocene, forming an inlet of the Adriatic (De Giorgi 1895; Piccinno 1978). Marine erosion would have therefore contributed to the present lake basin form. The shores of Alimini Grande today are in all but a few places, formed of exposed Pliocene and Pleistocene calcarenites.

De Giorgi (1895) suggests that Alimini Piccolo originated as a tectonically controlled basin, which in the early Quaternary was not linked to Alimini Grande. It seems possible that the Strittu channel results from abrasion and solution of the Pleistocene calcarenites by lake waters, along a fault or fracture system aligned between the two lakes. Small caves situated high on both sides of the channel incision, could have been formed or enlarged by high lake waters. Alternatively they could be karst features developed along the line of weakness between the two lakes. These natural rock shelters attracted early prehistoric usage, as evidenced by Epigravettian and Neolithic industries found within them (Piccinno 1978).

3.4 Karst morphology

In parts of the study-area, in common with other parts of the Salento Peninsula, a well-developed karst system within the Cretaceous limestones has influenced the morphology of overlying Pliocene and Pleistocene calcarenites. Most conspicuous are the doline-type depressions in some areas, especially where a high density of surface fractures exists in the surface lithology. Doline formation often results from a combination of processes, including solution weathering at the surface, piping and subsidence (Jennings 1985). Most dolines within the study-area have probably formed mainly by solution processes disintegrating the calcareous rocks along faults and fractures.

Shallow, doline-type depressions are frequent in the Pleistocene calcarenite morphology, particularly to the west of the Alimini lakes and north-west of San Foca (Fig. 3.3). It appears from the map by Guerrichio & Zezza (1982), that the area between Lecce, Otranto and San Cataldo encompasses the highest density of doline formation in Salento south of Brindisi. The calcarenite floor of these dolines is never exposed, but covered by detrital materials whose relative impermeability often give rise to wet surface conditions and luxuriant vegetation growth. Soils in these localities consequently have a high organic matter content, unlike the red earths or the light brown soils on surrounding land.

Other karst features have developed within the study-area. Most common are surface solution features developed beneath the soil layer, including solution pipes (roughly conical or cylindrical holes up to several metres deep, formed by solution processes at the soil-rock interface). Clear examples are exposed by a quarry in the Pleistocene calcarenites, 2 km to the north-west of San Foca, and along a new road cutting through Miocene calcarenites between Melendugno and Borgagne. The solution pipes are invariably filled with red earths, which also cover the surrounding ground surface beneath mid-brown soils, unless stripped by erosion (see 3.6.1).

Smaller features of karst sculpturing are frequently exposed at the surface today on elevated and sloping ground inland, where superficial sediments have been removed. Solution pipes are visible on the denuded Pliocene cliff tops at Roca Vecchia. Some have been undercut by marine erosion, releasing their contents and remaining as holes on the cliff edge.

In rocky foreshore locations, the periodic inundation of solution holes and hollows by sea water, and its subsequent evaporation, leads to salt crystallisation. The author has observed substantial salt crystallisation in shallow pools on the beach platform near Torre San Stefano, which in former times perhaps provided an economic resource. In the same location, narrow, artificial channels have been cut to facilitate the flow of sea water into and between deeper pools, evidently to assist fishing activities. Similar features are in use today at Porto Badisco, south of Otranto, to keep captured shellfish fresh.

Caves of karst origin in the study-area, are only apparent in parts of the Pliocene coastal zone, excepting the possible karst origin of caves beside the Strittu channel. The Grotta Poesia at Roca Vecchia has been enlarged by marine erosion, but a spring issuing into the cave and the presence of other caves detected by Georadar (Pagliara 1987) suggests these are of karst origin.

3.5 Surface drainage and water supply

3.5.1 Surface drainage

Few natural water-courses exist within the study-area and none contain flowing water all year round. The channels are mostly controlled by sub-surface fractures, faults and karst systems, and have been further modified by recent man-made canalisation. Ephemeral stream flows result from either prolonged periods of rainfall or, more frequently, from intense rainfall over a short period of time. The annual rainfall distribution pattern for this area is markedly seasonal. Most falls in the autumn and winter, often as intense storm precipitation, resulting in torrential stream flow for short periods; total average annual rainfall at Lecce is 628 mm/year (Cali 1971). Between May and September, rainfall is minimal and drought conditions may prevail. Consequently, most stream beds are dry over the summer months.

In a few parts of the study-area, channels incised into the Pliocene and Pleistocene calcarenites attest to more intense pluvial conditions between the early Pleistocene and the onset of Mediterranean climatic conditions; ephemeral streams flow in parts of these channels today. The most notable example in the study-area is that partially

occupied by the Canale del Brunese, outflowing into the bay of Torre dell'Orso. Another with exposed rock scars exists 1.5 km west of Roca Vecchia.

Small channels drain into Alimini Grande from the north and west. The only channel flowing into Alimini Piccolo, does so at the south-western end of the lake; its name, 'Rio Grande', belies its small and ephemeral status. Other channels in the study-area are no more than 1 km long and are oriented normal to the coastline, where they outflow or terminate in coastal marsh.

Just south of the study-area, the river Idro occupies seasonally the bottom of a deep valley incised into a karst system in the Pliocene calcarenites. The river's waters are mostly diverted to irrigate surrounding land, but it naturally outflows at Otranto. Its catchment extends no more than 3 km to the south-west of Otranto.

3.5.2 Groundwater

A perennial water source is available from the groundwater system, which is an important feature of this part of Salento although insufficient to satisfy present urban and agricultural demand.

The level of the deep freshwater aquifer, 'falda di base', is related to the intruded sea-level, upon which the aquifer floats (2.5.2). This aquifer is accessible through wells in the study-area. Perched aquifers exist in limited areas where impermeable clays are intercalated with the Pleistocene calcarenites (Largaiolli *et al.* 1969). The two aquifers are for the most part separate, but local fissuring and karst features render the clays permeable in places, allowing communication between them. In this way, the levels of some perched groundwater bodies are influenced by sea-level. Such interconnections have been detected in the vicinity of the Idume springs, in the Adriatic coastal zone 12 km north of San Cataldo (Tadolini *et al.* 1971).

Some perched aquifers are independent of the deep aquifer and sea-level in the region north of Otranto (Rossi 1969), including the study-area. It may therefore be assumed that some areas of perched groundwater in the study-area have been unaffected by relative sea-level change during the Holocene. This point has relevance to the study of past population and vegetation distributions in this area, in that a potentially accessible freshwater supply could have existed here throughout prehistory, irrespective of distance from the coast.

The extent and significance of this resource depend, however, on ground surface conditions and the input of rainfall to phreatic waters. Given the high permeability of the Pliocene and Pleistocene calcarenites and the generally thin, friable nature of

surface soils today, rainwater readily penetrates through these layers and collects above the impermeable clays, where present. Disturbance of the natural vegetation cover since probably Neolithic times, followed by millennia of agricultural and pastoral landuse, will have progressively altered the nature of surface deposits, consequently influencing surface flow and through flow of rain-water.

3.5.3 Springs and the distribution of marsh

In places where phreatic levels intersect the ground surface, springs issue from the perched groundwater bodies. If drainage is impeded, marshy areas and areas of standing water develop. Marshy areas and surface water bodies are particularly frequent in the part of Salento encompassed by the study-area. In each case the freshwater input is maintained by springs and surface drainage. Marshy areas were more extensive in the past, prior to reclamation works this century (see 4.3); the distribution of past and present marsh is illustrated in Fig. 4.1).

In the southern part of the study-area, Alimini Piccolo is the largest natural freshwater body in Salento, and indeed in Puglia. The lake is fed by springs issuing on its western side, where the basin morphology intersects an impervious layer within the calcarenites. Springs similarly issue into Alimini Grande along its western shore, where the freshwater mixes with sea water which enters the lake from the Adriatic, creating brackish water conditions. Small pockets of Phragmites reeds and other marsh plants grow around these spring issues at the lake margin. Between the Alimini lakes and the Cesine coastal marshlands, springs are scarce and mainly occur at the coast. Along the coast east of Alimini Piccolo, two springs flow into the sea inlet at Torre San Stefano, and at a point 1.5 km further south another flows into the sea via a short channel.

Elsewhere, small marshy areas exist in some of the shallow, doline type depressions, where the phreatic level is close to the ground surface, maintaining perennial moist conditions in the surface sediments. These depressions are often thickly vegetated with marsh plants dominated by Phragmites reeds. Some, however, have been cleared and artificially drained of excess water, for cultivation. Two sizable examples of unreclaimed marshy basins remain in the study-area. One lies beside the northern-most point of Alimini Grande (see 4.3 & 5.2.2). The second lies 2 km to the north-west of San Foca (see 4.3 & 5.2.5).

At the northern end of the study-area, perched groundwater emerges at the surface and contributes to the marsh areas and water bodies of the Cesine nature reserve. The largest lagoon, Pantano Grande, occupies an elongate depression of karst origin

(Guerrichio & Zezza 1982). At present its waters are more saline than sea water, suggesting that evaporation and marine inflow exceed freshwater input from groundwater.

3.6 Unconsolidated late-Quaternary deposits

3.6.1 Red earths

Remnants of red earth deposits are visible throughout the study-area on dry ground. It usually lies directly above the calcarenite base, be it of Pleistocene, Pliocene or Miocene age, and fills fissures or karst features such as solution pipes in the calcarenite surface. As mentioned in 3.4, road cuttings and quarry sections through karst features in the calcarenites, expose greater depths of the red earth fill. This fill appears to be unstratified, though colour in some cases grades from a deep, burgundy-red at the base to a bright orange near the surface. Texture may grade similarly, from predominantly clay-sized particles at the base to a high sand content nearer the surface. In the vicinity of San Foca, sandy red earths in some karst solution pipes were found to contain Mesolithic stone tools (Ingravallo 1980). This suggests the holes were partially filled by materials eroding from surrounding land in Mesolithic or post-Mesolithic times.

If the ground surface is vegetated, a mid-brown soil is often present to an approximate depth of 20 cm above the red earth. Where the surface is sparsely vegetated this soil layer has commonly been removed by erosional processes, leaving red earths exposed at the surface. They are particularly conspicuous beneath the extensive olive groves in the area, which are often kept clear of other vegetation.

Red earths are often exposed on eroding cliff tops, particularly on parts of the higher Pliocene cliffs where it is still protected by macchia vegetation. In other parts, especially close to the cliff edge, only the bare rock surface remains after the protective vegetation has been destroyed deliberately or otherwise by man. Off-road-vehicle access to many of the cliff-top areas contributes to the ongoing removal of unconsolidated sediments. On lower sections of cliff coastline the red deposits are sometimes overlain by active dunes, as observed along a 1 km stretch of coast southwards from a point 1.5 km south of San Andrea.

At the back of the beach platform, 0.75 km north of Torre San Stefano, a sandy red earth overlies whitish-yellow sands. This red material must have been either originally deposited in this area by wind, or redeposited here by aeolian or fluvial transport of red earths from areas inland.

It thus appears that red earths constitute the earliest unconsolidated deposits in the study-area, with the possible exception of limited fossil dune sands. Though much reduced in depth and extent by erosion, these deposits occur above each of the Miocene to Pleistocene geological units. They appear similar in colour and texture, despite apparent differences in composition of the underlying calcarenites. This could suggest these deposits are of aeolian origin from a source outside the region, rather than a residual product from weathering of the calcarenites, as is commonly assumed (see 9.5.7ii). Limited finds of Mesolithic artefacts within red earths in the study-area point to late-Pleistocene deposition or re-deposition of this material (see 9.5.7ii). In order for such uniform and homogenous deposition to take place, the recipient land surface must have been sparsely vegetated, perhaps by steppe-type herbaceous vegetation.

3.6.2 Calcrete

Calcrete hardpans are visible on many parts of the exposed coastal cliff tops, where they form a hard, laminated crust approximately 1 cm thick overlying the calcarenites. In some places the crust has been broken and partially removed by sub-aerial weathering processes. Calcrete hardpans have not been observed within unconsolidated deposits in situations comparable to the crosta of the Tavoliere, but then sediment depth above bedrock in the study-area is commonly less than 50 cm. The hardpan represents part of a calcrete profile developed within overlying soils or unconsolidated deposits.

An example of a more complete calcrete profile exists 2 km north of San Foca, where a block of the Pleistocene cliff has recently fallen away to expose a section including what is probably the lower part of a calcrete profile. The calcarenite is covered by a hardpan, approximately 1 cm thick, which is overlain by a dense, grey layer of calcium carbonate of clay-silt texture, varying in thickness between 5 cm and 12 cm. Above this, angular nodules of cemented carbonate and shelly debris lie within a brown soil matrix, forming a layer of between 20 cm and 30 cm thick. A pale brown, sandy layer constituting the present surface soil overlies this sequence, but it is possible that the calcrete profile developed in a formerly deeper soil which has since been truncated by erosion. On the basis of this field evidence, it may only be said that the calcrete formed since the early Pleistocene.

In the sequence of calcrete profile formation described by Gile *et al.* (1966), the laminar horizon is formed by a long term, periodic accretion of carbonate over thousands of years. However, Goudie (1973) states that some calcretes have formed within living memory.

Partially covered calcrete hardpans have also been observed by the author in the Cesine area of coastal marsh and lagoons. Here, shallow lagoons and generally thin sandy deposits lie above the gently undulating surface of the Pleistocene calcarenites. In restricted areas, for example in places around the lagoon margins, erosional processes have removed overlying unconsolidated deposits, exposing a calcrete hardpan covering the calcarenite.

A narrow, modern, artificial channel, cut through Pleistocene rock in the northern part of the Cesine, affords a view of the hardpan in section, complete with overlying deposits. On the western side of the channel, the upper part of these deposits is dated approximately by an archaeological feature beside the channel. A circular arrangement of calcarenite blocks embedded in the present land surface probably represents foundations of a Bronze Age construction (Pagliara, pers. comm. 1989); pottery fragments of late Bronze Age type are currently eroding from surface soils in the vicinity of the archaeological feature. Very little material has accumulated above the late Bronze Age land-surface in this location. The relationship of this site to the local Cesine environment is considered further in 9.11 and 10.2.

A hardpan is visible in the channel section either side of the feature, but it is not discernible beneath the feature. Only a grey-brown, clay-rich soil lies between the foundation stones and the Pleistocene bedrock (Fig. 3.4). It seems that construction of the feature has in some way impeded calcrete formation at this spot, therefore it may be deduced that the hardpan formed during or after the Bronze Age; that is assuming the site is correctly dated. On the opposite side of the channel, the hardpan is overlain by a grey, indurated deposit incorporating fragments of the same style pottery. A second hardpan layer partially covers this deposit. This clearly indicates that processes of calcrete formation have been operative since the Bronze Age, and that hardpans had not necessarily developed before this time in this location.

These ideas do not necessarily apply to calcrete hardpans elsewhere in the study-area, as their development depends upon highly localised soil and hydrometeorological conditions.

3.6.3 Water-lain deposits and deposits of wet ground

The spatial distribution of these deposits is controlled by the distribution of springs and areas of wet ground. According to geological maps covering the study-area, all such deposits are of Holocene age; their principal locations are shown in Fig. 3.2.

Alluvial deposits in the study-area are restricted to the few short and narrow stream channels, and are of little significance. Of more importance are colmate deposits in

areas of standing water, where drainage is impeded by impermeable sediments above the calcarenites. These deposits accumulate in the shallow depressions associated with fracturing and karst development in the underlying calcarenites, and with local presence of perched groundwater. Sediments from surrounding slopes are transported to these areas by wind or surface runoff. Therefore it is predominantly the fine fraction of a sediment which is transported to these depressions.

Detrital organic materials from local aquatic and marsh vegetation add to these deposits. In some of these basins, for example that to the north of Alimini Grande and the basin to the north-west of San Foca (3.5.3), peaty deposits have formed from the dense marsh type vegetation dominated by Phragmites. These deposits will have accumulated for as long as sufficiently moist conditions have existed at the ground surface.

In areas of open water, namely the Alimini lakes and the Cesine lagoons, calcareous sands, silts and clays have accumulated as lacustrine deposits, derived from minerals in the surrounding basin. Some of the sediments are autochthonous, being composed of organic materials and minerals within the water bodies themselves.

3.6.4 Soils and soil erosion

On the slopes and higher ground away from the doline depressions, soils are generally thin and impoverished. Most areas accessible to agricultural practices have been cleared of semi-natural vegetation, and cultivated. Soils of these areas consequently have a reduced humus content and are more vulnerable to desiccation and erosional processes. The fine particle fraction is often partially removed by eluviation and wind erosion.

In a study of soil erosion in Puglia, Vlorá (1963) identifies rainwater runoff as being responsible for a large proportion of soil erosion in all regions of the province, including the more arid parts. The violence of autumn rains following a long dry-season can cause brief periods of intense erosion, particularly on sloping, sparsely vegetated land; summer rainstorms can also be damaging. Sediments transported by resultant surface runoff and ephemeral stream flows, generally collect in the shallow depressions, augmenting their fertility at the expense of surrounding land. Vlorá (1963) notes that this pattern of soil erosion is widespread following deforestation and the progressive degradation of grazing lands.

The same areas are vulnerable to erosion by wind. The flat, dry, coastal region between Brindisi and Otranto, incorporating the study-area, is particularly subject to aeolian erosion (Vlorá 1963). In order to arrest the advance of coastal sands inland,

the state forestry administration has re-forested with pines much of the coastal margin between San Cataldo and Otranto. Sands have damaged the fertility of some agricultural land where such intervention is lacking.

Thus soils in most parts of the study-area today are greatly altered by a history of ploughing, cultivation and grazing pressure, which have enhanced the efficiency of erosional processes, following the destruction of natural vegetation cover. Former woodland or macchia vegetation would have conserved and maintained deeper, more organic soils by adding humus to the soil, intercepting rainfall, reducing temperature variations at the soil surface, reducing evaporation from the soil, moderating the impact of wind and impeding soil movement. Accelerated soil erosion during the Holocene may be expected to have commenced with the first clearances of natural vegetation by man.

3.6.5 Aeolian deposits

Materials transported by wind are dispersed throughout the surface soils of the study-area, and in some places form distinct deposits away from the present coastline. Reddish-brown sands occur on the shallow slopes bordering marsh along the western margin of Alimini Piccolo. According to De Marco *et al.* (1983), these are remnants of dunes and are probably derived from beach sands combined with sands weathered from the calcarenites and from red earths (see 9.4.3). Fossil dunes also exist^{on} both sides of the channel which links Alimini Grande to the sea; these are now fixed by pine plantations. Similar fossil dunes occur at the coastal end of the elongate depression west of Roca Vecchia, and in small areas within 200 m of the present low cliff coastline at Torre Specchia Ruggeri and at 1 km to 2 km south of this point.

3.6.6 Coastal dunes and coastline dynamics

Cordons of active dunes occur in all the low-level coastal parts of the study-area. Two major tracts exist (Fig. 3.2): the first extends along the coast between Torre Specchia Ruggeri and the pumping station at the northern limit of the Cesine reserve; the second extends from the channel linking Alimini Grande to the sea, northwards as far as a point 1.5 km south of San Andrea, and southwards as far as a point 0.75 km south of the channel outlet. Short dune cordons exist in low embayments, namely at Torre dell'Orso and at 0.5 km south of San Foca. In each case the dune cordons relate to

present sea-level. In places along the Cesine coastline, dunes are being undercut by storm waves, suggesting active retreat of the coast.

The undercut dunes reveal stark laminations of black sands and pale yellow sands, which also appear as banded areas on the sloping beaches. Contrasting patches of the two sands appear in other areas along the study-area coastline, particularly along the Alimini tract of dunes and sandy beach. The pale yellow sand is mostly composed of carbonates including shell fragments and locally derived minerals from the coastal calcarenites. The black sands are composed of heavy minerals of volcanic origin, including pyroxene, glauconite and magnetite (Zezza 1969b). These originate from the extinct volcano, Monte Vulture, and are brought to the Adriatic Sea by the River Ofanto (2.2.4). Longshore currents, which generally circulate in an anti-clockwise direction in the Adriatic, transport some of these minerals southwards along the Puglian coast. Most, however, are transported northwards by secondary, clockwise eddy-currents in the Gulf of Manfredonia (Fabricius & Schmidt-Thomé 1971). Differential deposition of the two sands, by both marine and aeolian agents, is caused by their weight difference; the black minerals are deposited more rapidly than the yellow sands.

Due to the paucity of rivers flowing into the Adriatic from the Murge and Salento, the discharge of sediment from these regions to the littoral zone is very low. Consequently little material is available for transport along the shore. The most significant inputs of sediment to the Adriatic from Puglia, are made by the rivers of the Tavoliere, bringing sediments from the southern Apennine foothills and from the plain itself. Some of this sediment is transported southwards together with that from the Ofanto river and some from the northern Adriatic, but much contributes to the aggrading Adriatic coastline of the Tavoliere. To the west of the Murge, sediments eroded from the southern Apennines bordering the Bradano Trench, are discharged into the Ionian Sea and so contribute nothing to the Adriatic coastline.

Thus the Adriatic coast of Salento is relatively starved of sediment. Along the tracts of cliff coastline, beach deposits are restricted to embayments and small coves, but afford little protection for the readily erodible Pliocene and Pleistocene calcarenites. Most of the cliff coastline is actively retreating by marine action undercutting the cliff base and preferentially eroding lines of weakness in the exposed calcarenites. As a result, erosional features such as abrasion platforms, wave-cut arches, collapsed blocks and stacks are frequent. Stacks are especially numerous between San Foca and Torre Specchia Ruggeri, within 250 m offshore from the present cliff line.

The prevalent winds, and therefore wave direction along the study-area coastline, are from northern quadrants; those from the south are much less frequent (Margiotta *et al.* 1983). Given the general NW-SE alignment of this coast, very few parts are sheltered from attack by prevalent waves. A study of beach and near-shore dynamics in the bay

of Torre dell'Orso (Margiotta *et al.* 1983) demonstrated that the northern part of the beach and adjacent cliffs are most subject to erosion. Evidence for considerable coastal retreat in historical times is provided in many places along the cliff tops, where predominantly medieval features cut into the rock have been partially lost by cliff collapse. Pagliara (1987) cites a number of examples, particularly in the vicinity of Roca Vecchia, where remains of tombs, wells, buildings and quarried areas relating to medieval settlement, have been truncated by cliff erosion.

3.7 Semi-natural vegetation and landuse

Agricultural landuse dominates the present landscape of the study-area. Works of irrigation and reclamation this century have increased the extent of cultivable land, reducing areas of semi-natural vegetation still further. Even so, each of the semi-natural vegetation communities identified in 2.7, are represented within the study-area. These are restricted to those areas which are unsuitable for cultivation, or those which are protected by private enclosures or by reserve status, as in the case of the Cesine World Wildlife Fund Reserve.

A survey of the spatial distribution of semi-natural vegetation communities within the study-area is given here, together with their dominant constituents; species compositions are considered in detail in chapters 5 and 8, with respect to specific locations selected for sampling.

3.7.1 Woodland

Mature oak woodlands, popularly believed to have once covered much of this region, have all but disappeared. Fortunately, small stands of regenerated, mixed oak woodland have been protected by private land-owners. These are usually surrounded by high, dry stone walls, and access is private. Plots seldom exceed 9 hectares, and are dispersed within the central part of the study-area (see Fig. 3.5). Beneath the predominantly evergreen oak canopy, the low shrub layer commonly includes *Hedera helix* (Ivy), *Pistacia lentiscus*, and *Asparagus acutifolius*. Grasses and bracken are among the herbaceous layer in these shaded areas.

The use of pine plantations to prevent coastal dune sands from invading agricultural land was mentioned in 3.6.4. Aleppo pine (*Pinus halepensis*) is the species most frequently planted, as it can withstand prolonged drought and grows well on sands and

calcareous soils. Other pine species have been planted in lesser numbers, including Maritime Pine (*Pinus pinaster*), first introduced to the area in 1905 (Congedo 1974).

The Aleppo Pine also grows spontaneously in the study-area. The most significant area of Aleppo Pine woods away from the coastline, occurs on the western margin of Alimini Grande, extending half way along the length of the lake from the bridge over the Strittu channel.

3.7.2 Isolated trees in the landscape

Individual fig trees frequently grow beside, or from within dry stone walls. *Quercus coccifera* often forms bushy trees in similar positions, where they are not an obstruction to cultivation. *Eucalyptus*, poplars and pines are among trees commonly planted beside roads and trackways.

3.7.3 Macchia

Though still more extensive than natural woodlands, areas of macchia have similarly been greatly reduced by the expansion of agricultural land. Macchia is confined to those parts of the study-area of marginal suitability for agriculture, mostly close to the coast and in the Cesine reserve. The dense growths of sclerophyllous macchia species, commonly include much *Pistacia lentiscus*. In the Cesine reserve, macchia generally lies between pine woods and the marshy areas, and in restricted areas lying between the dune cordon and marshy areas. It also occurs in similar situations behind dunes and beside pine woodlands in the low, coastal area east of the Alimini lakes.

In some coastal cliff areas, soils are fixed by macchia. For example, macchia dominated by species of *Cistus* and *Juniperus* grow on soils above red earths on the cliff-top zone within 1 km south of San Andrea.

3.7.4 Garigue and herbaceous vegetation

Garigue type vegetation is common in places where erosional processes have reduced soil depths to a thin layer between outcropping bedrock. Relatively high areas and slopes which have become too impoverished for cultivation, consequently develop a dispersed, low shrub and herbaceous vegetation which commonly includes *Rosmarinus officinalis* and other aromatic plants. It is a widely distributed vegetation type within

the study-area, and may be found for example, on the east-facing slopes above the western side of Alimini Piccolo and on high areas beside the Strittu channel.

Some dry, stony surfaces lack even dispersed shrubs and have a sparse herbaceous or steppe-like vegetation. Species of Plantago and species of Gramineae, including Stipa capensis and Briza maxima, are common.

Numerous and diverse herbaceous plants are to be found throughout the study-area on neglected agricultural land and on disturbed ground beside trackways and field boundaries, for example. Many species of Compositae are common, together with Malva sylvestris, Scabiosa sp., species of Papaver and Boraginaceae.

3.7.5 Freshwater marsh

The most extensive area of freshwater marshland remaining in the study-area, surrounds Alimini Piccolo. Dense reed beds of predominantly Phragmites, have colonised all the moist and waterlogged land around the lake, and extend into the lake waters to a depth of 40 cm to 60 cm (Amico & Macchia 1964). Frequently occurring among the reeds are Typha (Bulrush) and Scirpus (Common Clubrush) in the wettest areas, and Cyperaceae, Calystegia cf. sepium (bindweed), Epilobium sp. and Mentha aquatica (Water Mint) on wet to moist soils.

Similar flora dominated by reeds occurs in all the doline type, marshy depressions within the study-area, which have not been reclaimed for cultivation. The largest of such areas occur in depressions at the northern end of Alimini Grande, to the north-west of Alimini Grande, to the north-west of San Foca and in parts of the Cesine reserve.

3.7.6 Saltmarsh

Areas of saltmarsh are restricted to the Cesine reserve, within the study-area. Marshy conditions and lagoons arise here behind the dune cordon, which impedes the outflow of groundwater issuing at the surface in this coastal zone. As freshwaters become mixed with sea water, salinities vary spatially and seasonally. Generally, areas furthest inland are least saline.

A series of particularly dry years, including 1988 to 1990, has significantly reduced the extent of the lagoons, concentrating their salinity to levels higher than that of the sea, and exposing wide areas of mud flats. A water sample taken from Pantano Grande in May 1990, for example, had a salinity twice that of sea water (Hunt pers. comm.).

Isolated glassworts grow on the mud flats, whilst other vegetation is confined to higher levels. Extensive areas of freshwater marsh vegetation dominated by Phragmites, grow on the landward side of each of the Cesine water bodies. In fact, Medagli (1981) records Phragmites extending into the lagoon waters along their western shores. In May 1990, only dead roots of Phragmites existed on the western shore of Pantano Grande, owing to the intolerable level of the lagoon salinity.

Drier ground between the areas of lagoon and marsh is densely vegetated, largely with Juncus acutus (Sharp-pointed Rush) and species of Cyperaceae.

3.7.7 Coastal dune vegetation

All dune cordons along the study-area coastline are to some extent fixed by vegetation. As stated by Medagli (1981), the most diffuse and abundant species are Elymus farctus (Sand Couch) and Ammophila arenaria (Marram); also common is Eryngium maritimum. The South African plant, Carpobrotus acinaciformis has been introduced to the dunes in the Cesine reserve, for its stabilising capacity.

Some halophilous plants grow on the sandy beaches in front of the dunes. These include Salsola kali (Saltwort) and Calystegia soldanella (Sea bindweed).

3.7.8 Modern landuse

Formally planted olive groves cover a large proportion of the dry territory in the study-area, away from the coastal strip. Soils and red earths beneath the olives are often hoed and kept free of other vegetation. Vinyards occupy some areas between olive groves, and fruit trees, including citrus fruits, are planted in dispersed, small areas.

Much land between the olive plantations and the coastal pine plantations is used for cereal cultivation. Open cereal fields extend, for example, from the high ground above the eastern side of Alimini Piccolo to the pine plantations at Torre San Stefano. Cereals are also cultivated in some areas inland, often on shallow slopes around the depressed localities but away from marshy parts. They are grown to the north and north-west of Alimini Grande, for example, and further to the north between Borgagne and San Andrea.

Reclaimed marshy depressions are usually divided into small fields, in which a variety of crops are grown. Likewise, low slopes beside the marsh encircling Alimini Piccolo are cultivated with the aid of irrigation waters from the lake. On the sandy deposits of the western side, crops include tomatoes and cereals. The more organic-rich soils on

the eastern lake-side are planted with various crops including young vine plants. A reclaimed area to the south of the Cesine reserve, known as Ficherelle, and areas west of the reserve are partly divided into small plots and cultivated manually. Some parts of the Cesine area were cultivated prior to the planting of pines and its designation as a nature reserve (Corpo Forestale, Lecce pers. comm.).

Very little evidence for animal husbandry exists in the study-area landscape today. Sheep and goats are more common south of Otranto, grazing the high, rocky pastures.

3.8 Summary of environmental attributes in the study area

The gently undulating surface morphology is mostly controlled by faulting, fracturing and karst development within the Pliocene and Pleistocene calcarenites. Depressions of doline form are especially frequent in this part of Salento. Laminar, calcrete hardpans are visible in places, directly above the calcarenites. In the Cesine reserve, however, some hardpans have probably developed since Bronze Age times, under local environmental conditions.

Red earths lie directly above the calcarenites in most parts and are the earliest unconsolidated deposits in this region, with the possible exception of small traces of fossil dunes as seen near Torre San Stefano. It may be assumed that the red earth deposits mostly pre-date the Mesolithic period, but some deposition or re-deposition has certainly taken place since Mesolithic times.

Present soils form a generally thin layer above the red deposits or directly above the calcarenites, and often do not provide continuous cover, especially on relatively high and sloping ground. Thus, very little remains of Holocene deposits above the Pleistocene land surface in most of the study-area. Erosional processes continue to reduce the extent of unconsolidated deposits above bedrock in exposed areas. On dry ground, areas of semi-natural macchia provide effective protection of the soils against erosion, but where vegetation is sparse, soils are impoverished by eluviation and aeolian erosion.

Depositional areas for eroded materials are restricted to the morphological depressions. Drainage is often impeded in these locations, allowing both allochthonous and autochthonous materials to accumulate. It is possible, therefore, that the sedimentary sequence within these depressions partly reflects the pattern of soil erosion on surrounding slopes. Thus the depressed areas, which are essentially the only depositional areas for locally derived sediments, could provide a record of local

environmental change associated with vegetation disturbance and sediment displacement.

The presence of perched groundwater bodies in this region is highly significant in terms of the physical environment, vegetation, and human economy. Some of these freshwater sources are independent of sea-level, and possibly existed throughout prehistory, though they depend upon the input of rainwater through surface sediments. Changes in climate, vegetation cover and surface sediment characteristics will have influenced this input.

The Alimini lakes have probably existed to some extent since at least the middle to late Pleistocene, as the Strittu channel was in existence prior to Upper Palaeolithic times. Freshwaters contributed to the formation of the Alimini Piccolo basin, whilst Alimini Grande formerly existed as a sea inlet.

The low and indented tracts of cliff coastline provide natural harbours and numerous landing opportunities for small boats; this coastline is more approachable than the high, cliff coastline south of Otranto. The cliffs are actively eroding, and offshore stacks attest to formerly more extensive coastal lands. Sea-level rise and possible tectonic subsidence during the Holocene are mechanisms which will have caused progressive retreat of the coastline configuration.

Chapter 4

ENVIRONMENTAL CHANGE WITHIN THE STUDY-AREA: OBSERVATIONS AND EXISTING IDEAS

4.1 Introduction

Spatial differences in environmental conditions have been identified in chapter 3, together with both natural and man-made processes of environmental change within the study-area. Importantly, this survey has identified zones of net sediment accumulation, upon which the present research analyses into environmental change are focussed (chapters 5 to 12).

Before these analyses, perceptions of environmental change in the study-area are put forward here, based on field observations and existing information from documentary sources relating to the environment in post-Roman times. Sediments and botanical remains have not previously been recovered from archaeological sites within the study-area, and palaeoeconomic information is not available.

Aspects of the environment that are known to have changed, with significance for human population in the area, are relative sea-level, climate and the inter-related variables of soils, vegetation and freshwater availability.

4.2 Relative sea-level change

Present coastal morphology does not reveal any evidence for a Holocene sea-level higher than that of present. Rather, the limited evidence suggests continuing sea-level rise. Along the tracts of cliff coastline, any evidence for former sea-levels is obscured by cliff-collapse, but on the low, sandy coastal tract between San Cataldo and the pumping station at the northern end of the Cesine, there is evidence for relative sea-level rise.

A port was established at San Cataldo during Imperial Roman times to serve the Roman town of Lupiae (Lecce). Under the rule of Emperor Hadrian, a mole known as the 'Molo d'Adriano' was constructed in the 2nd century A.D. Though partly damaged by marine erosion, the mole extends from the sands at San Cataldo, into the sea for approximately 500 m and to a depth of between 6 m and 7 m below present sea-level (Congedo 1984). The present submergence of this feature is believed to be more

than at the time of construction, but the height of subsequent sea-level rise has not been determined. Foundations of other buildings are also submerged close to the mole, indicating relative sea-level rise in the past two millennia.

At a point 2 km south of San Cataldo, near the pumping station (chapter 3 Fig. 3.1), marine erosion has exposed further constructions, tombs and artefacts of Late Republican and Imperial age (Pagliara 1987). These lie on the present shoreline, but submerged remains in the near-shore area point to marine encroachment over the low, coastal lands. According to Congedo (1984), submerged foundations of the church of San Giovanni lie 4 m below sea-level at this location. A postulated rise in sea-level of at least 4 m in no more than 2000 years is more than double the generally accepted rate of the eustatic element of sea-level change in the late Holocene, of approximately 1 m per millennium (12.5.1). If correct, then a component of relative sea-level rise would have to be accounted for by tectonic subsidence in the order of 2 m in this coastal zone. This is improbable, although some degree of subsidence may have affected this zone during the Holocene (3.3). The present author is not aware of any research concerned with the neotectonic situation on the Adriatic side of Salento.

Potential exists here for specialist archaeologists to relate submerged archaeological features to former sea-levels. At present it is appropriate to conclude that relative sea-level rise of probably at least 1 m per millennium has occurred since the 2nd century A.D.

Rising sea-level will have increased the erosive capacity of the sea against tracts of cliff coastline, preferentially eroding lines of weakness in the calcarenites, causing cliff collapse and coastal retreat. Remains of a coastal installation of Imperial Roman age at San Foca have been mostly destroyed by coastal erosion. According to D'Andria (1980), only the most landward part of the site is left. Earlier remains of proto-historic hut settlements with foundations on the calcarenite, exist beside the present cliffs at Roca Vecchia, San Andrea and Otranto (Pagliara 1987). These must relate to a former coastline some distance seawards of the present cliffs (see 12.5.3).

Along tracts of low coastline fringed by dune cordons, the present sea-level partially controls the existence of coastal marshlands and water bodies. This situation exists in the Cesine reserve and behind dunes north of the channel linking Alimini Grande to the sea.

4.3 Areas of marsh

It is probable that areas of coastal marsh will have existed throughout the Holocene in depressions along low-lying coastal tracts, where drainage is impeded. Marshy conditions could also have persisted inland independently of sea-level, the most important controlling factors being the occurrence of localised depressions, surface conditions promoting runoff and the presence of groundwater bodies intersecting the ground-surface (3.5.3). Apart from morphology, these are related to soils, vegetation cover and climate.

As identified in 3.6, zones of sediment accumulation in the largely denuded landscape of the study-area, are confined to the shallow depressions occupied by marsh or former marsh, together with the Cesine lagoons and the Alimini lakes. The extent of marshy conditions in the study-area has been vastly altered over the past century through artificial drainage and reclamation works. An appraisal of the natural marsh distribution, prior to such intervention, is of value to the present research aims.

Following publication of a law in 1882 on the reclamation of 'marsh and marshy terrain' in order to combat malaria in this region, a survey was completed of all marshy areas within the province of Otranto, including the study-area. The ensuing report by Orlando (1885) presents details of marsh distribution, their extent, seasonality, source of water and recommendations for improvement. The approximate position and extent of marshy areas existing prior to reclamation works is illustrated in Fig. 4.1 and described below, as interpreted from the report of 1885. Orlando (1885) commented that the unhygienic effects of all these marshes influenced a zone reaching 10 km inland, exceeding the confines of the study-area and resulting in the virtual abandonment of agricultural land.

Palude Fiorello: This marsh covered 30 hectares behind dunes, south of San Cataldo. It was generated by rainwater runoff from higher land to the west, which collected in this location to a depth of 1.2 m. Most of the waters evaporated in the dry months; exposed soils were cultivated with corn. Today a pine plantation covers this zone.

Palude le Cesine: This marsh zone covered 200 hectares; it was dominated by a body of open water, probably corresponding to Pantano Grande, supplied by rainwater runoff from land to the west and by sea water. It was connected to the sea at a number of points through the dunes. Today the artificial channel, 'Canale Colletore Cesine', connects the water bodies of the Cesine to each other and to the sea at the pumping station. In periods of high rainfall the water depth could reach 1.5 m. During summer

months, evaporation reduced the extent of the water body, exposing soils for cultivation.

Palude Cacari: This zone, covering 180 hectares, consisted of three marshes, Cocuzza, Graziosella and Rotondella, which correspond to water bodies lying to the north-west of Pantano Grande. These resulted from the collection of rainwater runoff in undrained depressed areas; they were linked to the sea at a point corresponding to the pumping station. Soils exposed during summer months were cultivated. Both the Palude le Cesine and the Palude Cacari have been partially controlled by artificial channels, but they are conserved as wetlands within the Cesine reserve.

Paludi di Termolito, Vacca and Cipollaro: These marshes covered an area of 16 hectares and resulted from rainwater runoff from land to the west, collecting in shallow depressions with no outflow. Turbid waters existed from September to April.

Il Campoletrano: This marsh covered an area of 33 hectares and resulted from rainwater runoff from land to the west and south, collecting in a shallow depression with no outflow. Turbid waters covered this area from September to June, reaching a maximum depth of 1.5 m. Today, all but two small marshy parts of this depression are reclaimed and cultivated.

La Longa: This marsh is referred to in 3.5.3 as the basin to the north-west of San Foca. It covered 47 hectares and received rainwater runoff from surrounding land, together with sea water which entered the basin during storms, via a channel linking it to the sea. Soils were inundated from September to April by waters reaching a maximum depth of 0.5 m. Today, dense Phragmites reeds and marsh vegetation occupy an extensive area in the lower part of the depression. Parts of its drier margins are cultivated.

Pantano le Candele: The exact location of this small marshy area, covering 15 hectares, is unclear from the report's description. As in the case of La Longa, this marsh was connected to the sea and received rainwater runoff and sea water. It was probably situated close to the coast near San Foca. Turbid waters covered the depression from September to April.

Lago Alimini (Alimini Grande): This area of marsh, named 'Traugnano', was situated to the north of the northern most end of the lake. It is referred to in section 3.5.3 as the basin to the north of Alimini Grande. According to Orlando (1885), the southern part of this marsh was connected to the lake and perennially submerged, whilst the

northern part dried out in summer. It would appear that this northern part constitutes the extensive depression with marsh vegetation existing today. Only a thin strip of Phragmites reeds fringe the northern end of the rocky lake-shore today.

Lago Fontanelle (Alimini Piccolo): Both the Alimini lakes receive freshwaters from springs and rainwater runoff from surrounding slopes. Much of the land surrounding Alimini Piccolo dried out in summer, when the lake level was reduced by evaporation and less recharge. Some land on its western side was used for cereal cultivation, but most surrounding land was abandoned and only used seasonally for grazing.

Paludi Sausi: Two marshy areas, covering in total 31.5 hectares, existed behind coastal dunes due east of Alimini Grande. These were generated by rainwater runoff collecting in depressions with no outlet to the sea; marshy ground could persist all year round. Pine plantations now encroach on these areas, though some marsh still exists here.

Paludi Pozzelle: A group of three marshes, Zollea, Longa and Fontana, existed to the west of Alimini Grande, collectively covering 37 hectares. Each collected rainwater runoff from surrounding land. Water depth could reach 0.7 m. Surrounding land was abandoned, apart from some seasonal pastoralism. These areas are now largely reclaimed and cultivated.

The Idro Valley: In summer the upper part of this valley was stagnant whilst the lower part was dry. De Giorgi (1882) noted the fertility of this valley, which supported a variety of crops from potatoes to cherries; local people were affected by malaria.

Thus, according to Orlando (1885), most of these marsh areas result from the collection of seasonally high rainfall runoff in closed depressions. These may therefore exist independently of sea-level, and would be unaffected by a more distant coastline than presently exists. Between San Cataldo and Torre Specchia Ruggeri, however, coastal dunes have influenced marsh development. Similarly, the Paludi Sausi are related to present sea-level.

Only in the case of the Alimini lakes are springs mentioned by Orlando (1885) as contributing to marshy conditions. The present author believes that groundwater intersects Holocene deposits in most of the perennially marshy depressions, including parts of the Cesine and the basins named La Longa and Traugnano. It is interesting to note that all these marsh areas, with the possible exception of parts of Paludi Pozzelle, lie below the 10 m contour (see Fig. 4.1) which may be a significant level with respect to the phreatic level of perched groundwater bodies in the Pleistocene calcarenites.

Surface runoff of rainwater will have become more significant in the region when areas were cleared of natural/semi-natural vegetation for cultivation. Soil loss will have concurrently increased, caused by runoff following intense, seasonal rainfall. In this way, the exposure of higher and sloping ground to intense rainfall, by the removal of protective vegetation cover, will have promoted the development of marshy conditions in depressed areas where the waters and their sediment loads collect.

4.4 Past vegetation

The composite impression given by old maps and traveller's accounts, and by research into Salentine historical geography (for example by Congedo 1974; Novembre 1965) is of progressive diminution in the coverage provided by dense *macchia* and mixed woodland, dominated by evergreen oaks. Increasing demands for timber and agricultural land throughout historical time, and probably since the Neolithic period, account for this change.

In the recent past, dense *macchia* was more extensive on unattractive land surrounding marshy terrain. The first topographic map of the region, compiled by Rizzi-Zannoni in 1806, depicts a virtually continuous belt of *macchia* and marsh vegetation from San Cataldo to the south of Alimini Piccolo. In the late 19th century, Orlando (1885) notes that Alimini Grande was surrounded by dense, tall *macchia*, and similarly that *macchia* extended landwards from the Paludi Sausi for a distance of 2 km. By the late 1880's, however, Groves (1887) reports that much *macchia* of *Quercus pseudococcifera* around the Alimini lakes, had been cleared for cultivation. Even so, a semi-natural shrubby wood of *Quercus pseudococcifera*, covering 101 hectares and known as Bosco Pozzello, existed beside the marsh on the western margin of Alimini Piccolo until 1952 (Congedo 1974). The 'wood' was cleared by works of land reformation, resulting in an exposed, rocky surface.

When Swinburne passed by Alimini Grande in the 1770's, en route from Gallipoli to Lecce, he commented that the vegetation for miles around was dominated by bushes of *Quercus ilex* or *Quercus coccifera*. Further along the route, between the Alimini lakes and Lecce, he adds that

'the face of the country is too rocky, and too bare of trees, corn and grass, to be agreeable' (Swinburne 1783).

It appears that in the late 18th century, the zone covered by the study-area was relatively neglected when compared to the extensive olive groves reported around

Gallipoli, and the olive, wheat, oat, barley and cotton cultivation around Taranto (Swinburne 1783).

On the map of 1806 by Rizzi-Zannoni, two restricted woodland areas are shown near to the study-area, namely the Bosco di Belvedere on high ground roughly mid-way between Gallipoli and Castro, and the Bosco di Calimera which extended to the east of Calimera on high ground west of the study-area. Neither woodland exists today, but the extant Bosco S. Elia (5 km south-west of Maglie) is regarded as a residual wood, probably representative of the Bosco di Belvedere (Amico & Macchia 1964). As such, it is the most important relict woodland in the Province of Lecce (Novembre 1965).

The Bosco di Calimera was exploited by the medieval inhabitants of Calimera, for timber and wood for charcoal production (Congedo 1984). The small wooded plots enclosed by stone walls in the study-area, probably originated from deliberate planting by private individuals on land partitioned from the communal and feudal land divisions of the 19th century.

In 1874 the first geometrically surveyed, topographic map of the region was produced by the Istituto Topografico Militare. This and subsequent maps, together with other historical documents, have formed the basis of research by Novembre (1964) into the former extent of macchia in the region, based upon the spatial distribution of toponyms and phytonyms. According to Novembre (1964), numerous place-names in Salento, referable at least to the 17th century, allude to the former extent of macchia and woodland and also to particular species comprising these vegetation types; the name Lecce, for example, may be derived from phytonyms relating to Quercus ilex.

The author concludes that in medieval times, dense macchia covered much of Salento, particularly beside the coast. Its destruction was accelerated in the 18th century, with the expansion of cereal cultivation, together with existing pastoral practices. The degradation of macchia in the 18th and 19th centuries is linked with the expansion of marshy conditions, as interpreted from toponyms. By the end of the 19th century, the Macchia di Roca in the study-area had disappeared, and the Macchia di San Cataldo had more than halved.

4.5 Population distribution in the study-area; present and past

Following from the observations by Colamonico (1916) on population distribution in Puglia, described in section 2.9, it is evident in the part of Salento comprising the study-area, that all sizable population centres have developed at least 5 km from the coast.

Otranto is excepted from this observation and owes its development to the importance of its harbour, being at the point of Italy closest to the Aegean coast. Elsewhere along the study-area coastline, small settlements have developed around natural harbours, probably associated with fishing activities, which are important to the local economy. These are, namely, San Foca, Roca Vecchia, Torre dell'Orso and San Andrea, all of which lie along the Pliocene cliff coastline (chapter 3 Fig. 3.2). Only in the past 25 years have these villages expanded, mainly associated with residential and tourist development and the building of a coastal road linking San Cataldo to Otranto (Pagliara 1987).

Population centres inland lie outside the confines of the study-area, including Vernole and Melendugno which are of medieval origin (Pagliara 1987). Within the study-area, settlement is comprised of dispersed masserie or farmsteads. Many masserie are medieval in origin and no longer occupied. Those built from the 16th century to the 18th century are often fortified with a tower and high enclosing walls, constructed from the local calcarenite. Such defences were necessary against frequent raids by Turks and Saracens invading coastal lands around the Salento Peninsula (Sergi 1957). During this medieval period, towers were constructed at regular distance intervals around the coast to provide warning of invasions. The medieval occupants of masserie kept sheep-herds and cultivated cereals on land which progressively encroached on coastal marshlands and macchia; olive cultivation was also developed more extensively during this period (Sergi 1957).

Whilst the masserie provided protection for the inhabitants and their sheep against attack, the rural population was also vulnerable to malaria from the infested marshes. Both hazards led to the abandonment of many of these dwellings, and malaria continued to limit the rural population of the area until works of land improvement began (4.3).

Human groups probably began to have an impact on the study-area landscape in the Neolithic period, but evidence exists for much earlier populations within the study-area. Piccinno (1978) records four distinct areas of prehistoric remains beside the Alimini lakes (Fig. 4.2), identified during systematic exploration of this locality. The first area, on high land above the western side of the Strittu channel, contained flints of probable late Epigravettian industry (Mesolithic). Rock shelters beside the Strittu channel have already been mentioned (3.3), containing Epigravettian and Neolithic industries. On the east side of the channel, the Grotta Sacara also contained faunal remains including the animals, Ovis, Capra, Sus scrofa, Equus caballus and the mollusc Cardium, though the age of these remains is not determined.

In the second area, on the eastern side of the channel at the northern end of Alimini Piccolo, Epigravettian flint workings and Neolithic flint and obsidian workings have

been related to seasonal activity at this location. In the third area, near the western margin of Alimini Grande, surface stations are indicated by the presence of abundant lithics; the industry is more advanced than Romanellian (Upper Palaeolithic). The fourth area occurs on presently marshy ground, west of the northern end of Alimini Grande, from which lithic remains of Mousterian (Middle Palaeolithic) to Neolithic age have been recovered. According to Piccinno (1978), the Upper Palaeolithic industries at these sites are analogous with those from other cave sites in Salento, including Grotta Romanelli, Grotta Zinzulusa, Grotta del Cavallo and Uluzzo.

The concentration of early sites in this locality may in part be attributed to the availability of rock shelters and of freshwater springs. Providing sufficient groundwater reserves existed, the present author proposes that both lake-basins would have contained freshwater bodies of variable size throughout the period of activity at these sites. Sea-level at the end of the Pleistocene and in the early Holocene would have been too low to penetrate the basin of Alimini Grande, which has a maximum depth of 3.82 m below modern sea-level (De Giorgi 1895). Animals and human groups alike would be attracted to supplies of fresh water, though the abundance of this supply, and the consequent extent of the lakes will have varied according to Holocene climatic change, sea-level and hydrological conditions, discussed in chapter 12. With low water levels, the morphology of both lake-basins and the channel could have assisted in the control of herded animals, and enhanced hunting opportunities.

Mesolithic presence near San Foca has already been noted (3.6.1), where Ingravallo (1980) suggests the lithic industry relates to late Romanellian age. Neolithic industries were also found at San Foca (Ingravallo 1980), besides those found near the Alimini lakes. Artefacts of Neolithic age have been found in many parts of Salento, including at Acaia, bordering the study-area south-west of the Cesine (Bernardini 1955).

Evidence for Bronze Age settlement in the study-area includes a site in the Cesine reserve, mentioned in section 3.6.2, and deposits at the site of Roca Vecchia (Pagliara pers.comm.). The megalithic features of Salento, comprised of dolmen, menhir and specchie, have been associated with Bronze Age groups; examples of dolmen exist near the study-area, to the west of Melendugno. Bronze Age settlement and economic activities are likely to have affected much of the study-area, particularly in association with the coast which became increasingly important during this period for contact across the Adriatic. Archaeological evidence testifies that Mycenaeans frequented the Salentine coast since the Bronze Age (D'Andria 1988).

In the 9th century B.C., at the beginning of the Iron Age, a hut settlement was established at Otranto and trade increased between Salento and Greece. Otranto appears to have been a centre for the redistribution of goods to inland settlements, and according to D'Andria (1988), pastoral products from Salento could have been traded

for exotic goods. The port of Roca Vecchia probably developed similarly for trade across the Adriatic, and acted as a redistribution centre to large settlements inland, such as Cavallino and pre-Roman Lecce and Rudiae, lying to the west of the study-area (Fig. 4.3).

During the Iron Age, the ancient people of Salento developed as a group known as the Messapians. Some centres, including Cavallino, were transformed under Hellenistic influence, and agriculture on surrounding land became more organised (D'Andria 1988). Other centres including Otranto and Vaste, continued as hut settlements.

Greek settlement began in Otranto and neighbouring territory one century before Greek colonies were established at Brindisi and on the Ionian coast of Salento. With the development of the Greek colony of Taranto, tension among the Messapians increased in the first half of the 5th century B.C., leading to conflict and the destruction of many Messapian settlements, including Cavallino (D'Andria 1988). With increasing Roman presence in the region during the 4th and 3rd centuries B.C., however, the Messapians joined the Tarentines in being anti-Roman. Large fortifications were constructed around major settlements during this period. At Roca Vecchia, construction began of outer enclosing walls during the the 4th and 3rd centuries B.C. (see 10.1), but was later interrupted by events of the same period (Pagliara 1987). Following the destruction and abandonment of many Messapian towns caused by Roman conquests in Salento, the population became reorganised under Roman control.

During the Messapian and Roman eras, no population centres are known to have been located between the coast of the study-area and centres at a considerable distance inland. Principal Roman centres near the study-area were Lupiae (Lecce) and Rudiae, whilst Roman settlement within the study-area was focussed on the coast at San Cataldo (4.2), San Giovanni, San Foca, Roca Vecchia and Otranto, associated with fishing and commercial activities across the Adriatic. Tombs of both Messapian and late Roman age have been found at San Giovanni, also known as 'Li Salappi' (Mustilli 1957).

D'Andria (1980) suggests that the fishing village of Imperial Roman age at San Foca served a rural settlement inland, around which agricultural practices were organised. Otranto remained an important harbour for shipping to Epirus and other parts of Greece, and a Roman road was constructed to link it to the Via Appia at Brindisi; beyond Otranto, the road continued to Santa Maria di Leuca. Known as the Via Traiana, this road passed through the study-area and is believed to have crossed the Strittu channel between the Alimini lakes, en route from Lupiae and Rudiae to Hydruntum, Roman Otranto (De Giorgi 1895).

The inhabitants of Salento became farmers and merchants under Roman control (Shaw-Briggs 1910) and according to Novembre (1979), the general pattern of population and agricultural organisation persisted until medieval times. This post-Roman period was, however, very unsettled as a result of many foreign incursions by land and by sea. In the 8th and 9th centuries A.D., towns near the Adriatic coast were raided by Saracens, and in the 11th and 12th centuries Normans became established in Salento.

In the 14th century A.D., Roca Vecchia was redeveloped as a successful port and market for Lecce trade, but according to Shaw-Briggs (1910) the walled town was destroyed by royal decree in the mid-16th century, in response to invasions and smuggling problems; the population resettled at Roca Nuova, 3 km inland from Roca Vecchia. By the mid-16th century, Lecce was the largest population centre in Puglia. Later medieval settlement at Roca Vecchia is described by Pagliara (1987), including the use of artificial rock dwellings. Troglodytic dwellings also existed near the present Cesine reserve (Uggeri 1974).

It can be said that population distribution within the study-area from late prehistory to medieval times has been focussed on the coast. Settlement centres developed for the exploitation of marine resources and trading opportunities across the Adriatic. Large accumulations of pottery fragments on the sea floor on both sides of Torre dell'Orso bay, mark the sites of frequently used anchorages from the 7th century B.C. to late medieval times (Pagliara 1987). The Adriatic coastline between San Cataldo and Otranto is more approachable than that south of Otranto, and therefore assumed great importance for maritime communications across the Adriatic. Its significance is reflected by the exaggerated depiction of coastal indentations on early maps of the region, including the earliest map of Puglia, by Gastaldi in 1567 (see Colamonico 1939), and the map by Greuter in 1657 (see Almagià 1920).

The presence of surface water bodies, springs and the relatively easy accessibility to groundwater within the study-area must also have attracted settlement in this part of Salento, since early prehistory. Wells at Roca Vecchia have long made use of perched groundwater reserves. Within the walled settlement, a well dated to the 3rd or 4th century B.C. was revealed by archaeological excavations, together with a well dated to the 16th century (see 10.1) which still draws freshwater (Pagliara pers. comm.). As has been explained, however, these same environmental advantages of an approachable coastline and the presence of surface water bodies, have also created threatening conditions for peoples in historic times, through vulnerability to invasion and malaria.

Chapter 5

THE SEDIMENT SAMPLING LOCATIONS**5.1 The selection of sediment-core sampling locations for palynological analysis**

Limited areas of late-Quaternary sediment accumulation in the study-area were identified in chapter 3. These largely correspond to shallow depressions in the land surface, most of which are marshy unless artificially drained. It is well known that marshy sedimentary conditions are favourable for palynological investigations, because pollen and other organic-walled microfossils usually preserve well in such environments; optimal conditions for organic microfossil preservation are provided by waterlogged and anaerobic sediments. The destruction of these microfossils, which typically have a sporopollenin wall, commonly arises from microbial attack or oxidising conditions. Seasonal wetting and drying of sediments tends to promote these destructive conditions.

Locations for sediment sampling were therefore selected in areas which remain moist at the surface during the dry, summer months. Within these areas, zones were avoided where natural or man-made disturbance of sediments was evident or suspected, including the vicinity of drainage channels and surfaces disturbed by ploughing and cultivation. Selection of sampling locations was further made favouring those areas with the highest probability of continuous Holocene sedimentation, which also collectively represent diverse depositional environments, distributed throughout the study-area. The following depositional areas were identified as having the greatest potential to yield evidence of former environmental conditions towards the research aims; reasons for their selection are summarised here:

5.1.1 Alimini Piccolo, marginal lacustrine and marsh sediments

The freshwater lake and marsh environments are influenced, to a degree, by brackish waters entering the lake from Alimini Grande, which in turn receives saline water from the Adriatic. Lake-sediment stratigraphy and incorporated microfossils may therefore be sensitive to Holocene sea-level change and consequent changes to the lake environment.

Sediments in and around Alimini Piccolo are derived from the basin catchment and from autochthonous materials. Thus sediment stratigraphy, pollen and microfossils also potentially reflect environmental and/or landuse changes in the catchment of the lake.

5.1.2 Marsh basin sediments north of Alimini Grande

This freshwater marsh accumulates sediment from the basin catchment and from the decay of local plants and other organisms. These marsh sediments, their stratigraphy, pollen and microfossils have the potential to reflect environmental and/or landuse changes in the catchment of the marsh.

This is possibly the best location in the study-area for detecting regional vegetation history. It is a broad marsh basin, situated further from the coast than other suitable marshes, occupying an open position next to Alimini Grande, and whose sediment stratigraphy is expected to be less complex than that in a lacustrine environment. Flooding of the basin by possible higher lake levels of Alimini Grande during the Holocene, should be detected by examination of microfossil assemblages.

5.1.3 Marsh basin sediments north-west of San Foca

This freshwater marsh accumulates sediments from the basin catchment and from the decay of local plants and other organisms. These marsh sediments, their stratigraphy, pollen and microfossils have the potential to reflect environmental and/or landuse changes in the catchment of the marsh. The possible influx of marine water (4.3) should be detected by examination of microfossil assemblages.

5.1.4 Cesine lagoon-margin sediments and marsh sediments

Sediments accumulate in these coastal depressions from inland catchments and from the littoral environment. The sediments and their incorporated pollen and microfossils, from varied locations within the Cesine area, have the potential to reflect environmental and/or landuse changes within this low-lying zone.

Microfossils are expected to derive from terrestrial environments and from waters of varying salinity. Those remains from aquatic organisms probably relate to certain salinity ranges. In this way they may reflect any change in dominance of freshwater

with respect to marine water. Thus the sediments and the incorporated microfossils potentially reflect the increasing influence of marine waters, as a likely consequence of relative sea-level rise in the Holocene.

5.2 Locations of the sediment-cores

For each of the areas identified in 5.1 as most suitable for sediment-core sampling and palynological analysis, details are given here of local basin-morphology, sediment sources and vegetation zones; other depositional areas whose sediments were explored are also recorded here. Detailed descriptions of vegetation composition at each core location are given in chapter 8, with respect to the pollen assemblages of surface-samples from these locations.

Grid references are given to the nearest 100 m for each selected core location (within Universal Transverse Mercator Grid Zone 34T), taken from 1:50000 and 1:25000 topographic maps by the Istituto Geografico Militare. Core extraction procedures are given in chapter 6.

As descriptions of sediment-core stratigraphy in this research are based upon both field observations and laboratory analyses, details of core stratigraphy are given in chapter 9, together with the palynological analyses of each core; depth of sediments penetrated by each core is noted here.

5.2.1 Alimini Piccolo

i) Basin morphology and sediments

This elongate, probably fault controlled, basin (3.3) is occupied today by a freshwater lake approximately 2 km long and 0.5 km wide, fed by springs issuing along its western margin and at the Rio Grande and Strittu inlets (Fig. 5.1). The Rio Grande supplies water to the lake ephemerally, as does surface runoff from surrounding slopes. De Giorgi, writing in 1895, before recent landuse changes, noted that the lake depth varied between a summer minimum of 0.6 m and a winter maximum of 2.5 m; winter lake levels would reach between 1 m and 1.5 m a.s.l.

The Strittu channel bottom is at a higher level than the bottom of Alimini Piccolo. The width of its waters is now artificially constrained by improvement works which extend to the lake itself, circumscribing the water-body with a gabion wall; according to a water-management person at Alimini Piccolo, the wall was constructed in the

1940's. In 1955 a gate was installed in the channel, for the purpose of impeding the flow of brackish water from Alimini Grande to Alimini Piccolo during high seas (Congedo 1972); the gate no longer functions. Prior to these works associated with the use of Alimini Piccolo's waters for irrigation, the channel width varied between 20 m and 30 m in summer, and up to 50 m in winter, when its average depth was 1.5 m (De Giorgi 1895). Brackish waters from Alimini Grande would then have influenced the predominantly freshwater lake far more than at present.

The large seasonal fluctuation in lake level is accounted for by the deliberate closure of the sea-inlet to Alimini Grande in winter, for fishing purposes. This was achieved by accelerating the accumulation of shifting coastal dune sands in the channel, with the aid of temporary man-made barrages. Today the inlet is artificially controlled by walls, and is periodically dredged to prevent accumulating sands from blocking the channel.

The input of sediment to Alimini Piccolo is of concern to the Authority managing the irrigation works which use the lake's waters, because accumulating sediments are progressively blocking spring issues along the lake margin. A study by De Marco *et al.* (1983) comparing recent lake sediments with surface deposits on the basin slopes around the lake, concluded that most sediment deposited in the lake is transported from the basin by sheet runoff and by ephemeral flows of the Rio Grande. Two sediment types were recognised, one derived from the calcarenites and the other from residual dune sands on the low, western slopes of the lake basin; an aeolian element was also identified. The coarser sediments, input by the Rio Grande, are redistributed in the lake along the direction of water flow, which runs from the south-west towards the Strittu channel in the north. Fine sediments are deposited in the hydro-dynamically calm areas.

According to De Marco *et al.* (1983), only a small proportion of sediment is produced by chemical precipitation and organic detritus within the lake. Around the lake margins, autochthonous sediment is produced by aquatic and marsh plants, by lake algae and by calcium carbonate precipitation.

Calcareous, lacustrine sediments are common in shallow, hardwater lakes, and often originate from a combination of allochthonous carbonates, organic carbonate production and inorganic precipitation of carbonates. Kelts and Hsü (1978) comment that calcareous sediments may accumulate in the order of metres per hundreds of years, due to biogenic factors involving photosynthesis by lake macrophyta and microphyta, depleting carbon dioxide in the lake waters and consequently increasing calcite saturation. The authors suggest that higher rates of carbonate sedimentation are possible in the littoral zone of lakes, due to the assimilating activity of macrophytes. According to De Marco *et al.* (1983), the zone of maximum accumulation of

precipitated carbonate in Alimini Piccolo is found in the southern and 'calmest' part of the lake, towards its eastern side.

De Marco *et al.* (1983) were unable to establish whether modern rates of erosion in the lake-basin catchment, and consequent sedimentation rates in the lake are higher now than in past times, prior to extensive cultivation around the lake. An examination of lake sediment stratigraphy sampled by sediment coring is necessary to provide information on past sedimentation patterns. This research project is the first to contribute information on stratigraphy and sedimentation rates in Alimini Piccolo (see chapter 9).

ii) Vegetation zones

With continuing input of sediment to the lake from the surrounding cultivated slopes, the dense Phragmites reed beds bordering the lake encroach progressively further into the lake itself. These reeds dominate the lake-side vegetation, extending from the seasonally and perennially waterlogged ground around the lake, into the lake waters to a depth of 0.6 m. The control of brackish water influx to the lake has further encouraged dense growth of reeds and freshwater aquatic plants at the lake margin.

Friable, sandy soils between the waterlogged ground and the steeper calcarenite slopes, are today irrigated and cultivated. The transitional zone of seasonally wet ground between the cultivated soils and the reed marsh is dominated by a lower, herbaceous marsh vegetation commonly including rushes and sedges. Along the western lake-side, patches of bracken and brambles are evident at the margin between marsh vegetation and cultivated land. These plants, which also appear with Rumex (Docks), Equisetum sp. and Ligustrum (Privet), have perhaps survived from the former vegetation cover of this zone, before it was cleared for agricultural use. Wild plants on the disturbed, cultivated ground include Papaver sp. (Poppy), Legousia speculum-veneris (Venus's Looking-glass) and many Compositae species, for example Chrysanthemum coronarium (Crown Daisy).

The thin, stony soils on steeper slopes above the western side of the lake, support a garigue-type vegetation. At the north-western end of the basin, occasional olive trees survive amongst the garigue.

iii) Core locations

Core name:	AP88	Grid reference:	BK832499
	1AP		BK828514
	2AP & 3AP		BK822512

Sites for sampling the lake and marsh sediments of Alimini Piccolo were selected mindful of basin morphology and prevailing conditions of sediment deposition. Sites in the vicinities of the Rio Grande and Strittu channels were avoided, as were areas of evident man-made disturbance associated with irrigation works and cultivation.

Although the zone of deepest and least disturbed sedimentation lies, in theory, in the central part of the lake, the water flow from south to north indicated by De Marco *et al.* (1983) may disturb sedimentation patterns in the lake. The shallow, relatively still waters at the eastern and north-western lake-margins provide less disturbed, sedimentary environments, superior for the present research purposes.

An area of reed-mat extending over waters at the south-eastern end of the lake, and reduced to stubble by cutting and burning at the time of fieldwork, provided an opportune platform for obtaining core AP88 through actual lake sediments (Fig. 5.1). A continuous sediment-core was obtained, extending from the lake water/sediment interface to a depth of 3.6 m below lake-water level. Dense, tenacious, grey clay or marl forming the bottom 0.9 m of the core, resisted deeper penetration by the corer.

A further core, 1AP, was obtained from marsh sediments on the north-eastern side of the lake, in a more landward position relative to the present water-body (Fig. 5.1). In this part of the lake-side, the dense reed beds are mostly contained by the wall of gabions around the lake. Core 1AP was extracted from a point mid-way across the more herbaceous marsh zone, and 0.39 m above the level of Alimini Piccolo at the time of coring; surface soil conditions were almost dry at the time of coring. Core 1AP was obtained to a depth of 6.67 m; further penetration by the corer was prevented by stiff, tenacious, grey clay, as at the base of core AP88. It was impossible to obtain a continuous core due to the fluid state of three sections of the core sediments.

Two cores were obtained from the north-western margin of Alimini Piccolo, in order to compare the stratigraphy of marsh sediments on the western side with those on the eastern lake-side. Core 3AP was extracted from within the waterlogged fringe of the *Phragmites* reed bed. Working on the assumption that the lake-margin sedimentary sequence becomes deeper and possibly more complete with increasing proximity to the lake, the core was extracted from a point as close to the lake waters as practicable. The ground surface at the core location was 0.17 m above the lake level at the time of core extraction, and a continuous sediment-core was obtained to a depth of 3.25 m.

Attempts were made to obtain a core closer to the lake, but these failed here and elsewhere along the western margin due to the degree of waterlogging and incohesiveness of the sediments. Core 2AP was extracted within herbaceous marsh vegetation, 26.4 m west of core 3AP. Surface conditions were dry at this location, which was 0.21 m above lake level at the time of core extraction. A continuous sediment core was obtained to a depth of 2.42 m. At the base of both cores, fluid sands prevented deeper sampling.

5.2.2 Marsh basin at the northern end of Alimini Grande

No sediment deposits suitable for core sampling were found around the margins of Alimini Grande. Most of the lake's shoreline is formed by exposed rock, and in indented parts where sediments do accumulate, they are either disturbed by spring outflows or are sandy and disturbed by wave action. Potentially the best core sampling location in the vicinity of Alimini Grande, is in the marsh area beyond the northern end of the lake (Fig. 5.1)

i) Basin morphology and sediments

This karst depression is approximately circular in plan and 300 m in diameter. It is separated from Alimini Grande by dry ground, and has no apparent contact with the brackish waters of the lake. The gentle, cultivated slopes on its eastern side suddenly steepen at the marsh edge. Gradients on other sides of the basin are obscured by dense marsh vegetation around the basin margin. No water body is apparent in the basin and no streams flow directly into the basin. Perennially moist surface conditions are maintained here by groundwater. A drainage ditch skirts the western edge of the marsh and drains into the north-western shore of Alimini Grande. Another drains from the eastern most edge of the marsh to the northern end of the lake.

The sediment fill in the depression must derive from fine, allochthonous sediments transported to the depression by runoff waters from slopes to the north, west and east, combined with aeolian deposits and autochthonous, organic products of marsh vegetation.

ii) Vegetation zones

The moist soils are densely vegetated with marsh plants dominated by Phragmites reeds. In addition to the common marsh plants, described together with the surface-sample analyses in 8.1.2, occasional, small shrubs of Fraxinus cf. excelsior (Common Ash) were noted among the reeds. Ferns and Equisetum sp. were noted at the eastern margin of the marsh.

Small cereal plots cover most parts of the dry slopes surrounding the marsh. Plants commonly growing on disturbed ground beside trackways and among the cereals, include Papaver sp., Stachys, Echium cf. lycopsis (Purple Viper's Bugloss) and Reseda lutea (Wild Mignonette).

iii) Core location

Core name: 1AG Grid reference: BK821558

Access to the marsh was most practicable from its eastern side, although the dense Phragmites reeds hindered access in all parts. A sediment-core sampling location was selected mid-way between the northern and southern edges of the marsh, and westwards approximately one third of the distance across the marsh (Fig. 5.1). Ground conditions were moist at the time of coring in early summer.

A continuous sediment-core was extracted to a depth of 4.58 m, at which orange clay forming the lower 1.12 m became too wet to be retrieved by the coring equipment. Coring continued to a depth of 4.81 m, where incohesive, orange clay was still present, with an increasing content of limestone granules.

5.2.3 Paludi Pozzelle

An unreclaimed remnant of these former marshes (4.3) exists in the depression north of Masseria Pagliarone, 0.5 km west of Alimini Grande (Fig. 5.1). Cereal fields surround the marsh, on the dry slopes of the depression. A well at the marsh edge reveals that the groundwater level is close to the ground surface in this location.

An exploratory sediment core was extracted within the Phragmites reed bed, but limestone was reached at a depth of 1.04 m. Core stratigraphy was recorded for comparison with core 1AG (see 9.6), but further analyses were not carried out.

Core name: PP1 Grid reference: BK813543

5.2.4 The depression west of Roca Vecchia

This elongate and probably tectonically controlled depression, mentioned in 3.3, is the zone of sediment accumulation closest to the important archaeological site of Roca Vecchia (Fig. 5.2). The sediments have been greatly disturbed by ploughing, cultivation and drainage ditches, and are therefore unsuitable for palynological analyses. An exploratory core was, however, obtained from a central point within the depression and west of Roca Vecchia (Fig. 5.2), in order to sample the infilling sediments; coring was halted at a depth of 0.95 m, by uncorable sands.

Core name: RV88 Grid reference: BK805628

5.2.5 Marsh basin 2 km to the north-west of San Foca

i) Basin morphology and sediments

This roughly circular depression, approximately 500 m in diameter, contains the most extensive area of marsh between the Alimini lakes and the Cesine area (Fig. 5.2). Slopes steepen around the basin margin, but the present marsh, though extensive, does not occupy the entire basin. A small drainage channel links the basin to the coast, 0.75 km away.

Sediment fill in the depression must derive from fine materials transported from surrounding slopes by runoff waters, together with aeolian deposits and organic products of the marsh vegetation.

ii) Vegetation zones

Very dense Phragmites reeds occupy the marsh area. The reed- bed density is reduced on the drier, marsh margins where other marsh plants, are more frequent (see 8.1.2).

On dry slopes surrounding the marsh, small areas are cultivated between patches of outcropping calcarenite. Plantago sp. is widespread on the dry, rocky areas. Patchy growth of bracken was noted on the dry slopes. Olive plantations occupy the higher,

stony ground to the north, west and east of the basin, whilst cereals are grown to the south.

iii) Core locations

Core name:	SF88	Grid reference:	BK773654
	SF1		BK772653

The density of the reed vegetation severely impeded access to the lower basin area. An exploratory core sampling location was therefore selected within the reed margin on the eastern side, approximately 100 m south of the channel (Fig. 5.2); a sediment-core, SF88, was obtained to a depth of 1.3 m, where basal calcarenites were reached. Subsequently, core SF1 was obtained within the marsh margin on the south-eastern side, further from the rocky, basin margin. A continuous sediment-core was extracted to 2.87 m, at which depth sands mixed with calcarenite fragments resisted further penetration by the corer. Surface conditions were dry at the time of coring in early summer.

5.2.6 Cesine marshes and lagoons

i) Basin morphology and sediments

The calcarenite bedrock is often exposed on the slightly higher ground between the marsh or lagoon filled depressions, and appears to undulate in directions both parallel to the coast and transverse to the coast. Sediments accumulate in the shallow depressions of this low, undulating surface. The three water bodies known as the 'Salapi', at the northern end of the reserve, and the largest water body, 'Pantano Grande', are each connected to the artificial channel, 'Canale Colletore Cesine', which outflows at the pumping station (Fig. 5.3). Groundwater and surface-water runoff provide freshwater input to these water bodies, and mix with sea water penetrating the dune cordon and also entering via the channel. Reclamation works, of which the channel is part, were completed in the Cesine area by 1947 (Cali 1971), and have maintained these water bodies and surrounding marsh areas in a much reduced extent; formerly, the autumn and winter rains caused notable increases in water levels (Medagli 1981).

Fine sediments transported by runoff from slopes to the west of the Cesine, accumulate in the marsh areas and on the landward side of the water bodies. Silts and

sands predominate in the water body bottoms; autochthonous deposits are mostly restricted to algal and micro-animal remains. In the marsh areas which fringe the landward side of the water bodies and also cover the more landward depressions, Phragmites reeds and associated marsh vegetation contribute to accumulating autochthonous sediments. Aeolian sands are deposited throughout the Cesine area.

ii) Vegetation zones

Until a century ago, the natural and semi-natural vegetation of this area was undisturbed, consisting almost exclusively of marsh vegetation around the then more extensive areas of water (Medagli 1981), together with macchia and dune vegetation. Vegetation patterns have subsequently been altered by reclamation works and reforestation. Existing vegetation zones within the Cesine reserve have been identified by Medagli (1981), together with their principal component species. These zones are summarised below and illustrated in Fig. 5.3; dominant species of each zone are given here, whilst other zonal species identified by Medagli are listed in Appendix B.

a) Woodland zones:

Pine species constitute 90% of the wooded areas, most of which were planted 50 years ago; Pinus halepensis and Pinus pinaster are the dominant species. Trees were scarce and confined to restricted dry areas prior to reclamation works. In places, Eucalyptus rostrata has been planted among the pines and also along trackways, together with Eucalyptus globulus. Quercus ilex has been introduced to a small zone on the north-western side of the reserve. Besides the Acacia and Tamarix species introduced to the Cesine for their sand-fixing qualities, other introduced species include Populus nigra and Salix alba growing along the artificial channels. Ulmus campestris, Quercus aegilops and Pittosporum tobira have also been introduced in small numbers.

Undergrowth is sometimes completely lacking on the dark, needle-covered ground beneath dense pine stands. But in some areas Rubia peregrina (Wild Madder) dominates the undergrowth, and in others Pteridium aquilinum (Bracken) or Phillyrea are dominant.

b) Macchia zones:

Medagli (1981) suggested that macchia and woody macchia of Quercus ilex could once have been common in the drier parts of the Cesine, but its degradation and disappearance has favoured more thermophilous macchia species, including Olea europea and Quercus coccifera. Today, macchia usually occupies transitional areas

between the woodland and marsh areas, its composition varies between different zones. Macchia landwards of the Salapi includes many species, listed in Appendix B, but Quercus coccifera and Q. ilex are absent. In the vicinity of Pantano Grande, macchia is dominated by Myrtus communis, Pistacia lentiscus and Phillyrea angustifolia, and includes tall Quercus coccifera. Macchia bordering the northern section of the drainage channel, near the pumping station, is dominated by species of Cistaceae.

c) Marsh zones:

Marsh vegetation, tolerant of some salinity, surrounds each of the water bodies and covers depressions further inland. Large tracts of marsh are dominated by Phragmites reeds, and others by Cladium mariscus (Great fen-sedge). Marsh areas further inland have lower salinities and become dry in winter, their vegetation therefore includes many different species, including various Ranunculaceae.

Various aquatic plants grow beside and in the artificial channels, including the species mentioned above, producing deposits of organic detritus. The water bodies themselves are devoid of emergent vegetation.

d) Dune and beach sands:

In addition to the halophilous plant species growing on dune and beach sands, mentioned in 3.7.7, are other species listed in Appendix B. Behind the dunes, which do not exceed 7 m in height, grow some evergreen plants, forming patches of macchia dominated by Juniperus oxycedrus and Juniperus phoenicea.

e) Wild, herbaceous plants of cultivated areas

Many herbaceous species grow around field margins and on abandoned cultivated ground; those listed by Medagli are given in Appendix B. As mentioned in 3.7.8, cultivated areas were more extensive on drier ground in the Cesine area, prior to reforestation.

iii) Core locations

Core name:	C1	Grid reference:	BK732717
	C2		BK725722
	C3		BK748702
	C4		BK748702
	PG		BK743706
	CS1		BK725724

Core name	CS2	Grid reference:	BK724721
	CM		BK745704

Mudflats exposed around the water bodies by exceptionally low water levels during the dry months of 1989, provided the opportunity to sample the water-lain, vegetation-free sediments most exposed to marine influence. Both the stratigraphy of the cores and the incorporated microfossils in these locations, possibly record changes in the local sedimentary environment brought about by Holocene sea-level rise. Core sampling of the mudflats along the eastern shores of both the largest Salapi lagoon and Pantano Grande, proved impracticable due to the high density of sand in these sediments, obstructing corer penetration. Finer muds accumulating at the northern and western margins of Pantano Grande and on the western margin of the Salapi, were sampled to a maximum depth of 1 m, beyond which sands resisted further penetration; of these, cores C1 and C2 were retained for examination (Fig. 5.3).

In addition to water-lain sediment sampling, a small, enclosed marsh basin, south of Pantano Grande and close to the coast at Ponte di Carlo, was selected as a potentially undisturbed site for sampling marsh-sediment stratigraphy. A series of trial cores along a west to east transect and a north to south transect in the central part of the basin, revealed general uniformity in the sediment sequence; core depths were again limited to a maximum depth of 1.53 m, by an impenetrable sandy layer or by bedrock. Cores C3 and C4 were retained for analysis.

On the basis of these exploratory cores, further sediment sampling locations with possibly deeper sediment sequences were selected in the marsh areas and at the marshy margins of the water-bodies, where terrestrial sediments from surrounding land collect, together with autochthonous sediments.

A sampling location was selected on the south-western shore of Pantano Grande (Fig. 5.3). This position is the most exposed of all the core locations, to lagoon waters and the marine influence. A continuous sediment-core, PG, was obtained to a depth of 2.03 m, below which sampling continued until calcarenite bedrock was reached at a depth of 2.25 m.

The location of core CS1 was selected with the objective of sampling sediments suitable for palynological analysis, in closest proximity to the Bronze Age archaeological feature described in 3.6.2. This feature is situated upon a calcarenite 'dome' between the two main Salapi water bodies, which descends abruptly to below water-level, within 10 m south of the feature. The artificial channel through the calcarenite continues, cut through marsh sediments, to the main Salapi lagoon.

Along the channel edge, just south of the calcarenite section, pottery shards of comparable texture to that found at the surface around the archaeological feature (3.6.2), are eroding out of the upper sediments mixed with abundant Cardium shells. If these shards are in situ, very little sediment has accumulated in this zone since the Bronze Age. Alternatively, the shards could have been washed over the calcarenite surface, down on to a Cardium-rich lagoon sediment in post-Bronze Age times. It is also possible that sediments excavated to create the channel were piled on those to the side, upsetting the 'natural' stratigraphy at the channel margin. The core location was therefore chosen within marsh vegetation at a distance of 12 m perpendicularly away from the channel edge, and 27 m from the limit of the calcarenite channel section. A continuous sediment-core was obtained, reaching bedrock at a depth of 1.53 m.

The location of core CS2 was selected in extensive Phragmites marsh at the most landward extent of the second largest Salapi water body (Fig. 5.3). At present the saline water body does not influence this zone of the marsh, which arises from groundwater levels close to the surface. A narrow macchia zone lies between the marsh and pine woodland to the west, south and east. A continuous sediment core was obtained to a depth of 1.76 m; sediments were further sampled to the calcarenite bedrock at a depth of 2.37 m.

An additional marsh sediment-core, CM, was selected within a Phragmites marsh basin, further inland and separated from the coastal marshes and water-bodies by a slightly elevated, calcarenite surface. This core was extracted in order to examine sediment stratigraphy in an interior location within the Cesine area, for comparison with the sediment stratigraphy of those cores close to existing water bodies. A continuous sediment-core was obtained to a depth of 0.9 m, below which sands were sampled until impenetrable calcarenite granules were reached at a depth of 1.48 m.

5.3 Surface-sample locations

A series of sediment samples were collected from the modern ground surface in order to test how well modern vegetation types in the study-area are represented in the modern pollen-rain assemblage, both in terms of vegetation communities and of individual taxa. Comparison of pollen frequencies in a sample, with the vegetation composition in the immediate and more distant vicinity of the sample location, provides important information towards interpretation of the fossil record. Of primary importance for understanding these relationships, are the dispersal and preservation characteristics of different pollen types, related to factors including prevailing winds and soil conditions.

Examination of the non-pollen microfossil assemblage in surface-samples from different vegetation zones provides information on associations between organisms, soil conditions and vegetation cover, of which little is yet known from other research. These analyses thereby provide further information to assist in the interpretation of the fossil sediments. Modern mud-samples were likewise collected for analysis from bottom sediments and shores of the water bodies involved in this research (see 5.4) The results of all surface-sample and modern mud-sample analyses are presented in chapter 8.

5.3.1 Surface-sampling strategy

Having identified principal vegetation communities and their spatial distribution within the study-area (3.7), surface-sample locations were selected to represent the diversity of vegetation zones. Though constrained by accessibility to much of the cultivated land and land within private enclosures, surface-samples were located as far as possible at random within a vegetation zone. As previously described, most of the study-area is now productive arable land, with the aid of irrigation, and semi-natural vegetation zones are restricted to those areas unattractive to cultivation.

Sampling was focussed on relatively undisturbed areas of semi-natural vegetation. Several samples were collected from cultivated land to assess the representation of plants of disturbed ground in respective pollen assemblages. Soils of these areas are, however, disturbed by ploughing and hoeing and in some places imported soil is spread over impoverished soils beneath olive groves. As a result, local pollen and other microfossils at the ground surface may be mixed with those from other contexts.

i) Spot and transect sampling

In most of the study-area, vegetation zones are delimited by human controls rather than by ecological controls. Spot sampling points were selected to represent these zones; spot surface-samples were also collected from each core location.

In the Cesine reserve and on the north-western margin of Alimini Piccolo, where transitions in vegetation type are related to gradients in local environmental variables, vegetation zones were sampled along transect lines. Lines were positioned and oriented so as to transect a maximum number of identified vegetation zones (following Gilbertson *et al.* 1985). Samples were collected systematically at regular distance

intervals along the transect, but the sampling interval was modified in places to accommodate significant vegetational or morphological changes.

The selected locations of spot samples and transects are as follows:

Sample 1: Olive grove: Mature plantation, south-east of Melendugno; grid reference BK746607.

Sample 2: Abandoned cultivated-ground: Former cereals field, lying between marshland and garigue on the western side of Alimini Piccolo; grid reference BK820510 (Fig. 5.4).

Sample 3: Garigue: Rocky slopes on the north-western side of the basin of Alimini Piccolo; grid reference BK819509 (Fig. 5.4).

Sample 4: Macchia/garigue: Dense garigue type vegetation with frequent shrubs on the eastern side of the Strittu channel; grid reference BK827523 (Fig. 5.4).

Sample 5: Coastal macchia: Dense macchia dominated by Juniperus sp. on red earths on the cliff tops to the south of San Andrea. (Dense macchia dominated by Pistacia lentiscus was sampled along the Cesine transect); grid reference BK829591.

Samples 6, 7 and 8: Oak woodland:

6: Enclosed mixed-woodland south of Roca Nuova, dominated by Quercus ilex and deciduous oak species; grid reference BK788602.

7: Young plantation of Quercus ilex on the western edge of the Cesine Reserve; grid reference BK727714 (Fig. 5.5).

8: Mature woodland dominated by Quercus ilex and Q. robur at S. Elia (south of the study-area). This is the most important oak woodland, sampling-location as its species composition is believed to represent former climax-woodlands of the region, as explained in 4.4; grid reference BK656408.

Samples 1AP, 3AP, 1AG, SF1, CS1, CS2 and PG: Marsh: These marsh zones, selected for sediment-core sampling, are represented by spot surface-samples (see Figs. 5.4 & 5.5).

The transition from *Phragmites* reed marsh to the herbaceous marsh zone at the north-western margin of Alimini Piccolo, was sampled along a 12 m transect (Fig. 5.4).

Coastal dune, marsh and macchia: The transition through dune, marsh and macchia zones to pine plantations in the Cesine reserve, was sampled along a 170 m transect line positioned across the Salapi region of the reserve (Fig. 5.5).

ii) Quadrats and vegetation description

Each surface-sample for palynological analysis, was collected from within a 1 m square quadrat; the procedure is described in 6.1.2. This quadrat size is most appropriate for describing vegetation cover where plants are up to the size of dwarf heath-plants (Gilbertson *et al.* 1985). In most locations, plants were within this size range, but larger plants were also recorded within a 1 m square quadrat as a first descriptive stage. For the purposes of this research, it was considered most useful to obtain detailed information on plant coverage within the 1 m quadrat, from which the surface-sample was collected, and then to record additional plant species present within a 5 m radius of the quadrat. In this way, the majority of plants contributing to local pollen rain should be registered. It is acknowledged, however, that plants observed in the field were those present and identifiable during the month of May; additional plants could appear at other times of the year.

Plants within each quadrat were identified as precisely as practicable, and at least to a level of identification attainable by pollen analysis. Where necessary, reference was made in the field to floral guides by Polunin & Smythies (1973), Polunin (1980), Polunin & Walters (1985), Polunin & Huxley (1987), Phillips (1988) and Schönfelder & Schönfelder (1990). Areal coverage by each plant was then visually estimated as a percentage of 1 square metre, and recorded according to a logarithmic rating scale suggested by Causton (1988) as follows:

Logarithmic scale rating:	% cover of 1 square metre:
1	up to 2%
2	3% - 10%
3	11% - 25%
4	26% - 50%
5	50% - 100%

This is a simpler alternative to the better known Braun-Blanquet and Domin scales of vegetation-cover assessment, and is sensitive to the fact that small differences among plants providing small ground-coverage are of greater significance than similar differences among plants providing large ground-coverage (Causton 1988); a significant point with respect to transect sampling across transitions between vegetation zones. The average height of each plant type within a quadrat was also recorded. Surface-sample quadrat descriptions are presented together with the results of the palynological analyses of respective surface-samples, in chapter 8.

Mollusc shells were also collected, where present within each quadrat. These have not been formally identified and are not incorporated in the present research analyses. A potentially useful record has, however, been obtained on the differences in spatial distribution of different mollusc taxa in association with differences in vegetation type and ground-surface conditions.

5.4 Modern water-lain sediment-samples

The sediment-cores collectively include water-lain sediments associated with freshwater, brackish and saline water bodies. Modern bottom muds and shore samples were therefore sampled from the freshwater lake, Alimini Piccolo, the brackish water lake, Alimini Grande and the hyper-saline lagoon, Pantano Grande. Sample locations are shown in Figs. 5.4 & 5.5, and are as follows:

- Sample A: North-east Alimini Piccolo, lake mud;
- Sample B: South-west Alimini Piccolo, lake mud;
- Sample C: North Alimini Grande, shore sediments;
- Sample D: East Alimini Grande, shore sediments;
- Sample E: West Pantano Grande, shore sediments;
- Sample F: East Pantano Grande, Shore sediments;

Microfossil assemblages within these modern samples, provide valuable information towards the interpretation of sediment-core samples. Results of the analyses of these samples are presented in 8.5.

5.5 Sediment sampling from archaeological deposits

Sediments were sought whose age could be estimated from their association with archaeological features, and in which microfossil preservation was a possibility. Suitable opportunities were sparse because of the desiccated, aerated conditions of the few datable archaeological sediments in the study-area. Even so, four samples from different contexts were collected for palynological analyses.

The first sample was obtained from wet sediments contained by the remains of a basket, retrieved from a well at the archaeological site of Roca Vecchia by Prof. C. Pagliara of the University of Lecce; the date of the basket and well construction have been determined archaeologically to the 3rd or 4th century B.C. Pollen subsequently extracted from the sample was well preserved, and results of the analyses are presented and discussed in chapter 10.

A second sample was collected from sediments excavated from the bottom 0.7 m of a 16th century A.D. well at the Roca Vecchia site. This well is cut through the calcarenite to a depth of 9.5 m below its opening. According to Pagliara (pers. comm. 1990) the bottom 0.7 m is filled with sediment incorporating bones, fragments of water-vessels and wooden artefacts. Above this, the well was filled with rubble and sediment, probably in the mid-16th century A.D. Despite the fact that wood is preserved in the bottom sediment, where the well still draws freshwater, no pollen was found in samples from the sediment matrix or from sediment trapped within cavities of incorporated bones.

A further sample from Roca Vecchia was collected by the author from a charcoal-rich, prehistoric layer exposed by an excavated section on the site. No pollen was obtained from this sample but some charred cereal grains were recovered; details of these grains and the sediments exposed by the section are given in chapter 10.

The fourth sample was collected from sediments associated with the the feature of probable Bronze Age in the Cesine reserve, described in section 3.6.2. The sample was obtained from beneath one of the calcarenite blocks at the channel side. Sediments in contact with these overlying blocks can be assumed to have remained unexposed since the time the blocks were laid. Results of the palynological analysis of this sample are presented in chapter 10.

Chapter 6 (part 1)

SEDIMENT SAMPLING AND PREPARATION METHODS

6.1 Field procedure

6.1.1 Sediment cores

All sediment cores were extracted using an Eijkelkamp gouge corer, with the exception of core AP88. Cores were obtained in undisturbed sections of 1 m length and 60 mm diameter. In the case of core 1AP it was necessary to use a 30 mm diameter Eijkelkamp gouge corer to penetrate dense grey clays. Resistant sand and clay layers were sampled at other core locations using an Edelman auger. Core AP88 was successfully obtained from sediment below shallow lake-water, using a Russian (Jowsey) peat corer.

Observations on core stratigraphy were made in the field prior to wrapping each core section tightly in aluminium foil. Core sections were then laid in half-round section plastic guttering of an appropriate diameter, to preserve their structure during transport and storage. Each core length was sealed with a wrapping of polythene film to minimise loss of moisture and access of air to the core.

6.1.2 Surface samples

As moss pollsters are rare in the selected sampling localities, samples were collected from the top 10 mm depth of soil. Approximately 5 ml of soil was taken from the centre of each 1 m square quadrat. Each sample was sealed in a plastic bag with as little air as possible.

Modern lake bottom and shore samples were similarly collected, with Formaldehyde solution added to retard the destruction of organic microfossils by organisms in the sample.

6.2 Laboratory Procedure

Cores and surface samples were stored at 4°C in a dark cold-store.

6.2.1 Core stratigraphy

Field observations of core stratigraphy were checked and recorded in more detail prior to sampling for palynological analysis. The stratigraphy of each core is described and illustrated in chapter 9.

6.2.2 X-ray radiography

X-ray radiographs were made of many core sections, using a Faxitron X-ray System model 43805N, in order to detect stratigraphic differences not discernible by eye. This technique is widely used in sedimentology (Roberts 1981) and has potential to detect tephra layers. Some of the radiographs revealed fine stratigraphic changes that were otherwise invisible, though none were composed of tephra. The likelihood of finding tephra in these sediments of Salento, is discussed in 11.1.4.

Stratigraphic changes displayed by the X-ray radiographs helped determine sampling points for palynological analysis. Mollusc shells were often clearly depicted on the radiographs, which provided a more accurate assessment of their distribution within the cores, than by visual inspection. Bioturbation is evident in some core sections.

6.2.3 Sampling for palynological analysis

As a basic procedure, all cores were sampled over a 10 mm unit at 10 cm intervals from a core surface cleaned of superficial material. Adjustments to this pattern were made where necessary to ensure that stratigraphic changes were sampled, and to avoid samples 'straddling' stratigraphic boundaries. Core AP88, analysed as a pilot study, was sampled at 20 cm intervals. As mentioned above, bioturbation affects parts of the cores, thereby limiting the resolution attainable by palynological analysis of the sediment column.

Sample size was in most cases 2 ml, measured volumetrically by displacement of water in a 25 ml measuring cylinder.

6.2.4 Sample preparation

All samples were prepared by a procedure of deflocculation, sieving and swirling based on that described by Hunt (1985); a flow diagram of the procedure is given in Appendix A. A sieve-mesh size of 7 μm was selected, which according to Cwynar *et al.* (1979) ensures the recovery of more pollen than larger mesh sizes, whilst allowing the removal of most fine sediment. This relatively gentle preparation method allows the recovery of other palynomorphs from the sediment, besides pollen, which contribute valuable environmental information to this study. Harsher methods, such as acetolysis, remove much of the non-sporopollenin palynofacies and may even damage pollen grains.

Many widely used techniques for the palynological preparation of non-lithified sediments begin with digestion of the sediment in potassium hydroxide (KOH). Procedures following this initial step vary, but commonly involve treatment by acetolysis, hydrochloric acid (HCl), hydrofluoric acid (HF), flotation in heavy liquids or oxidation. Details of these procedures, together with assessments of their efficiency are given in Faegri & Iversen (1964), Moore & Webb (1978) and Brown (1960).

The method employed in this research worked well on sediment samples with a high mineral content. For those with a high organic content, residues were produced with much lignin, cellular and amorphous debris which prolonged the time necessary to record the pollen and other microfossils.

6.2.5 Slide preparation

A known fraction of each residue in water was transferred by pipette to a small quantity of melted glycerol jelly mountant on a microscope slide, and covered by a 22 mm x 22 mm glass coverslip. The residue was first agitated thoroughly, and the number of drops transferred by pipette to the slide was recorded; the total number of drops in the original residue was also recorded so that absolute pollen frequencies could be later calculated (6.5.1ii). A sufficient number of drops was mounted, for each sample, to cover the coverslip area well, whilst not appearing too 'cluttered' under the microscope.

Glycerol jelly as a mounting medium has the advantage of producing a permanent mount, prepared easily from an aqueous residue. Its main disadvantage is that pollen grains may not simply be turned to view them from other angles. Most grains can be identified without turning them, but when necessary the problem was overcome by heating the slide briefly on a hotplate and touching the coverslip gently when the slide

is back under the microscope objective. Oil mountants facilitate the rotation of grains, but have the drawback of producing temporary mounts.

Petropoxy 154 resin was experimented with as an alternative mounting medium. It was found that a viscous mount could be produced with this material, in which pollen grains were rotatable, but which hardened after a few weeks when left in air at room temperature, producing a permanent mount. There are disadvantages in terms of additional preparation time and the difficulty in determining the amount of residue mounted on each slide.

Superior mounts can, however, be rapidly produced with Petropoxy 154 resin for photographic purposes. It has a refractive index (1.540 ± 0.001) slightly higher than that of glycerol jelly, but is relatively colourless. Best results are obtained by spreading residue thinly on a coverslip, and warming on a hotplate to evaporate off the water. The coverslip is then inverted onto Petropoxy resin on a microscope slide. Further heating of the slide then hardens the Petropoxy to produce a permanent, clear mount with palynomorphs in the same focal plane.

Chapter 6 (part 2)

PROCEDURES FOR RECORDING POLLEN AND OTHER MICROFOSSILS AND METHODS FOR THE PRESENTATION OF QUANTITATIVE DATA

6.3 Pollen and Spores

6.3.1 Counting

Pollen concentrations per ml of sediment were generally low in all core samples. A pollen sum of 200 or 250 pollen grains from terrestrial plants was chosen as an effective limit to counting in all core and surface samples. The statistical validity of this sum is explained by Rull (1987). He points out that uncommon types may be misestimated using a sum of 200, but to arrive at a true proportion of 1% for a pollen type would require a sum of 1620. All pollen of terrestrial origin was included in the sum, as changes in local as well as regional vegetation are important in this investigation. Cryptogam spores and pollen from aquatic plants were counted at the same time as terrestrial pollen, but are not included in the pollen sum. Cyperaceae have been included among aquatic plants because in all the core sample locations the Cyperaceae are today predominantly marshy ground types.

All pollen grains and spores were counted along successive, regularly spaced transects of the microscope slide, at a magnification of 400x on an Olympus microscope, model BH; pollen and spore counts were recorded on purpose-made logging sheets. The number of transects scanned to achieve the pollen sum was recorded for each sample in order that estimates of absolute pollen abundance could be calculated. Calculation procedures for percentages and absolute estimates from the raw data are explained in 6.5.

6.3.2 Identification

Pollen and spores were identified under transmitted light at a magnification of 400x. Light staining introduced at the end of the palynological preparation procedure (Appendix A), enhanced the clarity of the surface morphology of pollen grains and so assisted in their identification. Staining also helped differentiate pollen from other palynomorphs, few of which absorb any stain.

Though many of the pollen types encountered are from plants which exist in the flora of north-western Europe, some types are from flora distinctive of the Mediterranean region. Pollen identification keys for the NW European flora (Moore & Webb (1978), Faegri & Iversen (1964), Andrew (1984), were therefore of use, but no comparable keys exist to cover comprehensively the Mediterranean flora. Unpublished keys in Bates (1981) and Stevenson (1981) were helpful in the identification of some Mediterranean types.

The following publications illustrating and describing pollen morphology within studies from southern European and Mediterranean locations were especially useful:-

Italy: Accorsi & Forlani (1976), Arobba (1976), Braggio Morucchio & De Vincenzi (1980, 1981), Lona & Bertoldi (1972), Paoli & Cellai Ciuffi (1976). Dalmatia: Beug (1961a, 1961b). France: Elhai (1959). Israel: Horowitz & Baum (1967). Lebanon: Haddad (1969). Morocco: Panelatti (1960).

On certain genera: Maurizio & Louveaux (1962), Aubert *et al.* (1959), Oldfield (1959), Planchais (1962), Reille (1967), Van Campo & Elhai (1956). 'The North-West European Pollen Flora', series in Review of Palaeobotany & Palynology.

Identifications were further assisted by comparisons with modern pollen reference slides. The reference collection of the Dept. of Archaeology and Prehistory, University of Sheffield, was consulted together with reference slides of modern Mediterranean type material prepared by the author. Anthers from plants flowering within study-area were collected during fieldwork, and some were supplied by the Royal Botanic Gardens, Kew. Plant types were particularly selected for pollen reference material if they are a significant component of Mediterranean vegetation and are:

- a) difficult to differentiate from certain other pollen types e.g. Olea, as distinct from Fraxinus and other Oleaceae;
- b) not satisfactorily illustrated and described in the literature;
- c) exotic types, recently introduced to the study-area which would serve as markers in the fossil record, and may appear in surface samples, e.g. Carpobrotus acinaciformis.

Reference material is usually prepared by acetolysing flower anthers, but as acetolysis was not used on the sediment samples, a retting procedure was followed (following Dorning pers.comm., Coles pers.comm.); procedural details are given in Appendix A. Results were generally satisfactory, though some grains still possessed their intines, obscuring surface sculpture. Morphological descriptions of some of the prepared reference pollen are included in chapter 7 (part1).

6.4 Non-pollen microfossils

6.4.1 Counting

A range of well preserved non-pollen microfossils made up a large proportion of each sample residue. Microfossils recovered lay within the size range of 7 μm to 100 μm , as defined by the sieve mesh sizes used in the preparation procedure (see Appendix A). Macrofossils and other remains with dimensions greater than 100 μm , were collected during the initial sieving of each sample and retained for examination; details of these remains, their value and presentation within this research, are given in chapter 7 (part 3).

Microfossils with distinct form and known or potential interpretive value were recorded and counted. Less discrete remains, such as cellular plant material, fungal hyphae and pyrite, were recorded as present or absent. Microfossils were counted for the first 10 or 20 transects scanned for pollen counting (depending on the density of residue mounted on the slide). In practice, the frequency of most non-pollen microfossils was such that a good impression of the residue composition and microfossil abundances was achieved after 10 or 20 transects.

6.4.2 Identification

The types of microfossil recorded during the present analyses are described in detail in chapter 7 (part 2), together with notes on their environmental affinities. These details are referred to within the interpretations of fossil assemblages, from the core sediments (chapter 9). They divide into the following categories:

Plant, fungal, animal, and algal remains, microfossils of uncertain affinity and minerals.

6.5 The presentation of quantitative pollen and microfossil data

6.5.1 Pollen data

For each of the sediment cores selected for palynological analysis (see chapter 9), pollen data is presented firstly in a diagram of relative pollen percentages, and secondly

in a diagram of absolute pollen-frequency estimates per ml of sediment. The diagrams for each core, presented in chapter 9, complement each other and are interpreted together. Pollen data from the surface-sample analyses are presented in table format, as percentages of the pollen sum (chapter 8).

i) Percentage pollen frequencies

For each sample within a core, counts for each pollen type included in the pollen sum are presented as a percentage of the pollen sum. Diagrams of pollen percentages show variations in the relative frequencies of pollen types with sample depth in the core, and are independent of sediment composition and sedimentation rates.

Whilst diagrams of relative pollen frequencies usefully illustrate shifts in the relative dominance of certain pollen types, they do not necessarily represent changes in actual abundance of different pollen types. Furthermore, a change in the percentage of one pollen type causes compensatory changes in all other pollen percentages (Moore & Webb 1978). Faegri (1966) notes the importance of considering differences in the pollen productivity of the different species represented, in order to assess the significance of relative percentage values.

ii) Absolute pollen frequencies

Diagrams constructed from estimates of absolute pollen concentrations in each sample, allow changes in proportions of each pollen type within the pollen assemblage to be considered as independent variables (Bonny 1972). Those pollen and spore types excluded from the pollen sum (6.3), are represented in these diagrams together with the more significant and frequent pollen types. Variations in pollen concentrations within a sediment-core can be caused by change in the pollen-rain input, changes in pollen preservation associated with the depositional environment, and changes in sedimentation rates. Thus estimates of absolute pollen concentration in a sediment can provide valuable information about the environment at the time of deposition (Davis 1966). It is necessary, then, to interpret such estimates in the context of the sediment-sample attributes, including texture, composition, humification and compression (Moore & Webb 1978).

Estimates of absolute pollen frequency were determined from raw, pollen-count data by using a volumetric method, rather than by the addition of exotic pollen. Errors are inherent to each method, but those involving exotic pollen (see for example,

Benninghoff 1962; Stockmarr 1971) introduce another variable and source of error to the calculations; the number of exotic grains added to a sample can only be estimated, and it has to be assumed that these grains are evenly distributed throughout the fossil-pollen sample mounted on a slide.

Estimates of the absolute pollen frequency in 1 ml of sediment-sample, were calculated for each pollen type in each sample according to the following equation (source-author):

$$A = \frac{C \times D}{V \times T}$$

where A = absolute frequency-estimate per ml of sediment

C = Number of pollen grains counted (of a taxon)

T = Number of coverslip-transects traversed to count number of pollen grains (C)

D = Proportion of sample-residue traversed by each transect of the coverslip.

V = Volume of sediment sample (ml) processed from the core

Variable D is calculated from the following equation:

$$D = \frac{1 \times \text{no. of residue drops mounted on slide}}{45 \text{ no. of drops in total sample residue}}$$

The fraction, 1/45, represents the fraction of a coverslip traversed by one transect. Using the Olympus BH microscope, at a magnification of 400x, a 22 mm square coverslip is covered by 45 parallel transects.

As estimates of absolute pollen frequency can range from hundreds to many thousands of grains per ml of sediment-sample, square-roots of the absolute frequency-estimates have been presented in the 'absolute' pollen diagrams (chapter 9). The use of square-roots is advantageous, in that they display significant changes in pollen types that occur less abundantly, whilst suppressing large variations in abundantly occurring types. Hence, relatively small changes in line length plotted on the diagrams, represent significant changes in the absolute frequency estimate.

6.5.2 Non-pollen microfossil data

Estimates of absolute numbers of each counted microfossil type per ml of original sediment sample, were calculated in the same way as for pollen. For each sediment-core, square-roots of these absolute estimates are presented in diagrams constructed in the same format as those presenting pollen data (chapter 9).

Percentage calculations for each non-pollen microfossil type within a sample are irrelevant as relationships between the different types represented either do not exist or are not known. The data is best represented by diagrams of absolute abundances, where each microfossil is treated as an independent variable. Microfossil types were recorded as present or absent in the surface-samples and modern-mud samples; the data is presented in tabular form in chapter 8.

All diagrams of pollen and non-pollen microfossil frequencies were plotted using the graphics module of GIMMS (Version 5.1), manipulated by the author to produce conventional style pollen-diagrams. As far as the author is aware, this is the first time that this geoprocessing system has been used in this way.

Chapter 7 (part 1)

FOSSIL POLLEN

7.1 Points on the identification of certain pollen types of particular interest in this study

7.1.1 Quercus

As Quercus ilex is a dominant climax species of Mediterranean evergreen forest (De Philippis 1937) and is an important component of macchia, together with other evergreen Quercus species, it is important in this study to distinguish different types of Quercus pollen as far as possible. Pollen from evergreen species can be distinguished from that of deciduous species using light microscopy (LM), on the basis of grain morphology.

The Quercus ilex/coccifera type is rhomboid in equatorial view (Beug 1961a), has low scabrae in comparison with the tectum-thickness and columellae larger in comparison with smaller scabrae (Bates 1981). From examination of the reference slide prepared from modern Q. ilex pollen from the study-area (Plate 1/1-6), the present author notes the angularity of the colpi and feint, poroid areas central to each colpus. According to Planchais (1962), the colpi of Q. ilex and Q. coccifera are angled at the equator, and the grains of both species are generally smaller than other Quercus. Van Campo & Elhai (1956) add that pollen of Q. ilex is considerably smaller than that of a number of other Quercus species, including Q. pedunculata and Q. pubescens.

The Quercus pubescens/robur type (Plate 1/7-9) has an almost rectangular equatorial view and a prolate-spherical polar view (Beug 1961a), scabrae are higher in comparison with the tectum thickness and columellae are small in comparison with larger scabrae (Bates 1981).

Further morphological variations have been observed between and within the two groups, using SEM. Smit (1973) distinguishes a third and intermediate Quercus suber type by analyses of SEM imagery; he observes that both the Q. ilex/coccifera and Q. suber types are in fact tricolporate. Several authors have proposed keys to distinguish Quercus species beyond the two groups; these are discussed by Van Benthem *et al.* (1984), who advise that variation within species can be considerable while differences between species can be relatively slight.

In this research, Quercus pollen has been recorded as either Q. ilex/coccifera type or Q. pubescens/robur type, on the basis of differences in grain size, shape, prominence of scabrae and angularity of colpi (as illustrated in Plate 1). In the pollen diagrams of chapter 9, these are abbreviated further to 'Quercus ilex +' and 'Quercus pubescens +'.

7.1.2 Oleaceae

Fossil pollen from species of Fraxinus, Olea and Phillyrea may be expected in the samples studied. Difficulties in distinguishing genera of Oleaceae pollen are noted by Watts (1985) and by Van Zeist & Bottema (1977). Beug (1961a) notes that pollen of Fraxinus ornus may be mistaken for that of Phillyrea.

Oleaceae pollen were recorded as either Olea or Fraxinus type on the basis of reticulum luminae size and columellae length. If this distinction could not be consistently made, both were presented as total Oleaceae frequencies in the pollen diagrams (chapter 9).

A reference slide was prepared from modern pollen of a cultivated olive (Plate 2/4-6), in order to aid the differentiation of fossil Oleaceae. Most grains appear spherical or sub-spherical and approximately 20 µm in diameter. The reticulum appears bolder and more irregular than that of Fraxinus (Plate 2/1-3). Grains of Olea are tricolpate and occasionally tetracolpate; colpi are thin. Columellae are approximately 2 µm long. Pollen of Fraxinus species tend to have a thin exine with short colpi and a reticulum delicate in appearance. Further morphological descriptions of Oleaceae are given by Punt *et al.* (1991).

7.1.3 Tamarix

Although species of Tamarix within the study-area today are planted, some species were recorded from the study-area by Marinosci in 1870.

According to Baum *et al.* (1971) grains are mostly tricolpate and tectate with a fine to coarse, reticulate sculpture. The reference slide prepared from pollen of Tamarix cf. africana, showed most grains to be elliptical in equatorial view, tricolporate and finely reticulate (Plate 2/6-9). Their length approximated 17 µm, and diameter, 12 µm; colpi were long and thin.

7.1.4 Ostrya carpinifolia and Carpinus orientalis

Pollen of these species have similar morphology (Beug 1961a) and were not distinguished in this study. Pollen frequencies are represented as 'Ostrya/Carpinus orientalis' in the pollen diagrams.

7.1.5 Cynoglossum type

Pollen of Cynoglossum is very similar in size and morphology to that of Castanea (see Moore & Webb 1978), such that differentiation between the two can be difficult using light microscopy. In the present study, pollen grains identified as Cynoglossum rather than Castanea are represented as 'Cynoglossum type' in the pollen diagrams.

7.1.6 Compositae

Apart from the readily identifiable genera, Artemisia and Centaurea, the highly variable pollen grains of this family were recorded into the subfamilies, Liguliflorae and Tubuliflorae.

7.1.7 Gramineae

Pollen of this family was recorded into three groups based upon grain-size, which may be significant in terms of vegetation reconstruction from fossil pollen assemblages. It is widely acknowledged, however, that grain-size alone is an insufficient basis for confidently distinguishing between genera of Gramineae, for which detailed analysis of exine structure and sculpture is necessary (see Faegri & Iversen 1964; Moore & Webb 1978; Beug 1961b). Nevertheless, analyses of pollen assemblages in surface-samples from the study-area (chapter 8) show that distinctly small and distinctly large grains of Gramineae are respectively associated with areas of modern Phragmites and cereals. Size categories used in the present study are as follows:

- i) Grains of up to 15 μm were classed as Phragmites type (Plate 4/11,12); grains believed to be of Phragmites in the surface-samples (chapter 8) ranged between 11 μm and 15 μm diameter. Phragmites grains analysed by Hall (1990), from Ireland, varied between 18 μm and 25 μm , in which size-range pollen of other Gramineae were also present.

ii) Grains of greater than 37 μm were classed as cereal type. Almost all measured diameters of cereal pollen presented by Beug (1961b), exceeded 37 μm and ranged up to 60 μm . Some pollen of wild grasses, however, also lie in this size range (see Beug 1961b; Watts 1985).

iii) Grains of Gramineae lying between the two size classes were recorded simply as Gramineae.

7.1.8 Cistaceae

Cistus pollen (Plate 4/6,9) was distinguished from Helianthemum in this study. Species of Cistus are common elements of macchia and garigue in the study-area.

7.1.9 Pollen identification of other families

Pollen identification of the following families has not been taken further than family level, excepting several genera as noted: Caryophyllaceae- except Spergularia type; Chenopodiaceae; Cruciferae; Ericaceae - except Arbutus sp.; Labiatae; Liliaceae- except Asphodelus sp.; Ranunculaceae - except Thalictrum sp.; Rosaceae - except Potentilla sp. and Poterium sp.; Umbelliferae.

Unidentified pollen types were assigned a code number relating to the sample in which they were first seen. No type ever exceeded 1% of the pollen sum, and they are not shown in the pollen diagrams.

7.2 Morphological descriptions of pollen from specific exotic plants in the study-area

Additional descriptions are given here of pollen-grain morphology representing some exotic plant types introduced within areas of semi-natural vegetation in the study-area (apart from Citrus spp., which are cultivated). Their appearance in fossil-pollen assemblages would indicate a recent historical age of the incorporating sediment. The descriptions are based upon modern pollen prepared for reference by the author.

Acacia cyanophylla (Plate 3/1,2):

Pollen grains are smooth-walled and tightly grouped into polyads measuring approximately 49 μm long and 40 μm wide.

Opuntia ficus-indica (Plate 2/3,4):

Pollen grains are sub-spherical and poly-pantoporate, measuring approximately 112 μm in diameter. The exine reaches a thickness of 7 μm between the pori; pori are circular to quadrangular, and approximately 9 μm in diameter. Columellae are coarse and irregular, forming a loosely reticulate pattern.

Carpobrotus acinaciformis (Plate 4/1-3):

Pollen grains are spherical, tricolpate and echinate, measuring approximately 20 μm in diameter. Colpi are thin and poorly defined. Echinae are sparse, irregularly spaced and approximately 1 μm long.

Citrus limon (Plate 4/4,7,10):

Pollen grains are spherical, tetracolporate or pentacolporate, and reticulate. Grain diameter is approximately 23 μm .

Oleander sp. (Plate 4/5,8):

Pollen grains are spherical, triporate and scabrate. Pori are large, circular and ragged in outline, without annuli. Grain diameter is approximately 36 μm .

THE NON-POLLEN MICROFOSSILS

7.3 Introduction

Microfossils other than pollen were identified and recorded with reference to literature in the fields of biology, palynology, micropalaeontology and applied palaeoecological studies. Many of the microfossils recorded in this study were identified using published research of the Hugo de Vries Laboratory, University of Amsterdam (for example, van Geel 1978; van Geel *et al.* 1980/1981). These studies were based upon consultations with specialists in mycology, algology and invertebrate zoology in order to identify microfossil forms and their environmental affinities, principally from archaeological sites in the Netherlands. On the basis of this information, van der Wiel (1982), for example, combined evidence from pollen, fungal spores, algal microfossils and macroscopic remains to detect changes in groundwater level and river activity in the Hazendonk of south Holland, during Neolithic occupation of the area. Similar analyses were carried out by Pals *et al.* (1980) to investigate bog development in relation to Bronze Age settlement near Hoogkarspel, the Netherlands.

Not all microfossils are identifiable to the family, genus or species of living forms, but they can still have interpretive value. All microfossils in palynological preparations may be usefully recorded, as knowledge of their geographic distribution, associations with particular sedimentary conditions and other microfossils will progress, thus enhancing their value in future studies. A degree of selectivity in recording microfossil types is, however, necessary to be time effective, and selection is best made with the collective knowledge of earlier studies. In this way, microfossils have been identified to an appropriate level where they discriminate between habitat associations. Lesser known and possibly new forms showing clear stratigraphic variations, have also been recorded.

Each microfossil form recorded in the present research, is presented below under headings relating to its living form, where known. In each case the nature of the organism and its fossil form are defined, together with knowledge of its habitat restrictions. Typical microfossils found in this study are illustrated in Plates 5-12. The general frequency of different microfossils within samples of this study is noted here, but microfossil distributions in modern surface-samples and within each core are

discussed fully in chapters 8 and 9 respectively. Table 7.1 gives a summary list of all forms recorded in this research and indicates their presence/absence in each core.

7.4 Plant remains

7.4.1 Cell walls (Plate 5/1,3)

The presence/absence of fragmentary cellular plant material was recorded, though abundance varied between samples depending on the ratio of plant material to mineral matter in a sediment. Cellular configurations were often distinctive, but no attempt was made to identify plant type without an appropriate reference collection. Pieces of pine needle epidermis were, however, noted in some samples and recognised from van Geel *et al.* (1980/1981), Type 391.

7.4.2 Charcoal

In this study, black, angular fragments of woody (fibrous) material in sample residues were identified as charcoal. All identifiable fragments were counted but not measured; fragment size is a product of many factors, including taphonomic processes and perhaps processing procedures (Patterson *et al.* 1987). As most core sediments are not of the finely laminated, undisturbed type suited to finely resolved pollen and charred particle analysis (Tolonen 1986), neither the time consuming method of measuring charcoal particle area for different size classes (Waddington 1969) nor the point count method of area estimation (Clark 1983) were used.

Peaks in the charcoal curve for each core are assumed to represent higher fire frequency and thus could reflect human practices in the region. Charcoal curves may relate to vegetation changes suggested from pollen curves.

7.4.3 Other plant remains

Microfossils identified as leaf hairs, occurred in several samples in low numbers and were recorded as present/absent (Plate 5/2). Their basic form was recognised from Farr (1988) and Reid (1972).

7.5 Fungal remains

7.5.1 Fungal hyphae

Fungal hyphae represent the vegetative body (mycelium) of a fungus. They are common in most samples of this study, and were recorded as present/absent. Fungal hyphae have little known interpretive value, though Aaby (1983) associated hyphae length with processes of soil genesis.

7.5.2 Vesicular arbuscular mycorrhizae (VAM) (Plate 5/10,11)

Vesicular arbuscular mycorrhizae associate the roots of higher plants with fungal mycelia. These are the most widespread form of mycorrhiza, occurring on many herbaceous plants, ferns and liverworts (Gray & Williams 1971). Their presence in sample residues suggest that soil material was present in the original sample.

The mycorrhizae recorded in this study, were always smooth walled and yellow or brown; size varied. Individual specimens were counted.

7.5.3 Fungal spores

A wide variety of fungal spores was observed in the samples analysed. Most are probably terrestrial forms, but some aquatic forms may also be present (see Sherwood-Pike 1988). Identification to genus and species requires specialist mycological knowledge, however certain morphological types may be seen in association with particular sediment types or conditions (see for example, van Geel 1972). On the basis of spore morphology observed in sample analyses of the present study, fungal spores were recorded and counted into four categories:

Spore group 1 (Plate 5/4):

These spherical-square outline, single spores often have a pore. This group possibly includes Types 351 and 361 of van Geel *et al.* (1980/1981), who found it in high quantities associated with periods of human occupation.

Spore group 2 (Plate 5/5):

These spores are elliptical in outline and often have two protruding pores. Van Geel (1978) distinguishes two forms in this category, which he labels Type 55: i) a

smooth walled form occurring in mesotrophic conditions; ii) a form with longitudinal grooves associated with sediments containing a high amount of charred remains. Some forms of Type 55 may be associated with coprofilous species (van Geel *et al.* 1980/1981), and could indicate the availability of dung.

Spore group 3 (Plate 5/6-8):

These are septate spores of variable size. The number of septae varied from one to many. Van Geel (1978) distinguishes many septate spores, some appear to be restricted to certain peat types. Included in this category are conidia of the elongate type, cf. Type 25 (van Geel 1978). Helical septate conidia (Type 30 of van Geel 1978) are conspicuously absent from all samples. Perhaps this type is restricted to more northern latitudes, as van Geel (1978) did not find any particular associations of Type 30 with local conditions or substrates.

Spore group 4 (Plate 6/9):

These are irregular colonies of spores.

7.6 Invertebrate animal remains

7.6.1 Cladocera

Cladocera are members of the Crustacea, and almost exclusively inhabitants of freshwater; some are planktonic living in open lake water, but most are found in ponds, ditches or weedy margins of larger water bodies (Scourfield & Harding 1966). The fossil remains in samples are therefore worthy of note.

Some samples contained mouth parts of Cladocera (Plate 6/3) comparable with those illustrated by Roback (1970); these were counted and recorded as Cladocera remains. Head-shields of the Chydoridae (a family of Cladocera) were recognised from illustrations in Frey (1960), and counted separately (Plate 6/5).

7.6.2 Sponges (Porifera)

Most sponges are marine dwelling, but members of the family Spongillidae inhabit only freshwater (Vines & Rees 1972).

Sponge spicular remains, comprising scleres (Plate 6/7) and gemmoscleres (Plate 6/8), were observed in many samples and counted separately. Some spicular remains are illustrated by Racek (1970), though this information is not sufficient to identify those in this study. However, all scleres possessed an axial canal and could therefore represent freshwater sponges.

Spicular remains of fresh water sponges were common in the lake sediment core from Lago di Monterosi, central Italy (Racek 1970), where sponge fauna were shown to be most abundant before Roman times. Identified species provided information on water pH and temperature.

7.6.3 Foraminifera

Organic test-linings of these protists occurred in some samples (Plate 6/6). Most species of Foraminifera are marine dwelling but some tolerate brackish conditions (Murray 1979). Species could not be identified.

7.6.4 Unidentified animal remains

Other remains of invertebrate animals were counted and recorded as a single group. Included in this category are hairs, integument, invertebrate mandibles and compound insect eye fragments. Several examples are illustrated in Plate 6/1,2,4.

7.7 Algal remains

Microfossils were present from a number of divisions of the algae; some could be identified to genus and even species level. Each recorded form is discussed below; its algal division is shown in brackets.

7.7.1 Diatoms (Chrysophyta)

These are unicellular algae with a silicified cell wall (frustule). Diatoms can live wherever there is moisture (Barber & Haworth 1981) but different species occupy different niches and have distinct environmental constraints (Brasier 1980). Salinity is probably the most influential environmental factor affecting diatom distribution

(Bradbury 1975; Battarbee 1986); other important factors include water depth, pH and nutrient status. Interpretation of fossil diatom assemblages is complicated by the fact that marked temporal and spatial variations in diatom assemblages exist according to the interaction of these variables (Bradbury 1975).

Diatom frustules were common in many samples of this study, and a restricted, recurrent range of distinct morphological types were recognised (Plate 7); these were identified to genus and are listed below. Frustules generally appeared degraded with some loss of detail and ornament, probably due to use of potassium hydroxide (KOH) in the preparation procedure (Appendix A), though frustule preservation is sometimes poor in calcareous sediments. Since less resistant frustules may have been destroyed, it is likely that samples contained frustules of more species than have been recorded. Acid preparation techniques are normally used to isolate diatom frustules from sediments.

All fragments greater than 25% of a whole frustule were counted. The present author thanks Dr. E. Cox of the Dept. of Plant & Animal Sciences, University of Sheffield, for advice on identification of the diatoms. Consistency in their identification in all samples is the responsibility of the present author.

Taxa recorded:

<u>Amphora</u> cf. <u>mexicana</u>	<u>Nitzschia</u> sp.
<u>Campylodiscus</u> cf. <u>bicostatus</u>	<u>Paralia</u> sp.
<u>Craticula</u> cf. <u>cuspidata</u>	<u>Scoliopleura</u> sp.
<u>Cymbellonitzschia</u> sp.	<u>Surirella</u> cf. <u>striatula</u>
<u>Diploneis</u> cf. <u>bombus</u>	Unidentified diatom (type 1)
<u>Hantzschia</u> sp.	

Each of these diatoms tolerate brackish, shallow water conditions; none are exclusive to freshwater or entirely marine environments.

7.7.2 Dinoflagellates (Pyrrhophyta)

These are single celled algae with two flagellae. Generally the resistant resting cysts are preserved, but only some species regularly produce such cysts. Most known cysts are of marine species, but some represent species occupying brackish or freshwater niches. Less is known about non-marine forms yet these cysts potentially provide valuable information on past environmental conditions, particularly in marginal marine areas, as in the present study.

Dinoflagellate cyst diversity was low in the collective samples of this study. Cyst forms were identified on the basis of distinctive cyst morphology, and are listed below; each was counted separately:

i) Spiniferites spp.

Most cysts of Spiniferites sp. found within sediments of the present research, were similar in morphology to the specimens illustrated in Plate 8/1-4. There are many species within this dinoflagellate-cyst genus. Most are associated with marine environments, but some are found in brackish, estuarine waters (see for example McMinn 1991).

ii) Lingulodinium machaerophorum (Deflandre & Cookson)

Wall 1967

This dinoflagellate-cyst (Plate 8/5,6) is often associated with brackish, estuarine environments (see Downie & Singh; Morzadec-Kerfourn 1977) but it may also tolerate waters of high salinity (Harland 1983).

iii) Genus A

This palynomorph (Plate 9) was classed as a dinoflagellate cyst by the present author. Its morphology has a number of affinities with dinoflagellate cysts, including processes, a cingulum and an archeopyle. The numerous, thin, tapering processes are irregularly distributed over the surface of the cyst. Further work is necessary on the systematics of this cyst form.

The present author believes this may be a new species, since no description of comparable cysts could be found in published literature. Specimens were found mostly in samples from Alimini Piccolo (see 8.6, 9.2, 9.3), suggesting that the originating organism prefers a freshwater environment, and is possibly tolerant of low salinity.

7.7.3 Cyanophyceae (Cyanophyta/blue-green algae)

These algae occur as single or colonial cells bound by an outer cellulose sheath (Brasier 1980). Sheaths can be preserved in the fossil record (Plate 10/1,2). Cyanophyceae are abundant in most freshwater environments and are also common in soil, hot springs and in the marine littoral zone (Round 1973). According to van Geel (1986), their presence in lake deposits may indicate an alkaline environment.

Sheaths resembling Type 146 (van der Wiel 1982; van Geel 1986), labelled Gloeotrichia type, were recorded in many samples of this study. Gloeotrichia can be part of the planktonic community in large ponds, or part of the epiphytic flora growing on macroscopic plants in the freshwater littoral zone (Round 1973). A calcium deposit on sheath walls was observed in some samples (Plate 10/2). This occurs in some Cyanophyceae such as Gloeotrichia (Round 1973). Cyanophyceae recorded from samples in this study are believed to be of Gloeotrichia type; individual sheaths were counted.

Goulden (1970) notes that Gloeotrichia was common in the early history of Lago di Monterosi, central Italy. In Brugam's (1978) study of Linsley Pond, Connecticut, remains of Gloeotrichia were more abundant before European settlement around the lake, and appear to be indicative of less eutrophic conditions.

7.7.4 Botryococcus (Chlorophyta/green algae)

This colonial alga flourishes in freshwater lakes (Brasier 1980) but its tolerance of brackish water is widely acknowledged.

Irregular colonies were frequent in many samples and were often brightly stained (few other microfossils absorbed stain; Plate 10/3). Each colony was counted.

7.7.5 Pediastrum (Chlorophyta/green algae)

This is a flat, colonial alga (Plate 11/1,2). It comprises of between 8 and 128 cells (Brasier 1980). Species are planktonic and widely distributed in freshwater (Vines & Rees 1972) but also tolerate brackish water conditions and have been found in Cretaceous marine sediments (Evitt 1963); Pediastrum alone is not therefore a reliable indicator of totally freshwater conditions. This alga is often found amongst epiphytic algae on macroscopic plants in the freshwater littoral zone (Round 1973).

Most colonies observed in this study, have a pair of horn-like processes on each outer cell, and are of the species Pediastrum boryanum. Identification was made in accordance with descriptions in Vines and Rees (1972) and illustrations in Goulden (1970). Each colony was counted.

According to Goulden (1970), the abundance of Pediastrum boryanum in the early lake history of Lago di Monterosi, central Italy, may be related to a cooler climate at that time; Pediastrum duplex and P. simplex were more common during the warmer and relatively eutrophic, recent lake conditions. The widespread occurrence of P.

boryanum in fossil and modern samples of the present study, however, suggests that its distribution is not necessarily related to ambient temperature.

In cores studied from north-west Greece by Bottema (1974a), P. boryanum is common but other species are more restricted in distribution, possibly reflecting temperature and water quality differences. Bottema (1974a) also notes a negative relationship between Pediastrum and pollen of Sparganium, Typha latifolia and Lemna, and suggests growth of the alga is inhibited by the shade of such plants. In sediments from Gignac Lake and Second Lake, Ontario, increases in Pediastrum abundance reflect a forest clearance and farming phase detected from pollen diagrams (Burden *et al.* 1986). Similarly, in a sediment core from Myrtle Lake, north Minnesota, Janssen (1968) recorded a zonation of different Pediastrum species which appeared to be related to changes in peatland vegetation.

7.7.6 Zygnemataceae (Chlorophyta/green algae)

Spores from members of the Zygnemataceae were present in many samples and were usually brightly stained (Plate 10/4,5 & Plate 11/3-6). Their value as environmental indicators has often been demonstrated, particularly by the work of van Geel (1976, 1979) and van Geel & van der Hammen (1978). From differences in the stratigraphic variation of Zygnemataceae spore types, van Geel (1986) concludes there must be differences in habitat preference at least for spore production of different Zygnemataceae.

These algae are often found in small lakes, pools and in the littoral zone of larger lakes, but some species can live on wet soil (van Geel & van der Hammen 1978). The observed Zygnemataceae, detailed below, have a world-wide distribution. Others are more restricted, for example Debarya is noted by van Geel and van der Hammen (1978) as being restricted to a cold/cool climate. It did not appear in any sample of this study.

i) Spirogyra (Plate 11/4-6)

This is a filamentous alga inhabiting mainly freshwater. Smooth walled ellipsoidal spores with a longitudinal furrow were recognised in many samples as Spirogyra spores from comparison with Type 315 (van Geel *et al.* 1980/1981); occasional spores had a coarse, reticulate surface-sculpture (Plate 11/4). Their presence, according to van Geel *et al.* (1980/1981) is indicative of open, relatively eutrophic water. Van Geel (1976) cautions that some species of Spirogyra live in brackish water. Therefore, in the

absence of other Zygnemataceae spores in a sample, Spirogyra spores do not alone provide conclusive evidence for a freshwater environment.

ii) Zygnema (Plate 11/3)

This is a filamentous alga inhabiting freshwater. Certain spores of this alga are oblately spheroidal with a pitted surface (van Geel 1976). These were recognised from comparison with Type 314 (van Geel *et al.* 1980/1981) and are indicative of shallow, mesotrophic to eutrophic open water. This alga is also found in soil (Gray & Williams 1971).

iii) Mougeotia (Plate 10/4,5)

This is a filamentous alga inhabiting freshwater. Zygosporos of Mougeotia are quadrate, normally with concave sides and a densely pitted surface (van Geel 1976). These were recognised in many samples from comparison with Type 312 (van Geel *et al.* 1980/1981). Mougeotia species require shallow open water to produce zygosporos (Hoshaw 1968).

7.7.7 Desmids (Chlorophyta/green algae)

These are exclusively freshwater algae (Boney 1975). The desmid cell is divided in two by a central constriction. Cells observed in samples were almost always broken at the constriction, so half cells were counted.

In all cases identification to genus could be made by reference to Coesel (1979a & 1979b). Three genera occurred, namely Euastrum (Plate 10/8,11), Cosmarium (Plate 10/7,10) and Staurastrum (Plate 10/6,9). In the study by van Geel *et al.* (1980/1981), 'semicells' of Euastrum and Cosmarium were identified to species and provided an indicator for meso-eutrophic conditions.

7.8 Palynomorphs of uncertain affinity found in the present study

7.8.1 Concentricystes cf. circulus (Wolff 1934) Jansonius & Hills 1978.

Sporites circulus Wolff 1934, p67, pl.5, fig.28.

Concentricystes rubinus Rossignol 1962, p134. pl.2, fig.5.

The originating organism of this palynomorph, originally described as a cyst by Rossignol (1962), is unknown. The weakly ellipsoidal 'cysts' are colourless, with a raised concentric striation (Plate 12/1,2); individual 'cysts' were counted in the present study.

Three types of Concentricystes were identified by Rossignol (1962) from Pleistocene sediments in Israel, of which 'Forme B' closely resembles those occurring in sediments of this study. Since 'Forme B' occurred in a wadi bottom, Rossignol concludes this type is of fluvial origin. It was later found in Nile River muds (Rossignol 1969).

It is probably more common in Late Quaternary terrestrial sediments than it would appear from palynological reports, but occasionally it is mentioned. It is reported, for example, in floodplain deposits in Tuscany (Gilbertson *et al.* 1983) and in fluvial deposits near Modena, Italy (Accorsi *et al.* 1981). In the present research, more information on the distribution of this microfossil is provided, which suggests that Concentricystes is not necessarily directly associated with fluvial deposits (see chapters 8 and 9).

7.8.2 Type A

This is an unidentified cyst-type microfossil (Plate 12/3-6). It is possibly recorded for the first time in the present research analyses. It is ellipsoidal in equatorial view, and circular in polar view. The surface is densely covered by short (2 µm long) spike-like processes with broad bases, which appear bright under polarised light, possibly indicating a mineral outer surface. Some specimens appeared folded, suggesting the presence of an inner organic wall. An angular archeopyle exists at one pole of some specimens, suggestive of dinoflagellate cyst type morphology.

These microfossils were recorded only from cores AP88 and 1AP (see 9.2 and 9.3), associated with the lake sediments of Alimini Piccolo.

7.9 Mineral remains

7.9.1 Pyrite

Framboids of pyrite, or ferrous sulphide, were found in most core samples. These are commonly produced by sulphate reducing bacteria in anoxic conditions. Pyrite may form in a water column and at or below the sediment/water interface; intertidal sediments, including coastal lagoons, saltflats and estuaries are most favourable for its formation (Farr 1988). Since the sulphate in pyrite is mainly derived from sulphur compounds in the water body above the sediment (Love 1964), decreasing sulphate concentrations will suppress pyrite formation (Farr 1988). Sediments with abundant pyrite may therefore indicate saline water conditions.

In samples containing pyrite, small framboids often occurred within microfossils, as well as freely in some residues. The mineral was noted as present or absent.

Chapter 7 (part 3)

THE MACROFOSSILS**7.10 Coarse-residue contents**

As indicated in the palynological preparation procedure, described in Appendix A, coarse residues of the sediment-samples, comprising objects greater than 100 μm , were retained for examination. These residues consist of plant, animal and mineral remains, which can contribute further evidence for local environmental conditions, and provide important information for the interpretation of core-sediment stratigraphy.

Listed here are all the macrofossil types identified from samples in this study, together with explanations of their value as environmental indicators. Some elements of these residues also occur in microfossil form. Each type was recorded as present or absent in each of the surface-samples and in each of the sediment-core samples; the results are presented in tables in chapters 8 and 9.

7.11 Plant remains**7.11.1 Cell walls**

Macroscopic remains of cellular and woody plant material, together with charcoal, were recorded.

7.11.2 Charophyte oogonia

Charophytes are algal 'plants' which grow mainly in freshwater or brackish water up to 12 m deep (Brasier 1980); they are most frequent in calcareous waters (Round 1973). Oogonia enclose the egg-cells of these algae, and sometimes become calcified. They are preserved as macrofossils in both calcified and non-calcified states in some sediment-samples of this study.

7.12 Animal remains

7.12.1 Mollusc shells

i) Acroloxus cf. lacustris (Lake Limpet):

This is a freshwater mollusc living on plants or other solid material in clean, stagnant water (Pfleger & Chatfield 1988).

ii) Lymnaeidae (Pond Snails):

These gastropods predominantly dwell in stagnant, vegetated water. Although their shells were not identified to species in samples, their presence suggests marshy or pond conditions prevailed at the time of sediment deposition.

iii) Planorbidae (Ramshorn Snails):

These gastropods also mainly inhabit stagnant, vegetated water. Some species can tolerate temporary dry periods (Pfleger & Chatfield 1988). Species identification was not possible in this study, but the presence of their shells in samples is suggestive of marshy or pond conditions, possibly of an ephemeral nature.

iv) Scrobiculariidae:

Members of this bivalve family predominantly inhabit bottom-muds and sands in the inter-tidal and nearshore zone, often in estuaries (Tebble 1966), where freshwater mixes with saline water. Presence of their shells in samples suggests the existence of brackish water conditions.

v) Hydrobiidae:

Species of Hydrobiidae are commonly found on estuarine muds, in brackish water, salt marshes and lagoons (Phillips 1987).

vi) Cerastoderma edule (edible cockle) & Cerastoderma lamarki:

Cerastoderma edule inhabits sands and muds in the shore zone of brackish to saline water bodies, between mid-tide level and just below low water-mark (Tebble 1966); the habitat of Cerastoderma lamarki is similar. Tebble (1966) notes that Cerastoderma edule sometimes occurs in large populations, forming 'platforms' just below the surface of the sand.

7.12.2 Ostracods

Ostracods are small Crustacea enclosed by a chitinous or calcareous shell, in two valves, known as a carapace. Although some species live in humid, forest soils, most are water dwelling (Brasier 1980). Different species are tolerant of different salinity levels, and therefore potentially provide salinity indicators in the fossil record. Species identification of fossil ostracod carapaces is, however, complex and was not attempted in this study.

7.12.3 Foraminifera

These protozoans are enclosed by a hard 'test' or shell; test-linings were present in some microfossil assemblages (7.6.3). Benthic Foraminifera live on and in the bottom sediments of brackish waters and nearshore areas, mainly in sub-tidal areas or in pools in the inter-tidal zone (Murray 1979). The presence of their tests in sediment samples may thus be indicative of brackish to saline water conditions.

7.13 Mineral residue

Sand-sized grains of three mineral groups were recognised from the collective sediment-samples.

- i) Clasts of calcium carbonate probably originate from precipitation of this compound in a water body at the sample location.
- ii) Quartz grains may originate from the local calcarenites, and are transported to the sample locations by wind or water.
- iii) Black, green and orange minerals originate from the volcanic, heavy mineral suite transported along the littoral of the study-area (see 3.6.6).

Part 2

Results &
Interpretations

Chapter 8

**SURFACE-SAMPLES AND MODERN MUD-SAMPLES:
RESULTS OF THE FIELD SURVEY AND PALYNOLOGICAL ANALYSES****8.1 Introduction**

Studies on the representation of modern vegetation in Italy by modern pollen assemblages, are few. Existing studies, for example by Accorsi *et al.*⁽¹⁹⁸¹⁾ and by Braggio *et al.* (see Braggio Morucchio *et al.* 1988) are focussed on central and northern locations in Italy, where vegetation, climate, and edaphic conditions are significantly different from the environment of Salento. To the present author's knowledge, the surface-sample analyses of the present research provide information for the first time on the representation of modern vegetation zones by pollen assemblages in the semi-arid conditions of southern Italy.

Some studies of modern pollen assemblages within broadly similar vegetation communities, including macchia and garigue, have been carried out in parts of the eastern Mediterranean, including north-west Greece (Bottema 1974a), south-west Turkey (van Zeist *et al.* 1968), western Iran (Wright *et al.* 1967) and north-east Iran (Stevenson 1981); reference is made to these studies in 8.4.1. Much of the well known research into modern pollen dispersal and taphonomy is based on locations in north-west Europe and north America, and is primarily concerned with arboreal pollen (see for example, Andersen 1973; Janssen 1966; Tauber 1965).

The analysis of non-pollen microfossils in sediments from the study-area contributes greatly to the reconstruction of past environmental conditions within the present research (see chapter 9). Certainly, no previous studies have investigated the non-pollen microfossil assemblages within modern terrestrial and aquatic environments in south-east Italy.

In this chapter the following points are assessed, on the basis of surface-sample analyses from the study-area:

- i) How well are modern vegetation communities in the study-area represented by modern pollen assemblages, in terms of plant diversity and relative abundance?
- ii) How well are individual plant taxa represented in modern pollen assemblages, particularly those which are characteristic of a particular vegetation community?

- iii) Over what range are these pollen taxa dispersed? Can local elements of pollen rain be differentiated from regional elements?
- iv) To what extent are the different sedimentary environments of the study-area characterised by non-pollen microfossil assemblages?

8.2 The spot surface-samples

8.2.1 Data presentation

For each of the vegetation zones identified for sampling in 5.3.1, the results of vegetation cover assessment and respective pollen data are presented in tables. These tables allow direct comparison between plants observed in the field and plant types represented in the local, modern pollen-rain (see Tables 8.1 to 8.15)

Each table comprises three sections. In the first section, plants observed within a 1 m quadrat are listed alphabetically by their Latin name, together with the common name where appropriate. The average height of each plant type is recorded, followed by the percentage of the quadrat area covered by it, according to the scale in 5.3.1ii. Pollen types recorded from palynological analyses of the quadrat surface-sample, are recorded as a percentage of the total number of grains counted for each sample. A pollen sum of 200 grains was adopted, excluding Cryptogam spores and plants considered to be aquatic, as explained in 6.3.1. The actual number of grains counted of each pollen type is also recorded in the final column, inclusive of those types excluded from the pollen sum. In the case of surface-samples 3AP, CS1 and PG, percentage figures are omitted as the pollen concentrations were too poor to reach a total of 200 grains.

The second section lists additional plants identified within a 5 m radius of the quadrat centre, together with their respective pollen data. The third section lists remaining plant types represented by their pollen, but which were not observed growing within the quadrat or within 5 m around the quadrat.

In some cases, plants have been identified in the field to genus or species level, whilst their pollen in the surface-sample could not be identified beyond family level. In these cases pollen identified to family level is recorded against a representative of that family, if present, in the field list. For example, in Table 8.1, pollen identified as Labiatae is recorded against *Mentha* sp.; whilst this is the most likely source of Labiatae pollen at that spot, the pollen could have originated from another genus of the family outside the surveyed area.

The results table for each sample is accompanied (in 8.2.2) by information concerning ground-surface conditions, followed by an analysis of the sample results and comment on the non-pollen microfossils recorded from the sample. All recorded non-pollen microfossil types are defined in chapter 7(part 2). The presence/absence of each microfossil form in each spot surface-sample is summarised in Table 8.16 and discussed in 8.2.5.

Results of the spot surface-sample analyses are discussed collectively in 8.2.3, in which the degree to which different vegetation communities are represented by local pollen rain, is also assessed. The distributions of different plant types throughout the sampled locations, and the dispersal characteristics of their pollen, are discussed in 8.2.4.

8.2.2 Spot surface-sample results

Sample No: 1 Table 8.1

Olive grove, south-east of Melendugno.

Ground-surface conditions: Dry, sandy, red soil. Level ground shaded by mature olive canopy.

Comments on plants and pollen:

The olive canopy virtually covered the entire quadrat, and Olea is well represented in the pollen assemblage (77%). Sparse, herbaceous plants scattered the ground surface, much of which was kept clear of vegetation.

Of the three plant types identified in the quadrat, two are represented in the pollen assemblage. Of the five plant types identified within the 5 m radius, four are represented in the pollen assemblage.

A further seven pollen types were recorded from the sample, of which only cereal-type Gramineae grains (see 7.1.7) exceed 2%. None of the three arboreal pollen genera, Alnus, Pinus and Quercus were noted in the vicinity of the quadrat, though Pinus sp. is common throughout the study-area, as are bushes of Quercus coccifera. The remaining pollen can be associated with plants of disturbed ground.

Thus the pollen assemblage and relative abundance of different pollen types in the sample, reflect quite accurately the local vegetation and elements of regional vegetation.

Non-pollen microfossils:

Cellular plant remains, animal fragments and each of the fungal spore-types are well represented in the sample. Apart from a leaf-hair, no other microfossils were recorded.

Sample No: 2 Table 8.2

Abandoned cultivated-land, western side of Alimini Piccolo.

Ground-surface conditions: Dry, calcareous, sandy soil containing calcarenite fragments. Gentle slope facing east.

Comments on plants and pollen:

Euphorbia sp. was the only shrub occurring within the quadrat. All other plants within the quadrat and within a 5 m radius, were herbaceous taxa, common on disturbed ground. Grasses and cereals dominated the quadrat and are well represented in the pollen assemblage (22% and 17.5% respectively). Compositae contribute the largest proportion of pollen to the sample (47%) and occur abundantly in this vegetation zone.

Of the eight plant types identified in the quadrat, three are represented in the pollen assemblage. Of the fourteen plant types identified within the 5 m radius, seven are represented in the pollen assemblage.

A further nine pollen types were recorded from the sample, none of which exceed 2% of total pollen recorded. Of these, the arboreal genera Olea and Pinus were present within 500 m of the quadrat; Rhamnus sp., Juniperus sp. and Corylus sp. were not noted in the locality. The remaining pollen can be associated with plants of disturbed ground.

Thus most of the pollen types recorded, including the most abundant types, do reflect the disturbed ground environment of the surface-sample.

Non-pollen microfossils:

Cellular plant remains and charcoal are present in the sample. Mycorrhizae and each of the fungal-spore types are well represented, type 1 being dominant. Animal fragments are sparse, but Concentricystes sp. are frequent.

Sample No: 3 Table 8.3

Garigue on basin slopes west of Alimini Piccolo.

Ground-surface conditions: Dry, calcareous soils between outcropping calcarenite. Gentle slope facing east.

Comments on plants and pollen:

Two shrub species occurred within the quadrat, Cistus sp. and Euphorbia sp., and two further shrub species occurred within 5 m, Pistacia lentiscus and Quercus coccifera. Of these, Cistus and Quercus are represented in the pollen assemblage. Other plants within the quadrat were herbaceous taxa, of which only Compositae and Gramineae covered more than 2% of the quadrat; both families are well represented in the pollen assemblage, with Compositae (38.5%) represented more strongly than Gramineae (6.5%).

Of the eleven plant types identified in the quadrat, five are represented in the pollen assemblage. Of the fourteen plant types identified within the 5 m radius, six are represented in the pollen assemblage.

A further twelve pollen types were recorded from the sample, with a considerable percentage of the pollen sum represented by Pinus (15.5%) and by Oleaceae (13%). Cultivated olives and isolated pine trees existed within 500 m of the quadrat, and may account for these proportions. These percentages are, however, significantly higher than corresponding figures for Pinus and Oleaceae in sample 1, located within 100 m downslope to the east of sample 3. Sources for the other arboreal pollen, representing Juniperus sp. and Rhamnus sp., were not noted in the locality. The remaining pollen types represent plants of disturbed ground.

The variety of plant types in the quadrat, and within a 5 m radius, is not reflected in the pollen assemblage. But those taxa which are represented by pollen, are suggestive of garigue and open ground, dominated by herbaceous vegetation with occasional shrubs. The apparently significant proportions of Pinus and Oleaceae relate to more distant vegetation.

Non-pollen microfossils:

Cellular plant remains, charcoal and animal remains are present in the sample, and each of the fungal spore-types are well represented together with mycorrhizae. Of particular interest is the presence of Zygnema sp., the desmid Cosmarium sp., sponge sclere and frequent Concentricystes sp.. These are all normally considered freshwater organisms, but in this locality the only possible freshwater habitat would arise ephemerally from surface puddling of water following heavy rains.

Sample No: 4 Table 8.4

Macchia/garigue on the eastern side of Strittu channel.

Ground-surface conditions: Dry, calcareous soil containing calcarenite fragments.

Comments on plants and pollen:

Apart from the shrubby species Asparagus acutifolius and Pistacia lentiscus, all plants recorded in the quadrat and within a 5 m radius are herbaceous species. Much of the quadrat surface-area was covered by moss, but no spores of mosses were found in the surface-sample. Labiatae and Gramineae were predominant in the quadrat, and are represented by their pollen in the sample. Of the plants recorded within the quadrat and within the 5 m radius, Compositae contribute the largest proportion of the pollen sum (27.5%). Pollen of Pinus, however, is most frequent in the sample (35%); this strong presence probably originates from the Aleppo Pines on the western side of the Strittu channel, opposite the quadrat location, and from pine woods bordering the south-eastern side of Alimini Grande.

Of the six plant types identified in the quadrat, three are represented in the pollen assemblage. Of the sixteen plant types identified within the 5 m radius, seven are represented in the pollen assemblage.

A further ten pollen types, including Pinus, were recorded from the sample. The frequent Oleaceae pollen (9%) most likely originates from olive groves beyond the pine woods beside the Strittu channel. Other pollen types in the sample do not exceed 2.5%, and include the genera, Alnus, Juniperus and Vitis, none of which were observed in this locality. The remaining pollen types can be associated with garigue type vegetation.

Most of the pollen types present in the sample do point to a vegetation cover dominated by mixed herbaceous species, but apart from Ericaceae, the shrub elements of macchia/garigue are not represented by the pollen assemblage. The nearby presence of Oleaceae and Pinus is strongly represented.

Non-pollen microfossils:

Plant cellular remains and few animal remains are present in the surface-sample. Mycorrhizae and each of the fungal spore-types are represented; spore-type 1 is abundant. Concentricystes sp. is also present in the sample.

Sample No: 5 Table 8.5

Macchia on the coastal cliff-top, south of San Andrea.

Ground-surface conditions: Dry, red-earth.

Comments on plants and pollen:

Pollen from the surface-sample was in a poor state of preservation. Most grains were crumpled or broken such that they could not be identified. The presence of those that were identified are recorded in Table 8.5.

The quadrat vegetation was dominated by three plant types, of which only Juniperus was detected in the pollen assemblage. Of the other pollen types recorded, all taxa except Alnus, could be found within 500 m of the quadrat.

Non-pollen microfossils:

Cellular plant remains, animal fragments, mycorrhizae and spore-types 1 and 2 were observed in the surface-sample.

Sample No: 6 Table 8.6

Oak woodland in an enclosed, private plot south of Roca Nuova.

Ground-surface conditions: Dry, nodular clay-soil.

Comments on plant types and pollen:

The quadrat was covered on the ground by Hedera helix and above by a canopy of mixed Quercus species. Quercus is represented in the pollen assemblage, but only by few grains. Pollen concentration and preservation were poor from this sample. Of the nine plant types observed around the quadrat, four are represented by their pollen. These notably include Pteridium sp. and Pistacia lentiscus, associated with the woodland undergrowth.

Of the further nine pollen types recorded from the sample, Pinus is relatively highly abundant. The remaining types reflect the vegetation of disturbed ground, surrounding the woodland.

Whilst elements of the woodland vegetation are represented in the pollen assemblage, they appear to be less significant than characteristic elements of the surrounding cultivated landscape.

Non-pollen microfossils:

Cellular plant material is present in the sample. Animal fragments and type 1 fungal spores are abundant; type 4 fungal spores are present, as are freshwater sponge sclere.

Sample No: 7 Table 8.7

Oak woodland. A young plantation in Cesine reserve.

Ground-surface conditions: Dry, friable, organic soil covered by leaf litter.

Comments on plants and pollen:

A canopy of Quercus ilex virtually covered the quadrat, and is well represented in the surface-sample by Quercus pollen of a morphology attributed to evergreen oak species (see 7.1.1), contributing 74.5% of the pollen sum. Pinus is also well represented by pollen in the sample; pine plantations border this small oak plantation, the nearest pine tree being 15 m from the quadrat.

Of the four plant types identified in the quadrat, two are represented in the pollen assemblage.

Only two pollen types, Alnus and Oleaceae, were recorded from the sample without being evident in the vicinity of the quadrat. The Oleaceae pollen probably originates from olive groves adjacent to the Cesine woodland, or from 'wild' members of the Oleaceae within the Cesine reserve.

Thus the pollen assemblage accurately indicates local dominance of evergreen oak species, and detects the important presence of pine and Oleaceae in this area. However, among the species of woodland undergrowth, only Asparagus is represented in the sample.

Non-pollen microfossils:

The surface-sample contains much cellular plant material; charcoal and animal fragments are few. Only types 1 and 4 fungal spores are present, and in low numbers.

Sample No: 8 Table 8.8

Oak woodland, Bosco S. Elia.

Ground-surface conditions: Dry, shaded soil.

Comments on plants and pollen:

The quadrat was covered by a tree canopy which comprised of Quercus ilex and deciduous oak species, probably including Q. robur, named in the description of the woodland composition at S. Elia by Amico & Macchia (1964). Quercus pollen was frequent in the sample, and two pollen-morphological groups were distinguished, representing evergreen species and deciduous species; pollen representing evergreen species was most abundant. Collectively, Quercus pollen constitutes 41.5% of the

pollen sum. Hedera helix and Gramineae were the only taxa observed growing within the quadrat, and cover a small proportion of its area; both are represented in the pollen assemblage. Oleaceae contribute as much pollen to the sample as does Quercus (41.5%). This is explained by the close proximity of a mature olive grove, within 20 m of the sample location

All three plant types identified in the quadrat, are represented in the pollen assemblage. Of the six plant types identified within the 5 m radius, five are represented in the pollen assemblage

A further six pollen types were recorded from the sample. Two represent arboreal genera, Pinus and Rhamnus, both of which may be present within the woodland, but their pollen frequency within the samples is low.

The vegetation composition and relative abundance of different plant types in the vicinity of this quadrat is reflected well by the pollen assemblage and the relative proportions of different pollen types in the surface-sample.

Non-pollen microfossils:

Cellular plant material and animal fragments are present in the surface-sample. Each of the fungal spore-types are present; types 1 and 2 are well represented.

Sample: 1AP Table 8.9

Marsh: Phragmites reeds on the north-eastern side of Alimini Piccolo.

Ground surface conditions: Dry, organic-rich, friable soil.

Comments on plants and pollen:

Herbaceous plants and plants of wet ground, covered the quadrat and surrounding land. Compositae contribute the largest proportion of pollen to the sample (23%), but provided relatively little vegetation cover within the quadrat and the 5 m radius. Although Phragmites grew within and around the quadrat, it is not represented in the sample by small pollen grains of Gramineae (see 7.1.7). Gramineae are, however, well represented in the pollen assemblage (14%). Five plant types provided prominent coverage in the quadrat, but only Typha sp. and Calystegia sp. are represented in the pollen assemblage.

Of the nine plant types identified in the quadrat, five are represented in the pollen assemblage. Of the eleven plant types identified within the 5 m radius, seven are represented in the pollen assemblage.

A further fourteen pollen types were recorded from the sample, of which *Chenopodiaceae*, *Pinus* and *Quercus* are strongly represented. The *Chenopodiaceae* probably originate from goosefoots, which are common weeds of cultivation. Roadside pines within 1 km of the quadrat are probably the source of the *Pinus* pollen; isolated *Quercus* occur beside trackways, buildings and cultivated land on the east side of the lake. The presence of *Oleaceae* pollen may be explained by the existence of olive groves to the west and south of Alimini Piccolo. The presence of *Ruppia* pollen, and possibly the *Cyperaceae*, are indicative of water and wet ground.

Thus several characteristic elements of this marsh vegetation are represented in the pollen assemblage, but pollen from sources outside the marsh zone dominate in the pollen assemblage.

Non-pollen microfossils:

The surface-sample contains abundant charcoal, reflecting the current practice of clearing *Phragmites* reed beds by burning. Cellular plant material and animal fragments are present, as are mycorrhizae and each of the fungal spore-types. Also present are four water-dwelling diatom genera, *Melosira* sp., *Diploneis* sp., *Campylodiscus* sp. and *Paralia* sp., with the latter particularly abundant. Also present are the water-dwelling algae *Botryococcus* sp. and *Pediastrum* sp.. Cysts of *Spiniferites* sp. were also recorded; this is a marine dinoflagellate-cyst genus. Sponge sclere and *Concentricystes* sp. are also present.

Together, these microfossils reflect both a terrestrial, soil environment and an aquatic environment, providing complementary evidence in support of marsh elements in the pollen assemblage. It is unlikely that the dinoflagellate cysts indicate the influence of marine waters in this location; it is possible that they were transported to this point by onshore winds or by birds.

Sample 3AP Table 8.10

Marsh: *Phragmites* reeds on the north-western side of Alimini Piccolo.

Ground-surface conditions: Wet, highly organic soil covered by a residue of burnt vegetation.

Comments on plants and pollen:

The marsh plants were dominated by *Phragmites*, which is the only taxon in the quadrat to be represented in the surface-sample by pollen; small grains of *Gramineae*

(approximately 14 μm in diameter) in the sample are assumed to derive from these reeds (see 7.1.7), especially as other Gramineae were not observed in the field.

Of the nine plant types identified in the quadrat, one is represented in the pollen assemblage. Of the twelve plant types identified within the 5 m radius, three are represented in the pollen assemblage. The concentration of pollen in the sample was poor.

A further six pollen types were recorded from the sample, including other Gramineae. Cyperaceae dominate the pollen assemblage and probably originate from the adjacent, outer marsh zone. Local sources for the Oleaceae and Pinus pollen exist within 500 m of the quadrat.

Thus the diversity of the marsh vegetation is poorly represented by the pollen assemblage, but the notable presence of Phragmites and Cyperaceae pollen are indicative of the marsh environment. The other pollen types present do not significantly detract from such an interpretation based upon the pollen assemblage.

Non-pollen microfossils:

Cellular plant material, much of it darkened, and abundant charcoal provide evidence of burning. Mycorrhizae and each of the fungal spore-types are present. Surprisingly, no microfossils of aquatic organisms were recorded.

Sample No: 1AG Table 8.11

Marsh: Phragmites reeds north of Alimini Grande.

Ground-surface conditions: Wet, highly organic soil.

Comments on plants and pollen:

Marsh ferns provided the greatest cover values in this densely vegetated quadrat, and are represented by a low number of spores in the pollen assemblage. Phragmites sp. and Typha sp. were also prominent in the local vegetation, but only the former is represented by its pollen in the sample. The greatest proportion of pollen is contributed to the sample by members of the Compositae (29.5%), although plants of this family are relatively sparse in this locality. Pollen of Compositae is well known to be relatively resistant to corrosion (see for example Bottema 1975).

Of the nine plant types identified in the quadrat, four are represented in the pollen assemblage. Of the eleven plant types identified within the 5 m radius, four are represented in the pollen assemblage.

A further ten plant types were represented in the pollen assemblage. Pinus contributes a high proportion of the pollen sum (27.5%), and may be accounted for by a pine plantation within 500 m of the quadrat. Oleaceae also contribute a significant percentage (13.5%), and may originate from shrubs of Fraxinus cf. excelsior observed within the marsh, 20 m from the quadrat, as well as from olive groves on the upper basin-slopes to the north and west. Other pollen present from arboreal genera, are Alnus, Quercus and Juniperus; none of these were observed in the locality. The remaining pollen types relate to species favouring 'disturbed' ground.

Thus, elements of the marsh vegetation are represented in the pollen assemblage, though their relative proportions do not reflect their relative dominance in the quadrat. Vegetation types around the marsh basin are represented in the pollen assemblage.

Non-pollen microfossils:

Charcoal is abundant in the surface-sample, as are type 1 fungal spores. Animal fragments, mycorrhizae and spore-types 3 and 4 are present in the sample. Spores of Spirogyra sp. are present, indicating a moist, if not waterlogged environment, and adding support to the pollen indicators of marsh vegetation. Concentricystes sp. is also present.

Sample SF1 Table 8.12

Marsh fringe: Phragmites reeds north-west of San Foca.

Ground-surface conditions: Dry, sandy, organic soil.

Comment on plants and pollen:

Compositae and Phragmites reeds dominated the quadrat, but only the former is represented in the pollen assemblage, in which it is predominant (57.5%). Cyperaceae also formed a major element of the marsh vegetation and are well represented in the pollen assemblage. Grasses provided relatively little cover in the quadrat, but pollen of Gramineae are frequent in the sample (11%).

Of the five plant types identified in the quadrat, three are represented in the pollen assemblage.

A further seven pollen types were recorded from the surface-sample, among which Pinus and Oleaceae contribute significant proportions. Pine trees and an olive grove exist within 100 m of the quadrat. The remaining pollen represent plants of marshy and disturbed ground.

Thus, an indication of marshy conditions is provided by the abundant Cyperaceae and the presence of Typha sp. pollen in the pollen assemblage, but the other pollen types provide strong indications for disturbed, cultivated ground. This is in fact an accurate reflection of the local situation.

Non-pollen microfossils:

The surface-sample contains cellular plant material, abundant charcoal and animal remains. Mycorrhizae and each of the fungal spore-types are present, of which types 1 and 2 are abundant. This assemblage reflects the predominantly dry soil conditions.

Sample CS1 Table 8.13

Marsh fringe beside a saline water body, Salapi (Cesine)

Ground-surface conditions: Moist, sandy organic soil.

Comment on plants and pollen:

The quadrat was covered by dense Juncus acutus with occasional Phragmites; neither were represented in the pollen assemblage. Of the 5 plant types recorded within and around the quadrat, only bushes of Tamarix are represented in the pollen assemblage.

A further six pollen types were present in the sample in low numbers, including Pinus whose pollen was surprisingly sparse given the proximity of pine plantations. Pollen concentration in the surface-sample was poor.

Plant types represented in the surface sample generally reflect elements of the regional Cesine vegetation.

Non-pollen microfossils:

Cellular plant material, charcoal, mycorrhizae and each of the fungal spore-types are present in the sample; spore-type 1 is particularly abundant. Remains of Cyanophyceae were also present; these algae can be associated with soil or lakes. The microfossil assemblage suggests that this soil does not become inundated by the saline waters of the lagoon.

Sample CS2 Table 8.14

Marsh: Phragmites reeds, west of the Salapi (Cesine).

Ground-surface conditions: Moist, organic soil.

Comments on plants and pollen:

The quadrat was densely vegetated with three marsh-plant taxa, but none were represented in the pollen assemblage. Of the six plant types recorded around the quadrat, only Compositae were represented in the pollen assemblage.

A further five pollen types were recorded from the sample, in which Pinus is strongly dominant (94%) and originates from the pine plantations surrounding this marsh to the west, south and east. The remaining pollen types represent elements of the regional vegetation.

Non-pollen microfossils:

Cellular plant material, charcoal and animal fragments are abundant in the surface-sample. Mycorrhizae and fungal spore-type 1 are also abundant; the other fungal spore-types are present. Spirogyra sp. is present in the sample, reflecting moist soil conditions. The surprising presence of the test-linings of Foraminifera could be due to transport by wind or animals from the nearby lagoon or littoral zone.

Sample PG Table 8.15

Shore/marsh edge on the south-west side of Pantano Grande (Cesine).

Ground-surface conditions: Damp sands.

Comments on plants and pollen:

Of the four plant types observed in the quadrat and within a 5 m radius, only the Chenopodiaceae are represented in the pollen assemblage. A further three pollen types were recorded from the sample, of which Pinus is the most significant; pollen concentration was poor.

The presence of Chenopodiaceae pollen, unaccompanied by a range of pollen types from plants of disturbed ground, could permit the interpretation that the pollen originates from salt-tolerant species of Chenopodiaceae.

Non-pollen microfossils:

The surface-sample contains charcoal and abundant fungal spores of type 1; fungal spores of types 3 and 4 are also present. Four genera of diatoms are present, including Diploneis sp. and abundant Campylodiscus sp.. Sponge sclere, test-linings of Foraminifera and Botryococcus sp. are also present, all indicating the presence of a

water body with a degree of salinity. The microfossil assemblage thus supports the interpretation of salt-tolerant Chenopodiaceae.

8.2.3 The representation of vegetation zones by pollen assemblages in the spot surface-samples.

i) Cultivated ground

The vegetation of the two sampled areas of cultivated ground was well represented by pollen from their respective surface-samples. In sample 1 from an olive grove, the major presence of Olea sp. was indicated by the frequency of Oleaceae pollen, and the low proportion of pollen from plants of disturbed ground reflected the sparse undergrowth vegetation. The pollen assemblage of the sample from abandoned arable land mainly comprised of pollen from a greater range of disturbed-ground plant types, dominated by Gramineae and Compositae; as was the case in the field. Although the diversity of plants observed in the field is not reflected in the pollen assemblage, the pollen types recorded from the sample do represent the character of this vegetation zone. Grains of cereal-type Gramineae pollen were notably present in sample 1 from abandoned cultivated land.

ii) Garigue

In the field, the most significant difference between garigue plant communities and those of disturbed ground is the presence of dwarf shrubs in garigue. The pollen assemblage from the garigue surface-sample is very similar to that from the abandoned arable land. The presence of shrubs is only weakly represented in the surface-sample by pollen of Quercus and Ericaceae. This is important because differentiation of the two vegetation zones in fossil-pollen assemblage will depend upon the presence of pollen from characteristic shrub genera.

iii) Macchia

The pollen in sample 4, from a transitional zone between macchia and garigue vegetation, gives very little indication of the presence of shrubs, and could be interpreted as a sample from disturbed ground. Of the pollen recorded in sample 5, from the Juniperus/Cistus-macchia, only the presence of Juniperus pollen is suggestive of macchia. It should be noted, however, that Juniperus pollen was recorded in surface-samples from other vegetation zones. Surface-samples from macchia dominated by Pistacia lentiscus, are described as part of the Cesine transect analyses in 8.3.2.

iv) Oak woodland

In surface-samples 7 and 8, the oak-woodland canopy is clearly represented in the pollen assemblages, which are dominated by Quercus pollen. Pollen from evergreen oaks was distinguished from that of deciduous oaks, reflecting the mixed-oak composition of these woodlands. The results for sample 6 appear to be distorted significantly by pollen from vegetation surrounding the small, woodland plot.

In each of the three surface-sample locations (6, 7 & 8), Hedera helix and Pistacia lentiscus are common elements of the undergrowth. Pollen of Hedera helix was only recorded in sample 8, from the Bosco S. Elia. It occurred in none of the other spot or transect surface-samples, and may be interpreted as a woodland element.

The Bosco S. Elia is the most mature remnant of oak woodland, close to the study-area (4.4). As an objective of this research project is to detect the presence of ancient oak-woodlands in the study-area, the pollen assemblage of sample 8 provides an important reference for the interpretation of fossil pollen assemblages (in chapter 9) from the sediment-cores collected for analysis from the study-area (5.2).

v) Marsh

Each of the surface-samples from core locations were taken from zones of marsh vegetation. The species composition in the different areas of Phragmites marsh have many common elements, but few of these elements are represented in the pollen assemblage of their respective surface-samples. Pollen from plants characteristic of land surrounding each of the marsh locations, tends to be more strongly represented in the surface-samples than are pollen from the local marsh plants. Even so, all the marsh surface-samples except samples CS1 and CS2 from the Cesine, contain small proportions of pollen from at least one marsh plant type. Such tenuous indications of marsh vegetation are, however, frequently supported by elements of the non-pollen microfossil assemblage indicative of moist or wet ground conditions.

8.2.4 Notes on the distribution of certain plant types and pollen types in the different vegetation zones

Table 8.17 was compiled to summarise the combined data of the spot surface-sample analyses, and to illustrate differences in the distribution of different plant types and pollen types. Samples 5 and 6 are not included in the table, as their pollen data are distorted by poor pollen-preservation. The results displayed in this way provide a useful reference for the interpretation of sediment-core samples (see chapter 9). All

plant taxa identified at the surface-sample locations, or recorded from pollen in the surface-samples, are listed in alphabetical order.

Some plant types are clearly associated with a particular vegetation zone. For example Calystegia sepium, Epilobium sp., Juncus sp., Phragmites sp. and Typha sp. have a wide distribution within the marsh vegetation zones. These genera were poorly represented in the pollen assemblages, if at all. Should a combination of these genera be recorded in a fossil-pollen assemblage, local marshy conditions may be inferred. Genera such as Calystegia, however, include species which relate to other environments, including dunes in the Cesine. Similarly, members of the Labiatae observed in these surface-sample locations include marsh species and species of garigue and dry, disturbed ground. Fossil pollen from such genera or families must be interpreted as part of the pollen assemblage, and not in isolation.

As noted in 8.2.3, Hedera helix is clearly associated with the woodland areas sampled; its pollen was recorded only from a woodland sample. Other plants associated with the woodland samples have a wider distribution in the study-area. Pollen of Quercus only occurs in high proportions in the woodland samples, but it was recorded in low numbers from samples from cultivated land, garigue and marsh. Bushes of Pistacia lentiscus occur in woodland, macchia and garigue zones, but its pollen was only recorded once, in a marsh zone.

Many of the plants of disturbed ground, and their pollen, are clearly restricted to zones of cultivated land and garigue. They include Campanulaceae, cereal-type Gramineae, Hypericum sp., Malvaceae, Papaver sp. and Scabiosa sp.. Cistaceae could be included in this list, but Cistus species are frequent in macchia zones.

A number of the pollen-types and plant-types recorded from the surface-samples and their locations, are widely distributed in each of the vegetation zones. These include Chenopodiaceae, Compositae, Cruciferae, Gramineae, Oleaceae and Pinus. Although members of the Compositae are common in many of the surface-sample locations, they have often contributed a disproportionately high quantity of pollen to the surface-samples. Significant numbers of Oleaceae and Pinus pollen occur in many of the surface-samples, when they have no source in the immediate locality. Alnus pollen is present in four of the spot surface-samples, but no source was found in any of the vegetation zones.

8.2.5 The representation of surface-sediment conditions by non-pollen microfossils in the spot surface-samples

Each of the spot surface-samples was collected from terrestrial deposits with various moisture conditions at the time of sampling, and various degrees of vegetation cover. In Table 8.16, the presence of non-pollen microfossils in the spot surface-samples are recorded against a complete list of non-pollen microfossils recorded by the author from all the palynological analyses of this research project (see chapter 7, part 2). The table clearly shows which microfossils are common to the predominantly dry soils, rather than moist to wet deposits, against which microfossil assemblages from the modern mud-samples (8.5) and from the sediment-core samples (chapter 9), may be compared.

All the spot surface-samples contain cellular plant material, and most contain charcoal fragments. Mycorrhizae are present in all samples except those from the olive grove, oak woodlands and the shore of Pantano Grande. As mentioned in 7.5.2, vesicular arbuscular mycorrhizae are associated with the roots of herbaceous plants, ferns and liverworts; the lack of these plants in the above-mentioned sampling locations could explain the absence of mycorrhizae in the microfossil assemblage. Most of the samples contain each of the fungal spore-types and animal remains, in association with dry to wet, soil conditions. The presence of algal microfossils was in almost all cases related to the locally wet environmental situation of the surface-sample.

Useful information is provided by these analyses on the distribution of Concentricystes cf. circulus. It occurs in the dry, soil environments of samples 1, 2 and 3, as well as in the marshy conditions of samples 1AP and 1AG. As explained previously, the affinities of this microfossil are unknown, but in past studies it has been associated with fluvial and floodplain environments (see 7.8.1). The locations of samples 1, 2 and 3 are dry for most of the year, and only temporarily wetted by seasonal rains, which for short periods could produce puddling and sheet-wash on slopes. As this microfossil is quite abundant in these locations, it is unlikely to have been imported by chance, from wetter environments by wind or other agents. Based on its occurrence in these surface-samples, therefore, the present author suggests that Concentricystes cf. circulus is derived from an organism of terrestrial soils or sediments of varied moisture levels, but that fluvial or alluvial conditions are not necessary for its existence. Indeed, its association with floodplain deposits may simply result from the erosion of river-catchment soils and their redeposition in the floodplain.

It has been demonstrated, by the presence of cysts of Spiniferites sp. in sample 1AP and test-linings of Foraminifera in sample CS2 (8.2.2), that agents of transport such as wind and animals, which are not constrained by the geomorphological catchment, can redeposit microfossils in areas apparently outside their natural context. The odd

presence of these microfossils in the fossil-sediment record could therefore be misleading. This serves to emphasise that non-pollen microfossils from a sample should, like pollen, be interpreted as an assemblage, rather than as individuals.

In conclusion, the range of microfossils present in a sample provides valuable information on local environmental conditions, and may assist in the interpretation of a fossil pollen assemblage. The microfossil analyses of the spot surface-samples have illustrated their potential to complement and support the interpretation of fossil pollen.

8.3 The transect surface-samples

Two locations within the study-area were selected for surface-sampling along transect lines, as described in 5.3.1i. The principal objective of this sampling is to assess how well the traversed vegetation-types are represented by pollen assemblages in surface deposits from each zone, and how clearly spatial changes in vegetation zone are reflected by the pollen assemblages at different points along the transect. Analyses of the samples also provide further information on the relationship between non-pollen microfossils and local environmental conditions.

The first transect embraces transitions in the semi-natural vegetation zones of the Cesine, passing from the coastal dune cordon, through a zone of grass and rushes to a zone of macchia dominated by *Pistacia lentiscus*, which extends to the pine plantation; the transect location is illustrated in Fig. 5.5 (chapter 5). The results of palynological analyses of samples from these coastal margin vegetation-zones, provide important reference information for the interpretation of pollen and other microfossil assemblages from the Cesine sediment-cores.

Rising sea-level during the Holocene will have encroached upon the low-lying coastal area of the Cesine, altering the configuration of dune and lagoon areas. Vegetation zones would have consequently shifted in response to the impact of sea-level rise on local hydrology and edaphic environments. In order to detect such shifts and the increasing marine influence, through the analysis of core-sediments and their microfossils, it is first necessary to examine the accuracy with which modern microfossil assemblages reflect these vegetation zones and local environmental differences.

The second transect, at the north-western margin of Alimini Piccolo, spans the transition from dense *Phragmites* reed beds beside the lake, to the less waterlogged and more diverse marsh vegetation zone lying east of the cultivated land (5.2.1); the two marsh zones are related to differences in ground level with respect to lake-water level. The location of the transect is illustrated in Fig. 5.4 (chapter 5). Palynological analyses of samples collected along the transect were carried out to determine whether changes in the pollen and microfossil assemblage reflect differences in vegetation and surface conditions of the two zones. The analyses focussed upon the extent to which microfossil assemblages of the two zones could be shown to be distinct. If they are distinct, then the past positions of the marsh zones and related lake-level might be inferred from microfossil assemblages in the sediment cores.

8.3.1 Data presentation

To illustrate changes in the assemblages of pollen samples along the transects, the data is presented graphically by a series of histograms below a diagram of the transect profile, on which the vegetation zones are indicated; the Cesine transect is illustrated in Fig. 8.1 and that of Alimini Piccolo in Fig. 8.3.

Each histogram represents the pollen frequencies of one plant taxon as it varies across the transect; each bar on the graph represents the proportion of that pollen type in a surface-sample, and is aligned directly below that surface-sample point on the transect profile. Some of the pollen types occurring in low frequencies in the samples are not included in these diagrams, but data on their occurrence is given in the quadrat description tables (Tables 8.18 to 8.28).

Non-pollen microfossil assemblages in samples along the Cesine transect are also illustrated by histograms, in Fig. 8.2. The distribution of non-pollen microfossils along the Alimini Piccolo transect is summarised in Table 8.33. Equivalent data for the Cesine transect are also summarised in this way, in Table 8.29. These tables, in the same format as Table 8.16 representing the spot surface-samples, provide useful references for the interpretation of sediment-core samples in this research.

Before examining spatial differences in microfossil assemblages illustrated by the profile diagrams, the results of vegetation-cover assessment at each surface-sample location and respective pollen data, are presented in tables with comment, as for the spot surface-samples.

8.3.2 The Cesine transect results

Sample No: C1 Table 8.18

Crest of dune.

Ground-surface conditions: Dry sand.

Comments on plants and pollen:

Dominating the dune vegetation within the quadrat, is the exotic plant Carpobrotus acinaciformis, introduced for its reputed dune-stabilising qualities. Pollen from this species was identified by reference to modern pollen collected from the plant and prepared for palynological examination by the author (see 7.2); its pollen constituted 55.5% of pollen from the surface-sample. Carpobrotus acinaciformis has grown in Salento since at least the 19th century (Marinosci 1870), but it probably first appeared in the Cesine area since the 1930's, when stabilising plants were planted along this

stretch of coastal dunes. The appearance of its pollen in the fossil record would therefore indicate modern sediments.

The small proportion of the quadrat covered by Santolina sp. is represented by Compositae pollen in the sample. Marram Grass (Ammophila) is widespread along the dune cordon, and represented by Gramineae pollen in the sample. Thus, three of the four plant types recorded within 5 m of the sample location, are represented by pollen in the sample.

A further ten pollen types were recorded from the sample, of which Pinus is most abundant (15.5%), despite being 170 m up-wind of the pine plantations to the south-west. Cruciferae pollen also forms a high percentage of the pollen assemblage (14.4%), and probably originates from Cakile maritima (Sea Rocket) along the littoral. The Tamarix pollen originates from scattered Tamarix bushes landwards of the dunes.

Thus plants predominating in the dune environment are represented in the pollen assemblage by pollen of their respective families. In the fossil record, however, pollen of these families could occur together in a sediment sample, but their genera would not be determined. This pollen could originate from an environment other than a dune environment. In such cases, evidence from the non-pollen microfossil assemblage and sediment texture would help to resolve this problem.

Non-pollen microfossils:

As illustrated in Table 8.29, the dune environment represented by samples C1 and C2 has a smaller range of non-pollen microfossils than samples further inland. Those that occur are in relatively low numbers, as shown in Fig. 8.2. Mycorrhizae are absent from samples C1 and C2, but present in all other samples along the transect, reflecting the contrast in edaphic conditions and vegetation between the dune environment and conditions inland. The limited nature of the microfossil assemblage adds support to the interpretation of dune vegetation from the pollen assemblage.

Sample No: C2 Table 8.19

Base of dune cordon

Ground-surface conditions: Dry sand.

Comments on plants and pollen:

The dominance of Carpobrotus acinaciformis in the quadrat is again represented by the pollen frequency of this species in the surface-sample (45%). Grasses and sedges are

represented by low proportions of pollen; three of the five plant types recorded within 5 m of the surface-sample are represented in the pollen assemblage.

A further ten pollen types were recorded in the sample, of which the relatively high values for Compositae and Cruciferae probably reflect the presence of genera of these families in the dune environment. Thus the pollen assemblage at the base of the dune is similar to that on the dune.

Non-pollen microfossils:

The microfossil assemblage and frequencies are very similar to that of sample C1, but fungal spore-type 3 is also present.

Sample C3 Table 8.20

Rear of dune, margin of herbaceous vegetation.

Ground-surface conditions: Dry sand, covered by dead vegetation.

Comments on plants and pollen:

The vegetation composition of the quadrat was similar to that in samples C1 and C2, except that grasses covered a greater proportion of the quadrat than Carpobrotus acinaciformis. These relative changes in cover values are reflected by changes in respective pollen percentages (Fig. 8.1). The two other species noted within a 5 m radius of the quadrat, Juncus acutus and Pistacia lentiscus, are not represented in the pollen assemblage.

A further eleven pollen types were recorded from the sample. Compositae are strongly represented (21%), of which there are many species in the Cesine (see Medagli 1981). Tamarix and Pinus pollen are frequent.

Non-pollen microfossils:

The range of non-pollen microfossils in this sample is broader than in samples C1 and C2, as shown by Table 8.16, and frequencies of individual types are higher, as shown by Fig. 8.2. All four recorded fungal spore-types are present; type 1 is particularly abundant in this location. Mycorrhizae are also present, probably associated with the sample's position just within the herbaceous vegetation zone. Also present is the alga Botryococcus sp., tolerant of some salinity, and sponge scleres. These require a wet environment, and may indicate periodic inundation of this zone to the rear of the dunes by invading sea water or high groundwater levels.

Sample No: C4 Table 8.21

Coarse grass.

Ground-surface conditions: Dry, sandy soil.

Comment on plants and pollen:

Grasses dominated the vegetation cover of this quadrat, and are well represented in the pollen assemblage (25%), together with Cyperaceae and Plantago sp. pollen representing the other plants recorded within the 5 m radius.

A further nine pollen types were recorded from the sample, of which Compositae, Tamarix sp. and Pinus sp. are again frequent.

Non-pollen microfossils:

The assemblage is similar to that of sample C3, but Botryococcus sp. and sponge scleres are absent. Mycorrhizae are considerably more frequent in this zone of dense, herbaceous vegetation. Test-linings of Foraminifera were also recorded from this sample (Table 8.16) and probably originated from the sea or one of the nearby lagoons.

Sample No: C5 Table 8.22

Coarse grass.

Ground-surface conditions: Dry, sandy soil.

Comment on plants and pollen:

Despite the dominance of grasses in this quadrat, Gramineae pollen constitute only 4% of the total pollen assemblage. Members of the Compositae and Tamarix sp. occur within a 5 m radius of the quadrat, and are represented in the pollen assemblage, but the other species recorded in the field, Pistacia lentiscus and Juncus acutus, are not.

A further ten pollen types were recorded from the sample, including the macchia element- Myrtus sp..

Non-pollen microfossils:

The assemblage has much in common with samples C3 and C4, but Concentricystes sp. is also present in this sample. The occurrence of this microfossil in spot surface-samples from predominantly dry locations, has been discussed in 8.2.5.

Sample: C6 Table 8.23

Garigue/disturbed ground.

Ground-surface conditions: Dry, thin soil with calcarenite fragments.

Comments on plants and pollen:

The quadrat was dominated by grasses and Pistacia lentiscus, but only the former are represented by pollen in the sample. Carpobrotus acinaciformis was present on the stony ground included in the quadrat, and its pollen is present in the sample. Within a 5 m radius of the quadrat, Plantago sp. and Tamarix sp. are represented by their pollen in the sample. In total, five of the eight plant types recorded in the field at this location are represented in the pollen assemblage.

A further seven pollen types were recorded from the sample, among which Compositae are strongly represented.

Non-pollen microfossils:

Mycorrhizae are present, but significantly less frequent than in samples C4 and C5 in the dense herbaceous zone. Of the fungal spores, only type 1 is present in the sample. Both the pollen and microfossil assemblages of this surface-sample resemble those of the dune surface-samples.

Sample No: 7 Table 8.24

Garigue/disturbed ground.

Ground-surface conditions: Dry, calcareous soil.

Comments on plants and pollen:

At this point, the transect passes over the foundation stones of a structure, which probably dates to the Bronze Age (3.6.2). Species of Plantago dominated the quadrat, which was positioned within the circular 'hut' area, and Plantago sp. pollen is frequent in the sample (11%). Sedges also occurred in the quadrat, and are well represented in the pollen assemblage. Of the plant types occurring within a 5 m radius of the quadrat, Compositae, Gramineae and, notably, Pistacia lentiscus, are represented in the pollen assemblage.

A further six pollen types were recorded from the sample, all in low proportions apart from Pinus (74%).

Non-pollen microfossils:

Frequencies of microfossil types in this sample are generally low, relative to other samples, as shown by Fig. 8.2. This sample contains no microfossils that are uncommon along the transect.

Sample No: 8 Table 8.25

Macchia.

Ground-surface conditions: Dry, shaded, calcareous soil.

Comments on plants and pollen:

The dominance of the quadrat by Rhamnus sp., in this macchia zone, is not reflected in the pollen assemblage; pollen of this taxon was not found in the surface-sample.

Pistacia lentiscus is a major component of this macchia zone, and its pollen is present in the sample, though infrequent. Plantago sp. Gramineae and Compositae also occur within the quadrat, and are more strongly represented by their pollen. Five other plant types occur within a 5 m radius of the quadrat, of which Asparagus acutifolius and Tamarix sp. are represented by pollen in the sample. Asparagus acutifolius may be considered a plant of macchia or woodland undergrowth, but as its pollen is only identified to family level, its occurrence in the fossil record could not be distinguished from other members of the Liliaceae.

A further six pollen types were recorded from the sample in low frequencies, apart from Pinus (77%).

Non-pollen microfossils:

As shown by Fig. 8.2, frequencies of mycorrhizae, fungal spore-types 1 and 4 and animal fragments are more frequent in this sample below macchia, than they are in the two previous samples on ground with lower vegetation.

Sample No: 9 Table 8.26

Macchia.

Ground-surface conditions: Dry, shaded, calcareous soil.

Comments on plants and pollen:

Although Pistacia lentiscus covered most of the quadrat, it is not represented in the pollen assemblage and neither is the macchia plant, Rhamnus sp.. Grasses were the

only plant type represented both within the quadrat and in the pollen assemblage.

Pinus pollen dominates the pollen assemblage (90%), reflecting the proximity of the quadrat to the pine plantation.

A further five pollen types were recorded in low frequencies from the sample, none of which indicate the presence of macchia around the quadrat.

Non-pollen microfossils:

Frequencies of mycorrhizae and fungal spore-type 1 in the surface-sample are comparable to those in sample C8, whilst animal remains and spore-type 4 are less frequent.

Sample No: 10 Table 8.27

Garigue.

Ground-surface conditions: Dry, thin soil, broken by exposed calcarenite.

Comments on plants and pollen:

The stony surface within the quadrat was sparsely covered by herbaceous plants, lichen and moss, for which no representatives were found in the pollen assemblage. In fact, none of the plants recorded within a 5 m radius of the quadrat in this garigue zone, are represented in the pollen assemblage, except Pinus (99%); the quadrat was located on the margin of the pine plantation. Only two further pollen types are present in the sample.

Non-pollen microfossils:

The assemblage includes no non-pollen microfossils which are uncommon in samples taken along the transect.

Sample No: 11 Table 8.28

Pine plantation.

Ground-surface conditions: Dry, stony soil, covered by pine needles.

Comments on plants and pollen:

Whilst lichen covered most of the quadrat at ground level, the pine canopy covered the quadrat from above. Pinus sp. pollen dominates the sample (91%). Pistacia lentiscus and Plantago sp. also occurred within the quadrat, among the undergrowth, but only

the latter is represented in the pollen assemblage. None of the garigue type plants occurring within 5 m of the quadrat are represented in the sample.

Non-pollen microfossils:

Apart from the occurrence of Concentricystes sp. in this sample, the microfossil assemblage and frequencies are comparable to those of the previous three surface-samples along the transect.

8.3.3 The representation of vegetation zones by pollen assemblages along the Cesine transect

i) Dune sands

The domination of the dune-sand vegetation by Carpobrotus acinaciformis is accurately reflected by pollen in samples C1, C2 and C3. Fig. 8.1 clearly illustrates the strong relationship between the spatial distribution of this plant and the occurrence of its pollen in the surface-samples. Of the other major elements of dune vegetation, Cruciferae are well represented in the surface-samples, Gramineae and Compositae are represented in low proportions, but Calystegia soldanella was not represented at all. Pollen of Gramineae, Cruciferae and Compositae occur in most of the transect surface-samples (Fig. 8.1), and may only be indicative of a dune environment, from a fossil pollen assemblage, if sufficient supporting evidence is provided by the sediments and associated macrofossils and microfossils.

ii) Garigue/disturbed ground

Both transect quadrats of samples C6 and C7 include small bushes of the shrub Pistacia lentiscus, but pollen of this species was only recorded in sample C7; this sample also contained pollen from Myrtus sp., which is another plant of garigue and macchia zones. In both samples, the combination of pollen from Gramineae, Compositae, Cruciferae and Plantago sp., is suggestive of disturbed ground. Thus the pollen assemblages of both samples reflect adequately the disturbed-ground nature of this section of the transect, though the assemblage of sample C6 does not differ significantly from those of the grass and rush zone. The assemblage of sample C7 does indicate the additional presence of shrubs.

iii) Macchia

Whilst the dense and almost impenetrable macchia zone, crossed by the transect, is dominated by Pistacia lentiscus and Rhamnus sp., only the former is represented, albeit

weakly, and even then only in the first of the two surface-samples from this zone. The pollen assemblages from samples C8 and C9 are otherwise indistinguishable from those of preceding surface-samples from disturbed ground and coarse grassland.

iv) Pine plantation

The immediate presence of pine trees is strongly indicated by the abundance of Pinus pollen in samples C10 and C11, together with the paucity of pollen from other plants. As illustrated in Fig. 8.1, Pinus pollen forms a large proportion within pollen assemblages from each of the samples collected along the Cesine transect, but only when this proportion reached 90% in sample C9, was pine present within 5 m of the quadrat. The distribution of Pinus pollen along the transect (Fig. 8.1), suggests an approximately linear relationship between the proportion of pine pollen in a sample and its distance up-wind from the pine plantation. This pattern is similar to the relationship noted in northern Britain by Turner (1964a), between pine pollen frequencies and distance from a source.

8.3.4 Notes on the distribution of certain plant types and pollen types in the vegetation zones traversed by the transect

Table 8.30 was compiled to summarise the data of the Cesine transect surface-samples in the same way that Table 8.17 summarises the spot surface-sample data (8.2.4). The table complements Fig. 8.1 in that it illustrates differences in the distribution of plant types, as well as pollen types, along the transect.

It is clear from Table 8.30 that Calystegia, which here represents Calystegia soldanella, is a plant strongly associated with the dune environment. Its pollen, however, was not recorded from the transect samples. Similarly, Juncus acutus is restricted mainly to the zone of coarse-grass crossed by the transect, but its pollen was not observed in the surface-sample analyses; according to Birks & Birks (1980), pollen of Juncaceae do not preserve.

Of the plants occurring in the macchia zone, Rhamnus sp. was an important element, but odd pollen grains of this taxon were recorded only from samples in the dune environment. Pistacia lentiscus was the most dominant element of macchia vegetation, but it also occurred as scattered, small shrubs in each of the other vegetation zones along the transect. Though weakly represented in several of the pollen assemblages, pollen of Pistacia lentiscus was most frequent in samples C7 and C8 in the garigue and macchia zones.

Many of the plant types and their pollen recorded from the transect and surface-sample analyses, have a wide distribution across the transect zones. These include Gramineae, Compositae, Cyperaceae and Plantago sp., which were well represented by pollen in frequencies varying across the transect. Pollen of Chenopodiaceae and Cruciferae were widely distributed, but their sources were unclear.

Alnus pollen occurred in low proportions in five of the surface-samples, but no source was noted; long-distance transport is inferred.

8.3.5 The representation of surface-sediment conditions by non-pollen microfossils along the Cesine transect

The non-pollen microfossil assemblages for most of the transect surface-samples are comprised of the remains of plants and soil-dwelling organisms (Table 8.29). These relate to the dry surface-conditions traversed by the transect. In samples C3 and C4, the additional presence of several microfossils associated with wet habitats was recorded. These indicate the probability of seasonally wet conditions in this relatively low-lying part of the transect close to the dune cordon, illustrated in Fig. 8.2

Samples C1 and C2 from the dune sands contain fewer microfossils than occur in samples from the rest of the transect, and at considerably lower frequencies. The absence of mycorrhizae from these samples relates to the lack of soil conditions and suitable herbaceous vegetation. As shown in Fig. 8.2, mycorrhizae are most frequent in the zone of dense grass and rushes.

Fungal spore-type 1 is present in all samples along the transect, and in higher frequencies than the other fungal spore types (Fig. 8.2). It is notably abundant in sample C3, where potentially wet conditions may provide more favourable conditions for spore production.

The presence of Concentricystes cf. circulus in samples C5 and C11, adds further support to the suggestion made in 8.2.5, that the organism producing this microfossil does not require fluvial or alluvial conditions for its existence, as has been implied in previous work in which this microfossil figures (see 7.8.1).

8.3.6 The N.W. Alimini Piccolo transect-results

The vegetation compositions of the two marsh-zones traversed by this transect are represented by descriptions of vegetation within quadrats at the two extremes of the transect; these descriptions are given in Tables 8.31 and 8.32. Six surface-samples

were collected along the transect in order to test whether the transition between the two marsh-zones is detectable in pollen and non-pollen microfossil assemblages. Variations in the pollen frequencies of different plant types, recorded from the surface-samples, are illustrated in Fig. 8.3 relative to the transect profile. The non-pollen microfossil assemblage of each surface-sample is presented in Table 8.33.

8.3.7 The representation of the two marsh-zones by pollen assemblages along the transect

i) Phragmites reed-bed

The pollen assemblage of sample 1, collected from within the dense reed-bed, is dominated by Cyperaceae pollen, as are the pollen assemblages from each of the other transect surface-samples (Fig. 8.3). The Cyperaceae pollen probably originates from the outer marsh-zone, where sedges were most frequent. Gramineae pollen identified as Phragmites sp. (see 7.1.7) constitutes the next most significant element of the pollen assemblage from sample 1, and reflects the predominance of Phragmites reeds at this location. The proportion of Phragmites pollen (14%) is, however, surprisingly modest, given the high density of the reeds and the magnitude of their panicles.

Other herbaceous plants, represented by low amounts of pollen in this sample, exist in the outer marsh-zone. Low amounts of arboreal pollen are also present, of which Pinus, Oleaceae and Juniperus have sources within 100 m of the transect. No local source was noted for Corylus. Sample 2 was collected at the fringe of the reed-bed, and here too Phragmites pollen constitutes the largest proportion of the pollen assemblage, after Cyperaceae. The proportion of Phragmites pollen (10%) is lower than in sample 1, reflecting the peripheral location of the sample (Fig. 8.3). Other plants growing among the reeds, including Calystegia sepium and Epilobium sp., are not represented in these surface-samples. Thus the immediate presence of Phragmites reed-beds is reflected by relatively high proportions of Phragmites pollen alone.

ii) Outer, herbaceous marsh-zone

Gramineae pollen of Phragmites type is substantially less frequent in sample 3 (3%) and in all subsequent samples along the transect. This distinction between frequencies of Phragmites pollen in the reed-zone and in the outer, herbaceous marsh-zone, closely reflects the sharp boundary between the two zones as illustrated in Fig. 8.3. These results are comparable to those reported by Hall (1990) from a modern-pollen study in Northern Ireland, where proportions of Phragmites-type Gramineae pollen in surface-samples, fell sharply at distances greater than 5 m from a lake-side Phragmites fringe.

Other pollen in samples 3 to 6 represent a greater diversity of herbaceous species in this outer marsh-zone, than was recorded from the pollen assemblages of samples 1 and 2. Among these pollen types, Compositae are most frequent.

8.3.8 The representation of the two marsh-zones by non-pollen microfossils along the transect

As shown by Table 8.33, plant remains, mycorrhizae, fungal spores and animal fragments are common to all the transect surface-samples. Other microfossils recorded from these samples are related to water availability and wet soil, and are mostly concentrated in samples 1 and 3, corresponding to waterlogged ground dominated by Phragmites. In this way, the algae, Spirogyra sp., Mougeotia sp., Zygnema sp. and Cosmarium sp., which inhabit freshwater and sometimes wet soil (7.7.6), are concentrated towards the eastern end of the transect. Head-shields of Chydoridae, recorded from sample 3, are also suggestive of a vegetated, lake-margin environment (7.6.1). Concentricystes cf. circulus is again recorded along this transect, from the moist soil conditions of samples 3 and 6.

Table 8.33 illustrates that the non-pollen microfossils occurring along the transect form two groups. The first represents soil conditions beneath herbaceous vegetation across the length of the transect, and the second group reflects the presence of freshwater, particularly in the eastern part of the transect, corresponding to the Phragmites reed-bed.

8.4 Conclusions on the palynological analyses of the surface-samples

8.4.1 Pollen analyses

By comparing the pollen assemblages of the surface-samples with the vegetation composition in their immediate vicinity, important base-line reference information has been provided for the interpretation of fossil-pollen assemblages from the sediment-cores. The accuracy to which different vegetation zones in the study-area are represented in pollen assemblages has been tested, and useful information has been gained concerning the dispersal of different pollen types and their prominence in the samples.

Pollen assemblages from samples of cultivated and disturbed ground, are shown to reliably reflect the character of local vegetation, even if lacking its degree of diversity,

as in spot surface-sample no. 2 (8.2.3i). While 'medium' sized grains of Gramineae pollen are present in most of the surface-samples, large grains which may be classed as cereal type (see 7.1.7) are confined to modern agricultural land and garigue areas, where cereals are certainly present (Table 8.17). This distribution pattern concurs with previous observations that most pollen of cereals are poorly dispersed (Behre 1981; Maguire 1983).

In fossil sediments, however, such large grains may have originated from wild grasses (see 7.1.7). Only when other indicators of 'disturbed' ground are present in the fossil pollen assemblage, may arable land use be suggested. Even then there is not necessarily a clear distinction between pollen assemblages associated with arable land and those associated with pastoral land. From empirical analyses in Britain, Turner (1964b) suggested that pollen of cereals, Cruciferae and Chenopodiaceae characterise arable areas, while pollen of *Plantago* sp., *Rumex* sp. and spores of *Pteridium* are more frequent in pastoral areas. Behre (1981) cautions that weed floras vary regionally and will have changed in relation to developments in agricultural practice.

Many of the 'anthropogenic indicator' pollen taxa, including *Plantago*, *Rumex* and Chenopodiaceae, also occur in natural communities, especially in coastal zones (Behre 1981). Furthermore, the supposed 'pastoral indicator' types could occur as field-side weeds (Edwards 1979). Interpretation of economic practice from fossil pollen assemblages is best made with supporting archaeological evidence (Edwards 1979).

Analyses of surface-samples from garigue zones demonstrated the similarity between pollen assemblages of this vegetation type and those of disturbed ground. The results emphasised the importance of pollen from shrub species in particular, in distinguishing between surface-samples from the two vegetation zones (8.2.3iii, 8.3.3iii).

These studies have shown that despite the fact that evergreen shrub species provide dense ground cover in areas of semi-natural macchia, this distinctive vegetation type is unconvincingly represented by pollen assemblages from the spot surface-samples and transect surface-samples, collected from points beneath and adjacent to macchia (8.2.3iii, 8.3.3iii). Only in sample 5, from coastal macchia, was the local dominance of *Juniperus* sp. shrubs reflected in the pollen assemblage, but curiously pollen preservation was generally poor in this sample. The macchia zone traversed by the Cesine transect and dominated by *Pistacia lentiscus*, was barely detected in pollen assemblages from the transect surface-samples; both the range and abundance of shrubs present were not represented. The highest proportion of *Pistacia lentiscus* pollen occurring in any of the samples (1.5%), was recorded at the edge of this macchia zone (Fig. 8.1). The immediate presence of *Rhamnus* did not register at all in the pollen assemblages.

As shown in Tables 8.17 and 8.30, Pistacia plants were recorded in surface-sample locations far more frequently than it was represented in respective pollen assemblages. But when Pistacia pollen was present in a pollen assemblage, the shrub was invariably present in the immediate vicinity of the sampling location. Thus, results of these analyses suggest that Pistacia lentiscus produces a low amount of pollen which is rarely dispersed far from its source. The appearance of this pollen in fossil-pollen assemblages at levels as low as 1%, may therefore be significant and indicative of the local presence of Pistacia shrubs.

These findings are in close agreement with results of surface-sample analyses from other parts of the Mediterranean and Middle East. In a study of modern pollen-rain in western Iran, Wright *et al.* (1967) noted that Pistacia is surprisingly under-represented and 'erratically' represented in pollen assemblages, given that it is a wind-pollinated plant. Similar studies in Turkey (van Zeist *et al.* 1968), Greece (Bottema 1974a) and north-eastern Iran (Stevenson 1981) also established the under-representation of Pistacia pollen; Stevenson (1981) points out that the genus is dioecious, and representation of the plant by pollen depends on the local presence of male-flowering bushes. Members of the Rhamnaceae are also notably under-represented in pollen assemblages (van Zeist *et al.* 1968).

Unless pollen of evergreen shrubs is found in fossil-pollen assemblages, then the occurrence of past macchia may be a 'blind-spot' (after use of the term by Davis 1963) in the interpretation of past vegetation patterns from sediment-core samples. However, it is probable that past macchia within the study-area contained a large component of Quercus ilex as well as Quercus coccifera (see 4.4), both of which are likely to be represented in fossil-pollen assemblages. The spot surface-samples have shown that Quercus species are well represented in pollen assemblages where oaks exist near the sampling location (Table 8.17). Low proportions of Quercus pollen also constitute part of the regional pollen-rain.

In the present study, oak woodland was well represented in the surface-samples by high levels of Quercus pollen. Hedera helix was identified as an important element of the undergrowth which, when represented in a fossil-pollen assemblage, would endorse an interpretation of the local presence of oak woodland (8.2.3iv). Hedera helix is insect-pollinated and a sparse pollen producer (Huntley & Birks 1983; Faegri & Iversen 1964); its representation in a fossil-pollen assemblage in low numbers probably indicates significant local presence of the plant.

Pollen assemblages in surface-samples from the marsh-zones tended to be dominated by pollen of plants from the marsh-basin catchment, rather than from local marsh plants (8.2.3v). Pollen from plants common to these marsh areas, particularly

Phragmites sp. or Typha sp, are usually also present in small proportions, and are sufficient to indicate the presence of locally marshy ground.

Evidence for the low production and dispersal of Phragmites pollen was provided by the surface-sample transect through the marsh fringe of Alimini Piccolo (8.3.7). Results of these surface-sample analyses suggest that Typha pollen is similarly under-represented and poorly dispersed, thus enhancing its value as an indicator for marsh in fossil-pollen assemblages. The similarly low representation of Epilobium in these analyses, reflects the observation of Rybníčková & Rybníček (1971), that Epilobium in marsh vegetation is irregularly and under-represented in pollen assemblages. Cyperaceae pollen is well represented in surface-samples of the present study, and is particularly abundant in marsh vegetation-zones, as illustrated by the Alimini Piccolo transect-analyses.

It is noticeable from Tables 8.17 and 8.30, summarising pollen and plant distribution in the sampled locations, that Alnus pollen is present in low proportions in many of the surface-samples, despite the present author having failed to locate a specimen of this tree in the study-area. Alnus pollen is produced in high quantities and can travel long distances (Huntley & Birks 1983), frequently forming a component of pollen rain. For example, Braggio Morucchio *et al.* (1988) recorded Alnus pollen in surface-samples from Zannone Island, when the nearest source was at least 22 km to the north on the Italian mainland near Gaeta.

Pinus pollen is present in all the surface-samples and usually over-represented. On a smaller scale, pollen of Oleaceae is present and over-represented in many of the spot surface-samples, reflecting the widespread presence of cultivated olive in the landscape.

Thus pollen analyses of the surface-samples have provided a basis upon which local, regional and long-distance components may be discerned in the pollen assemblage of a sample. Observed associations between plant types within vegetation-zones and the composition of respective pollen assemblages, have highlighted the significance of certain pollen types in a fossil-pollen assemblage, and also the potential to mis-interpret certain pollen types and assemblages. As demonstrated by Oldfield (1970), the pollen rain at a given location is partly a function of pollen source-strengths, distance from the pollen-source and differential loss of pollen taxa. Interpretation of a pollen assemblage must be made in the context of the sample's position within the local environment. Information on vegetation-zones within the study-area, given in chapter 3, together with evaluations of pollen assemblages in the context of vegetation-survey information in this chapter, has helped define source areas for pollen from different plant types and communities within the study-area landscape. With the aid of this modern taphonomic information, it is possible to begin to interpret the fossil pollen assemblages.

8.4.2 Non-pollen microfossils

A number of non-pollen microfossil forms have been identified as common elements in the assemblages of each of the spot and transect samples; their distribution is illustrated in Tables 8.16, 8.29 and 8.33. Each surface-sample contained plant remains, fungal spores and animal fragments. Charcoal fragments and mycorrhizae were present in most samples; the presence of mycorrhizae appears to closely reflect the immediate presence of herbaceous vegetation (8.2.5, 8.3.5).

Other microfossils were clearly associated with wet and waterlogged conditions, as illustrated by microfossil occurrence in samples along the Alimini Piccolo transect (Table 8.33) and in spot surface-samples from marshy locations (Table 8.16). It has been shown, however, that microfossils from some predominantly water-dwelling organisms, may be present in low numbers in samples from dry locations. These occurrences may be explained by transport of the microfossil from outside the catchment of the sample location, and emphasise the need to interpret the assemblage as a whole (8.2.5).

In a number of these samples, examination of the non-pollen microfossil assemblage has offered substantive evidence to complement or assist interpretations made from the pollen assemblage, concerning soil-moisture conditions, salinity and the presence of water bodies in the local environment.

8.5 Modern mud-sample results

Non-pollen microfossils within the modern-mud samples were analysed; the results are summarised in Table 8.34. Some of the microfossil types common in the surface-samples are present in some of these water-lain sediment-samples, including plant cell-walls, fungal spores and animal fragments. These could originate from autochthonous organisms, or they could have been transported to the water bodies by surface-wash. Mycorrhizae are noticeably absent from each of these samples, adding support to the observation of their strict association with herbaceous plants in the surface-samples. Fungal spore-type 1 was present in each of the samples, though never in abundance. Fungal spore-type 4 was present in each of the sampled water bodies, but types 2 and 3 were only recorded in samples from Alimini Piccolo.

Table 8.34 illustrates that recorded microfossils of freshwater organisms are mostly confined to samples from the freshwater lake, Alimini Piccolo, but several types occur in sample E from the western side of Pantano Grande. Whilst this lagoon is saline, freshwater issues at points along the western margin where marsh plants are

established. Waters of mixed salinity therefore occur on the west side of Pantano Grande. In sample E, freshwater is indicated by the presence of Chydoridae and Cosmarium sp.. The remaining algal microfossils are tolerant of some salinity. Only microfossils of salt-tolerant algae and Foraminifera were recorded from sample F, on the eastern, more saline side of the lagoon.

In sample A from Alimini Piccolo, a freshwater environment is indicated by the desmids, Euastrum sp. and Staurastrum sp., and probable freshwater sponge-sclere. The algae Cyanophyceae, Botryococcus sp. and Pediastrum boryanum are common in freshwater, but are also tolerant of brackish conditions. The dinoflagellate cyst Genus A, was also recorded from sample A, and may represent a previously unknown freshwater/brackish water species (see 7.7.2).

Samples C and D from the brackish-water lake, Alimini Grande, contain few algal microfossils of water-dwelling organisms apart from diatoms. Of those that are present, sponge-sclere in both samples suggest the presence of freshwater, whilst Foraminifera test-linings suggest the presence of saline water.

Each of the mud-samples contained diatoms, whose assemblage and relative abundances were different for each of the three water bodies, but similar for the two samples from the same water body. The greatest diversity was recorded from Alimini Piccolo, where nine of the genera listed in 7.7.1 were present, though none dominated the assemblage. Samples from Alimini Grande were dominated by frequent frustules of Paralia; Diploneis was the only other genus recorded from these samples. Five of the genera listed in 7.7.1, were recorded from the Pantano Grande samples, but here the assemblages were dominated by abundant Campylodiscus and frequent Diploneis.

The non-pollen microfossil assemblages from the modern mud-samples are clearly different from those of the surface-samples, and reflect aquatic environments. Algal microfossils are more abundant in these samples than in the surface-samples, whilst fungal and plant microfossils are less frequent. Differences in salinity-levels between the three water bodies are indicated by the relative frequencies of different algal microfossils within the samples.

These analyses, summarised in Table 8.34, provide useful reference information in conjunction with corresponding analyses from the surface-samples. The combined information is an invaluable aid in the interpretation of past environmental conditions from the non-pollen microfossil assemblages in sediment-cores from the study-area.

Chapter 9

**THE SEDIMENT CORES
STRATIGRAPHY AND RESULTS OF PALYNOLOGICAL ANALYSES****9.1 Introduction**

The analyses completed for each core are summarised in Table 9.1; details of the core locations are given in 5.2. Cores were selected for palynological analysis on the basis of their sediment stratigraphy and potential for microfossil preservation (see 5.1).

For each core, results are presented and interpreted in three principal sections:

i) Core stratigraphy

The sediments of each core are represented by symbols in a stratigraphic column. The symbols are adapted from those of Troels-Smith (1955) to represent the sediments encountered in this research; a key is given in Fig. 9.1. Descriptions of core sediments include the occurrence of macrofossils in those cores sampled for palynological analysis. Details of the macrofossil types recorded in this research and their environmental associations, are given in chapter 7(part 3).

ii) Non-pollen microfossils

Absolute frequency estimates of each microfossil type recorded from the core samples are plotted against depth in the core; data presentation methods are given in 6.5. The results are described and interpreted on the basis of assemblage-zones determined from the microfossil spectra. Interpretations are made with reference to the descriptions of microfossil forms and their environmental associations given in chapter 7(part2).

iii) Fossil pollen

Results of the pollen analyses are presented in two complementary diagrams. In the first, pollen frequencies of taxa included in the pollen sum (as defined in 6.3.1) are plotted as a percentage of the pollen sum against core depth. The second diagram illustrates estimated absolute frequencies of the most prominent taxa in the pollen samples, together with frequencies of spores and pollen from wetland plants excluded from the pollen sum. This diagram also includes pollen concentration data for each sample in the core. Absolute frequency estimates were calculated according to the method given in 6.5.1ii.

Results of the pollen analyses are described and interpreted on the basis of assemblage-zones determined from the pollen spectra in both diagrams; these zones are determined independently of those discerned within the non-pollen microfossil spectra.

All pollen and non-pollen assemblage-zones were subjectively determined from the frequency diagrams to represent sections of the core in which samples have common assemblages of taxa, occurring in comparable frequencies. In each core, these zones have significance in the interpretation of local and regional environmental change; but they do not necessarily correlate with the zonation of any other core. The assemblage-zone concept, demonstrated by Cushing (1967a) and Birks (1970) for example, is more flexible than zonation systems related to chronology or climate.

Pollen concentration data provides useful additional information towards the interpretation of pollen assemblages. When poorly preserved pollen occurs in samples with a relatively low pollen concentration, it is likely that the pollen assemblage has been altered by differential preservation of pollen taxa (Hall 1981). Pollen preservation has been shown to vary between different sedimentary environments (Sangster & Dale 1964; Cushing 1967b; Havinga 1971). Pollen concentrations may also be affected by the vertical mobility of pollen grains through sediments and by the effect of sorting where a water body is present (Davis 1968; Holmes 1990).

9.2 CORE AP88

9.2.1 Core stratigraphy and macrofossils

As described in 5.2.1, core AP88 was extracted from beneath a floating reed-mat at the south-east margin of Alimini Piccolo; lake sediments lay 0.5 m below the surface of the lake waters. Depths in core stratigraphy are recorded in metres with respect to lake-level at the time of coring, hence the sequence begins at a depth of 0.5 m. Core-sediment stratigraphy is illustrated in Fig. 9.1, and macrofossil distributions are presented in Table 9.2.

(bottom of core)

- 3.6-2.86m Grey lake-marl. Plant remains and charcoal are sparsely present. Only in sample 3.1 m were other macrofossils present: shells of Hydrobiidae and Cerastoderma type and sparse ostracod carapaces.
(indistinct boundary)
- 2.86-2.68m Grey clay grading into brown peaty-clay. Plant remains, charcoal and shell-fragments are present.
(indistinct boundary)
- 2.68-2.58m Dark-brown peat with a high clay content.
(indistinct boundary)
- 2.58-2.45m Brown peat. Plant remains and charcoal are present. Ostracod carapaces and occasional shells of Scrobiculariidae, Hydrobiidae and Cerastoderma type are also present.
(indistinct boundary)
- 2.45-2.14m Black 'Substantia humosa' (Aaby & Berglund 1986). Homogenous, organic silt containing plant remains, charcoal and occasional Hydrobiidae.
(indistinct boundary)
- 2.14-1.88m Brown peat. Plant remains, occasional charophyte oogonia, shells of Hydrobiidae and tests of Foraminifera are present.
(indistinct boundary)
- 1.88-1.72m Peaty silt, grading into grey sand.
(sharp boundary)
- 1.72-1.5m Grey sand. A high density of shells is present throughout, mostly of Cerastoderma type. Also present are plant remains, charcoal, charophyte

- oogonia, shells of Scrobiculariidae and Hydrobiidae, ostracod carapaces and Foraminifera tests.
(sharp boundary)
- 1.5-1.47m Grey sand. Plant remains are present.
(sharp boundary)
- 1.47-1.27m Brown peat. Abundant plant remains and charcoal, and occasional shells of Hydrobiidae are present.
(sharp boundary)
- 1.27-1.21m Brown silty mud. Shell-fragments are present.
(sharp boundary)
- 1.21-1.2m Dense shell layer of bivalves of Cerastoderma.
(sharp boundary)
- 1.2-1.17m Grey-brown sandy clay. Humified organic matter is present
(sharp boundary)
- 1.17-1.02m Grey-brown sandy clay. Plant remains, charcoal, charophyte oogonia, shells of Scrobiculariidae, Cerastoderma and abundant Hydrobiidae are present. Foraminifera tests are present and ostracod carapaces are abundant.
(sharp boundary)
- 1.02-0.5m Grey lake-marl. Plant remains and charcoal are present, and charophyte oogonia are particularly abundant in the lower part of this layer. Shells of Hydrobiidae and ostracod carapaces are present throughout and particularly abundant in the lower part. At 0.7 m and below, Foraminifera tests and shells of Scrobiculariidae and Cerastoderma are also present.
(top of core)

9.2.2 Discussion of stratigraphy and macrofossil content

As shown in Table 9.1, plant remains and charcoal are present in all samples from the core. Charophyte oogonia appear mainly in the upper 1.5 m of the core, whilst tests of Foraminifera are confined to the upper 1.9 m, where mollusc shells and ostracod carapaces are most abundant. This macrofossil assemblage suggests the dominant presence of a brackish-water depositional environment for sediments above 1.9 m.

The grey marl at the base of the core is most likely formed of calcium carbonate precipitated from open lake water (see 5.2.1i); the inclusion of shells of *Cerastoderma* and Hydrobiidae at 3.1 m, confirms the existence of a lacustrine depositional environment. The over-lying peaty layer was probably formed beneath marsh vegetation at the lake-margin, indicating a lowering of lake-level and a westwards shift of the lake margin. Alternatively, this organic-rich sediment could originate from allochthonous soils transported by sheet-wash from the eastern side of the lake basin, to the lake margin.

Above 1.9 m and up to 1.47 m, the increased silt and sand content of sediments together with the dense concentration of shells of *Cerastoderma* type, is indicative of a lake-shore, brackish, shallow-water environment. This layer could constitute a 'platform' sometimes created by large populations of *Cerastoderma* in the shore zone (Tebble 1966). The peaty layer above these littoral sediments suggests that vegetation became established above the shore deposits.

Above 1.27 m, the return of sandy clay sediments, containing shells of aquatic molluscs, suggests that shore conditions were resumed at the core location, implying a rise in lake-level. From 1.02 m to the top of the core, corresponding to the present lake-bottom, a second layer of precipitated calcium carbonate indicates further rise of lake-level, and the eastwards shift of the lake margin.

9.2.3 Non-pollen microfossils

The core was sampled to a depth of 3.5 m for palynological analysis, but samples below 2.7 m in the lower lake-marl contained extremely sparse organic remains, comprised only of fragmentary cellular plant material. The lacustrine origin of this deposit was interpreted from the presence of incorporated mollusc shells and ostracod carapaces (9.2.2). It is possible that heightened oxic conditions in the calcareous sediment have allowed organic microfossils to decay during its post-depositional history.

Most microfossil types described in chapter 7(part2) are present in this core from 2.7 m upwards. Plant cell-walls and fungal hyphae were recorded in all samples. The abundance and distribution of other microfossils within the core often appear to be clearly associated with sediment stratigraphy, as illustrated in the diagram of microfossil distribution with core depth (Fig. 9.2). Four microfossil assemblage-zones are distinguished in this diagram.

Assemblage-zone 1:

This zone corresponds to the lower layer of lake-marl. Microfossils were only present in significant numbers in the top-most sample, at 2.7 m, where the marl is mixed with peaty sediments from the layer above. The assemblage of this sample is mostly comprised of charcoal, fungal remains and animal fragments, all in low quantities.

Spirogyra is the only alga represented. This alga can be soil-dwelling, and since other algae are absent, it probably represents input of soil material at the core location.

Lake-dwelling algae, deposited with the lake-marl, have probably not preserved.

Assemblage-zone 2:

All microfossil types present in zone 1 are many times more frequent throughout zone 2. Abundances of charcoal, mycorrhizae, fungal spore-types 1,2 and 4, and Spirogyra reach their highest levels in this zone of the core.

This assemblage-zone corresponds with the layer of black 'Substantia humosa' and the peaty silt layers above and below it. With reference to the Cesine transect surface-samples (8.2.5), high frequencies of mycorrhizae suggest herbaceous vegetation was present locally, and high frequencies of charcoal fragments imply burning of a local vegetation source. High frequencies of fungal spores are consistent with the organic-rich, moist sediment conditions of this zone. The presence of Concentricystes suggests that soil conditions existed at the core location, or that soil material was redeposited there (8.2.5).

Predominantly wet conditions are suggested by the presence of the freshwater algae Spirogyra, Mougeotia, Zygnema and desmids (see 7.7). The additional presence of Cyanophyceae and Botryococcus in the lower-most part of this zone, also suggest that a water body was present, perhaps ephemerally. The absence of pyrite framboids from sample residues at 2.3m and 2.5 m, however, suggests that these sediments were not associated with the brackish-water conditions which evidently influenced other sediments of the core, especially above 1.9 m (9.2.2); pyrite was recorded in all other samples from the core, except at 1.3 m.

The interpretation of this assemblage-zone complements that of the sediment-stratigraphy and macrofossils in this part of the core (9.2.2). The sediments and their fossil assemblage represent either a marsh environment at the lake margin, developed following a lowering of lake-level after deposition of the underlying marl, or they represent soil materials eroded from the eastern side of the lake basin and redeposited at the lake margin. The infrequency of aquatic algae gives support to the first interpretation.

Assemblage-zone 3:

The transition from zone 2 to zone 3 is marked by large decreases in the frequencies of charcoal, mycorrhizae and all the fungal spores, apart from type 3 which is present in comparable frequencies in both zones. This zone is also distinguished by the appearance of sponge spicules, diatom frustules and dinoflagellate cysts of genus A, all representing water-dwelling organisms. The planktonic algae, Botryococcus and Pediastrum, are consistently present and more frequent in this zone, whilst Spirogyra is less frequent. Both desmid genera, Euastrum and Cosmarium, reach peak values in the core in sample 1.5 m, and suggest the presence of freshwater (7.7.7).

This assemblage-zone incorporates the distinctive sand layer between 1.72 m and 1.5 m, dense with shells of Cerastoderma and other brackish water molluscs, ostracod carapaces and Foraminifera tests. The combined evidence from the sediments, macrofossils and the range of microfossils representing water-dwelling organisms in samples 1.7 m and 1.5 m, indicate a shallow-water, near-shore environment at the core location; both fresh and brackish water conditions are indicated. These conditions imply a rise in lake-level, submerging the sediments representing marshy conditions (zone 2), and necessarily causing an eastwards shift of the eastern lake-margin.

In peaty sediments overlying the dense shell and sand layer, the range and abundance of microfossils from water-dwelling organisms is greatly reduced. Fungal remains continue to be present in relatively low frequencies. This evidence suggests that a further period of marshy conditions existed at the core location, arising from the re-establishment of vegetation and probable lowering of the lake-level, and supports the interpretation made from macrofossil results in 9.2.2. The presence of Botryococcus and Pediastrum, together with sparse shells of Hydrobiidae, suggests however that these sediments were still influenced by lake waters.

At the top of zone 3, the sample at 1.1 m within sandy clay, contains a broader range of microfossils of aquatic organisms than are present in the peat below; Botryococcus and diatoms, dominated by Campylodiscus sp., are notably more frequent. This microfossil assemblage suggests that a fresh to brackish water-body existed at the core location.

Assemblage-zone 3 thus represents a period of marginal lake and marsh conditions at the core location, during which fluctuations in lake-level alternated the sedimentary environment between shallow water and shore conditions, and marsh conditions.

Assemblage-zone 4:

The lower boundary of this zone coincides with the sharp boundary between the sandy clay of zone 3 and the upper layer of lake-marl. Microfossil frequencies of

Botryococcus and Pediastrum are greatly increased in this zone, especially in sample 0.9 m. Cysts of Spiniferites, representing a brackish water to marine dinoflagellate genus (7.2.2), are consistently present in this zone together with diatoms.

This assemblage indicates the presence of an open, fresh to brackish water body above the core location, which prevails to the present day, and tends to confirm the proposed precipitated origin of the marly sediment. The reduced frequencies of mycorrhizae and fungal spore-types 2 and 3 in this zone, suggests that there is limited input of sediment from marsh or terrestrial deposits to the lake-marl. The specimens of Concentricystes in this zone may have originated from these terrestrial deposits. The reduced frequency of charcoal fragments perhaps further reflects the substantial eastwards shift of the lake edge, and the truly lacustrine sedimentary environment at the core location.

Microfossils of Type A (see 7.8.2) were observed only in this zone of the core, suggesting that they originate from aquatic organisms tolerant of low salinity.

9.2.4 Evidence for local environmental conditions from spores and pollen of aquatic plants.

Absolute frequency estimates of spores and pollen from plants of wet ground and aquatic plants are presented in Fig. 9.4. Their analysis further consolidates the interpretations based upon the sediments and their macrofossil and microfossil assemblages.

Spores of Filicopsida (ferns) are abundant below 2.0 m in the core, corresponding to assemblage-zone 2 in Fig. 9.2. In the surface-sample analyses (chapter 8), fern spores were only encountered in samples from garigue (sample 3) and from the marshy location of core 1AG (see Table 8.17). In both cases the spores were infrequent, even though ferns grew in the vicinity of core 1AG. The abundance of fern spores shown in Fig. 9.4, therefore suggest that ferns were a dominant element of the vegetation at the core location during the accumulation of the lower peaty sediments. This concurs the interpretation of assemblage-zone 2, that these sediments accumulated in a marsh environment. In some fossil sediments where preservation conditions are poor, however, high incidences of fern spores may be attributed to their high resistance to corrosion and oxidation (Dimbleby 1985).

Further evidence for a marsh environment is provided by the presence of spores of Osmunda regalis (Royal Fern) and pollen of Epilobium sp. (Willowherb) in sample 2.5 m, and the presence of pollen of Cyperaceae (sedges) and Typha sp. (Bulrush). In the surface-sample vegetation surveys and analyses, plants and pollen of Cyperaceae were frequent in marshy areas (see 8.3.7). Epilobium was observed only in marshy

locations, but was never represented in pollen assemblages (see Table 8.17). Similarly, Typha plants were confined to marshy areas and were occasionally represented by low numbers of pollen (Table 8.17). Low frequencies of Typha pollen in samples 2.3 m and 2.5 m suggest that Bulrushes were present locally, perhaps at the marsh fringe.

In sample 1.9 m, at the transition between assemblage-zones 2 and 3, pollen of Cyperaceae and Typha are abundant, whilst fern spores are just present. Typha pollen is present in considerable numbers throughout zone 3, but is absent from most of zone 4. In samples 1.7 m, 1.5 m and 1.1 m, some Typha grains appeared in clusters, suggesting that Bulrushes grew in the immediate vicinity of the core location. This evidence suggests that wetter conditions prevailed at the core location throughout the period represented by assemblage-zone 3, in agreement with deductions made from the microfossils. Further evidence for a rise in lake-level above the ground level of the marsh-soils, is provided by the presence at 1.7 m of pollen of Ruppia, a brackish-water plant, and pollen of Myriophyllum (Watermilfoil) at 1.3 m.

From 0.9 m to the top of the core, abundant Ruppia pollen coincides with assemblage-zone 4, suggesting the presence of a brackish water body at the core location. Ruppia is a submerged plant of shallow brackish water, rarely occurring in freshwater (Clapham *et al.* 1962).

9.2.5 Fossil Pollen

i) Pollen concentration and preservation

In most samples from core AP88, pollen concentration was estimated at between 2000 and 4000 grains per ml of sediment (Fig. 9.4). The pollen concentration in the sample at 1.5 m, immediately above the dense shell layer, is more than double the concentration in any other sample from the core. This might indicate that the overlying peaty sediments accumulated slowly following the deposition of the shore deposits.

Sands at the bottom of the dense shell layer, at 1.7 m, have a particularly low pollen concentration of c. 500 grains per ml, although preservation of observed pollen grains was generally good. This low concentration may be explained by the removal of fine particles and incorporated pollen from the sediments by rising lake waters within the relatively high energy zone of a lake-shore environment. Holmes (1990) suggests that pollen concentrations are further reduced in sands by abrasion, throughflow of grains and increased biodegradation owing to the relatively easy circulation of oxygenated waters.

At 2.7 m, pollen concentration was less than 100 grains per ml, and the preservation of grains was poor. Most grains in this sample were of Compositae (Liguliflorae type), which are considered to be among the most resistant to decay (Dimbleby 1985; Dimbleby & Evans 1974; Havinga 1967) yet many grains appeared corroded and thinned. Preservation conditions were clearly poor in this peaty clay, and were worse in the underlying lake-marl, from which no pollen was recorded.

Of possible relevance to the pollen record of this core, is the influence of lake waters during the lacustrine deposition phases. Sediment and pollen 'focussing' (Davis 1968), and the differential deposition of pollen grains relative to lake depth (Davis *et al.* 1971) may affect pollen assemblages in lacustrine sediments. Pollen deposited at the core location may have been transported by water, as well as by wind, from other parts of the lake catchment.

ii) Pollen assemblage-zones

Three pollen assemblage-zones were discerned from the diagrams of percentage pollen frequency (Fig. 9.3) and estimated absolute pollen frequency (Fig. 9.4).

Assemblage-zone A:

This zone is dominated by herbaceous pollen taxa, and coincides with non-pollen assemblage-zone 2, from which marsh conditions are interpreted (9.2.3). Its upper limit lies between samples at 1.9 m and 2.1 m, within a peat layer, and is apparently independent of a stratigraphic boundary. The lower limit of zone A is imposed by poor pollen preservation in sediments below 2.5 m.

Arboreal component: Quercus is the most frequent arboreal pollen taxon in assemblage-zone A. Both evergreen and deciduous Quercus are represented, constituting in total between 6% and 13% of the pollen sum (Fig. 9.3). These results suggest that both deciduous and evergreen oaks were present in the region and possibly in the lake-basin catchment, away from the marsh zone. Quercus pollen formed 3% or less of the pollen sum in most surface-samples taken from locations distant from oak woodlands or macchia in the study-area (8.2.2).

Tilia pollen is present only in zone A of the core, where it comprises less than 1% of the pollen sum in all three samples. Despite the low frequencies, its presence probably indicates that scattered Tilia grew locally; pollen dispersal is known to be poor from this genus, and it is under-represented in many pollen analyses (Andersen 1973).

Also present in proportions of less than 1% are pollen of Ostrya/Carpinus orientalis and Castanea in the upper and lower samples, and Ulmus, Corylus, Oleaceae and Alnus in the upper sample. Ostrya and Carpinus orientalis occur in modern mixed, deciduous oak woodlands and scrub of south-east Europe (Polunin & Walters 1985). According to Bottema (1974a), pollen production from these trees is high; Huntley and Birks (1983) suggest that substantial local presence is indicated by pollen proportions greater than 5%. In zone A, therefore, pollen of Ostrya/Carpinus orientalis type is interpreted as part of the regional pollen rain, which probably originated from more elevated areas of Salento.

Castanea, Ulmus, Corylus and certain Oleaceae are each potential components of mixed deciduous woodland, and may have existed amongst oaks on the drier slopes around Alimini Piccolo and in other parts of the study-area. Their low pollen frequencies in zone A suggest that sources were distant from the core location. The long-distance transport of Alnus pollen is well known (see 8.4.1).

Relatively low amounts of Pinus pollen (up to 4.2%) in this assemblage-zone suggest that pines were not growing in the lake-basin catchment, but probably occurred within the study-area. Pollen of Salix is frequent in this assemblage-zone, forming 10.8% of the pollen sum in sample 2.5 m. Local marshy conditions would have suited the growth of Salix beside Alimini Piccolo.

Shrub component: Shrub pollen was sparse in assemblage-zone A. Pollen of Rosaceae and Ericaceae are present in the upper and lower samples, and are likely to represent genera associated with wooded or scrub areas in drier parts of the lake-basin. Similarly the small presence of Rhamnus pollen (less than 1%) in sample 2.3 m is likely to originate from dry, wooded or scrub areas.

Pollen of Vitis occurs only in sample 2.1 m of this core, and at less than 1%. In the surface-sample analyses, Vitis pollen occurred in only two samples (Table 8.17) and at less than 1% in each, despite the fact that vines are cultivated in limited areas within the study-area. According to Faegri & Iversen (1964), Vitis is a sparse pollen producer. In analyses of fossil pollen from Giannitsa, Greece, Bottema (1974a) associates the presence of Vitis pollen with that of Salix and Alnus, as part of local marsh flora in the early Holocene. A similar association is possibly represented in assemblage-zone A of this core.

Herbaceous component: Compositae pollen of both the Liguliflorae and Tubuliflorae groups dominate the pollen assemblage of zone A, comprising from 44% of the pollen sum at 2.5 m, to 61% in sample 2.3 m. Bottema (1975) suggests that high frequencies of Liguliflorae pollen in lake sediments are often a residual product of differential pollen preservation. As noted in 9.2.4, fern spores are also frequent in this zone. Fern spores and Ligulifloraceous pollen are highly resistant to oxidation, and are commonly concentrated in soils and sediments where oxic conditions have affected the pollen assemblage (Dimbleby 1985; Hunt 1987). The abundance of Compositae pollen in zone A, however, may simply reflect pollen productivity rather than differential preservation. Many species of Compositae occur within the vegetation zones of the study-area landscape, and they were often over-represented in pollen assemblages of the surface-samples from abandoned cultivated land, garigue and some marsh locations (8.2.4).

Analyses of macrofossils, microfossils, spores and pollen of wetland plants in the core samples, have indicated that marshy conditions existed at the core location during the period corresponding to assemblage-zone A. In this case therefore, it is concluded that the abundant Compositae pollen originated from locally growing marsh Compositae.

Gramineae pollen are next most frequent in the lower two samples of zone A, reaching 13.5% in sample 2.3 m. The presence of Phragmites pollen in sample 2.5 m provides further evidence for the local presence of marsh vegetation (see 8.3.7).

Pollen of Chenopodiaceae are present throughout this zone, and are frequent in sample 2.1 m (19.7%), suggesting that members of this family grew locally. A similarly high frequency of Chenopodiaceae pollen occurs in the sample above, at 1.9 m within assemblage-zone B. Their abundance may reflect the influence of

encroaching brackish lake-waters on the marsh vegetation. The presence of pollen of other herbaceous plants in zone A is sporadic and at frequencies less than 5%.

Assemblage-zone B:

This zone is defined primarily by high frequencies of Quercus pollen within the core. It largely coincides with non-pollen microfossil zone 3, representing a marsh-fringe and lake-shore environment at the core location (9.2.3). The zone is divided into subzones B1 and B2, as significantly different frequencies were recorded for certain pollen types in the lower-most sample at 1.9 m.

Pollen concentrations vary greatly in zone B (Fig. 9.4), but this does not account for observed differences in certain pollen frequencies between subzones B1 and B2. For example, absolute frequency estimates for pollen of Oleaceae, Cruciferae and Gramineae are consistent in samples 1.9 m and 1.7 m, whilst overall pollen concentration in sample 1.9 m is in the order of eight times that of sample 1.7 m (Fig. 9.4). The subzones are clearly distinguished in Fig. 9.3 by changes in percentage pollen frequencies for these families.

Arboreal component: High frequencies of Quercus pollen suggest that oaks were present within the lake-basin catchment during the period represented by this zone. A marked increase in estimated absolute frequency and percentage frequency of Quercus pollen occurs from sample 2.1 m in zone A to sample 1.9 m in zone B1. In the sample at 1.9 m, Quercus pollen forms 37.5% of the pollen sum, the highest percentage frequency of Quercus in the core, of which 19.4% represents deciduous species and 12.3% represents evergreen species (ratio 1.5:1). In the surface-sample from the existing mixed-oak woodland, Bosco S. Elia, Quercus pollen comprised 41.5% of the pollen sum (8.2.2); the ratio of deciduous to evergreen Quercus pollen was 1:3.6. The total Quercus pollen frequency in sample 1.9 m (subzone B1) compares well with that from existing woodland, suggesting that oaks grew close to the core location, and that deciduous species were dominant.

In subzone B2, however, pollen from evergreen species is more frequent than that from deciduous species (Fig. 9.3). This shift in emphasis from deciduous to evergreen oaks could result from the possible degradation of woodland vegetation and increasing prominence of macchia.

Pollen of Corylus is more frequent in zone B than in zone A, particularly in the lower half of zone B where it forms up to 3% of the pollen sum. According to Huntley & Birks (1983) Corylus comprises between 2% and 25% of the land-pollen sum when it occurs in the understorey of mixed forests. Pollen of Ostrya/Carpinus orientalis type

increases in frequency to between 3% and 4% in the upper half of zone B. These trees are associated with mixed woodland and scrub (Polunin & Walters 1985).

Oleaceae are represented by increased percentage frequencies in subzone B2; frequencies are sufficiently high to suggest the local presence of Oleaceae. Members of this family, including *Fraxinus*, *Phillyrea* and *Olea*, are naturally associated with woodland and scrub or macchia vegetation. Different genera were not distinguished during palynological analyses of this core.

Pollen of *Pinus* and *Alnus* are again present in low amounts, and are attributed to input from regional pollen rain at the core location. *Salix* pollen is virtually absent from zone B, suggesting that this genus did not re-establish in the local environment following inundation of the previously existing marsh soils around the core location. Pollen of *Tilia* and *Ulmus* are absent from zone B, implying a change in woodland composition at least in the southern part of the lake-basin catchment.

Shrub component: Pollen representing shrub genera are conspicuously more frequent and consistently present in zone B than they are in zone A (Figs. 9.3 and 9.4).

Rhamnus and *Pistacia* pollen are present in the lower part of zone B. Both are known to be under-represented in pollen assemblages (van Zeist *et al.* 1968; Wright *et al.* 1967; Bottema 1974a) as shown by surface-samples from the study-area (8.4.1). The existence of their pollen provides a reliable indication that *Rhamnus* and *Pistacia* probably grew locally, close to the lake-shore during the period represented by samples 1.9 m and 1.7 m. Both shrubs grow in the understorey of oak woodlands and are also characteristic of macchia in this region (see chapter 8).

Pollen of *Hedera helix*, another under-represented taxon in pollen assemblages (8.4.1), appears in subzone B2. Although comprising less than 1% of the pollen sum, its presence strongly suggests that ivy grew locally. In the analyses of surface-samples from the study-area, *Hedera* pollen was recorded only in the sample from the mixed oak woodland of Bosco S. Elia (8.2.2). On the basis of this evidence, the occurrence of *Hedera* pollen may indicate the local presence of woodland, although this climber can also be associated with Mediterranean bush communities (Polunin & Walters 1985).

Rosaceae pollen is consistently present throughout zone B at frequencies of up to 3.5%, and may represent both shrub and herbaceous species.

Ericaceae pollen becomes more frequent in subzone B2. This poorly dispersed pollen type (Huntley & Birks 1983) is most likely to originate from shrubs in nearby woodland, scrub or macchia.

Herbaceous component: In subzone B1 the most frequent herbaceous pollen is of *Chenopodiaceae*, possibly reflecting the increased influence of saline lake-water at the core location. In subzone B2 *Chenopodiaceae* pollen is infrequent.

Compositae pollen frequencies do not exceed 4% in zone B, implying that marsh vegetation ceases to dominate the pollen rain at the core location. As noted in 9.2.4, fern spores show a similar abrupt decline between zone A and zone B.

Both *Cruciferae* and *Gramineae* pollen are present at low frequencies in subzone B1 (0.5% and 4.7% respectively), and both abruptly rise to frequencies of 26.4% and 22.6% respectively at the bottom of subzone B2 (Fig. 9.3); similarly high frequencies are maintained throughout subzone B2. Many species of *Cruciferae* favour exposed, dry habitats and some are associated with cultivated land (see 8.4.1). The high frequencies of *Cruciferae* pollen together with that of *Gramineae* in subzone B2, suggest that some open and non-marshy ground existed close to the core location.

Large grains of *Gramineae* pollen, which may originate from cereals (see 7.1.7), first appear in the core in subzone B2, coinciding with the apparent presence of open ground. Pollen of *Rumex* and *Artemisia* also first appear in zone B and are consistently present throughout the zone. These plants favour open vegetation and disturbed ground, but their pollen frequencies never exceed 2% in this zone, suggesting that they either occurred sparsely in the local vegetation or they originated from more distant locations. Similarly the presence of pollen of *Plantago* and *Melampyrum*, and spores of *Pteridium* cf. *aquilinum*, albeit in low frequencies, also suggest some areas of open vegetation existed within the lake-basin catchment.

Assemblage-zone C:

This zone is primarily defined by decreasing frequencies of *Quercus* pollen.

Arboreal component: Both percentage frequencies and estimates of absolute frequency of *Quercus* pollen gradually decline from the bottom to the top of zone C. Percentage frequency of *Quercus* pollen more than halves between the top of zone B and the bottom of zone C, and continues to decline from 6.9% at 1.1 m to 0.8% at 0.6 m. These figures suggest that oaks became scarce in the lake-basin catchment.

In Figs. 9.3 and 9.4, frequencies of *Corylus* and *Ostrya/Carpinus orientalis* pollen are shown to be at their highest in the core at the base of zone C, respectively comprising 6.5% and 7.4% of the pollen sum; frequencies decrease towards the top of the core. This suggests that in the earlier history of zone C, both types of tree probably existed within the lake-basin catchment. In the surface-sample analyses (8.2.2), *Corylus* pollen was recorded in just two samples and at less than 1% of the pollen sum; both were

from the western side of Alimini Piccolo. Pollen of Ostrya/Carpinus orientalis type was only observed in sample 1AP on the eastern side of Alimini Piccolo, at a frequency of 1%. Thus the frequencies recorded in assemblage-zone C decline to levels comparable with the modern pollen rain of these genera in the vicinity of the lake, suggesting that these trees became sparse in the study-area landscape.

Pollen of Betula, Fagus and Ulmus appear in frequencies of up to 1.2% and are interpreted as part of the regional pollen rain, and not significant components of vegetation within the study-area. Alnus pollen is more frequent in this zone, reaching 2.8% in sample 1.1 m. It is possible that isolated Alnus grew in locally wet areas.

Oleaceae pollen continues to be present in low frequencies in zone C until the uppermost sample at 0.6 m, where frequencies dramatically rise to 35%. In the analyses of surface-samples within the study-area (8.2.2), Oleaceae frequencies exceeded 10% in cases where olive trees, usually in plantations, existed within 500 m of the sample location. This high frequency at 0.6 m therefore suggests that cultivated olives existed within the south-eastern lake-basin catchment, during the period represented by the upper 0.5 m of core AP88. The isolated occurrence of Juglans regia pollen in this zone also suggests horticultural activity in the local landscape.

The relatively low frequencies of Pinus pollen throughout zone C suggest that pine trees which exist today beside trackways close to the core location, had not yet been planted within at least the south-eastern part of the basin. Large-scale planting of pines began in the study-area in the 1940's (Pagliara 1987), and modern Pinus pollen is present in high frequencies in surface-sample 1AP from the eastern side of Alimini Piccolo (8.2.2).

Shrub component: Pollen of Ericaceae and Rosaceae continue to be present throughout zone C in frequencies comparable to those in zone B, suggesting that scrub or macchia type vegetation existed nearby. The isolated presence of Rhamnus and Hedera helix pollen may also be associated with scrub or macchia.

Herbaceous component: Pollen of Chenopodiaceae is frequent at the bottom of zone C, and continues to be present in lower but significant frequencies throughout this zone. As suggested in explanation of high frequencies in zone B1, some members of the Chenopodiaceae may have become established at the lake-margin, in contact with brackish lake-waters.

Most notable among the herbaceous pollen spectra of this zone are the marked increases in frequency of Cruciferae, Rumex and Centaurea pollen in the upper three samples. Frequencies of Rumex rise from 2.9% at 0.9 m to 6.4% at 0.6 m, suggesting that disturbed ground existed close to the lake margin. High frequencies of Rumex in

pollen assemblages may be an indicator of human economic activity in the landscape (see 8.4.1), but opinions differ as to whether pollen of this taxon are more related to pastoral rather than arable landuse (Behre 1981; Maguire 1983). Pollen of Cruciferae have been associated with arable landuse (Turner 1964b; Behre 1981) as have species of Centaurea (Behre 1981). High frequencies of these taxa in zone C, combined with the presence of cereal-type Gramineae, do suggest that arable land existed in the lake-basin catchment.

9.2.6 Radiocarbon dates

Radiocarbon dates were determined for two sediment samples within core AP88. The samples were selected at 1.9 m and 1.2 m in order to define the time period represented by pollen assemblage zone B, in which maximum frequencies of Quercus pollen occur. Results of the radiocarbon assay, from the Groningen radiocarbon laboratory, are as follows:

GrN-17352	1.2 m	1765 ± 50 BP
GrN-17353	1.9 m	3675 ± 55 BP

Care was taken to avoid calcareous sediments and other sources of potentially older carbon, including mollusc shells. Some degree of hardwater error may, however, be inevitable in dating sediments from Alimini Piccolo and elsewhere in this region dominated by calcarenites. Older carbon in groundwater and surface waters, with a reduced carbon-14 content, may be incorporated by younger sediments (see Bowen 1978) and by organisms during photosynthesis (Lehman 1975). Consequently, the apparent radiocarbon age of a sediment may be older than its true age.

If independent sources of dating are available, for example from incorporated archaeological materials or a tephra layer of known age, it may be possible to correct radiocarbon dates. The error may vary widely throughout the core, however, due to changes in the carbon balance of waters influencing the sediments (Brugam 1978).

In core AP88, proximate means of dating the sediments were not available. The apparent ages of the two samples, according to their carbon-14 content, are therefore assumed to be maximum ages.

9.2.7 A chronology for environmental change, interpreted from Core AP88

The apparent difference in age between sediments at 1.9 m and 1.2 m, is 1910 years. Sedimentation rates over this period therefore averaged 0.1 m per 273 years. Rates will have varied according to sediment type, and diverse sediment types occur above and below these dated levels. Having said this, if the average sedimentation rate is extrapolated downwards in the core, below 1.9 m, then the top of the lower lake-marl has an apparent age of c. 5859 BP, placing it in the middle to late Neolithic period. This is probably a maximum age for the lower-most sediments in core AP88 in which pollen and other microfossils are preserved.

The carbon-14 age at 1.9 m, of 3675 ± 55 BP, apparently places these sediments in the early Bronze Age. On the basis of this date, the non-pollen assemblage-zones 1 and 2 (Fig. 9.2) and pollen assemblage-zone A (Figs. 9.3 & 9.4) may be attributed to the middle to late Neolithic period. According to this scheme, the transition from non-pollen assemblage-zone 2 to 3 and the corresponding transition from pollen assemblage-zone A to B, coincides with the transition from the late Neolithic to the early Bronze Age. These transitions are marked by distinct changes in the local environment, directly associated with changes in the water-table level, as indicated by analyses of sediments, macrofossils, microfossils and pollen in 9.2.1-5.

Macrofossil and microfossil evidence suggests that brackish waters were present at or near the core location throughout the period represented by the core. For saline water to enter Alimini Piccolo via the Strittu channel, it is probable that sea-level and the level of Alimini Grande, would have to be no more than 2 m below its present level; the average depth of the Strittu channel is 1.5 m below sea-level (De Giorgi 1895). According to models of Holocene sea-level rise (see 12.5.1), sea-level and the level of Alimini Grande probably exceeded 2 m below present levels around 3000 years ago. This suggests that the radiocarbon dates for core AP88 are 'too old'. It is possible, however, that saline water could enter Alimini Piccolo through fissures and karst channels below the level of the channel (see 3.3), when sea-level was more than 2 m below its present level. A residual salinity may also have remained in Alimini Piccolo since the ingress of marine waters into the Alimini lakes during the last interglacial, associated with the 'Tyrrhenian' transgression. Hence the radiocarbon dates are not necessarily in error by millennia.

A synthesis of environmental change in the vicinity of core AP88 is put forward here, within the framework of apparent ages represented by the core sediments.

i) In the middle Neolithic period, fresh to brackish lake-waters extended over the core location. Calcareous sediments were deposited under lacustrine conditions similar to those of today.

ii) During the middle to late Neolithic period lake-level was lowered relative to ground level at the lake-margin, caused either by a reduction in lake volume (implying a decline in climatic humidity) or by the accumulation of silt at the lake margin. Marsh vegetation became established at and around the core location, beneath which organic and peaty sediments accumulated. The lake edge existed some distance west of the core location, fringed by emergent vegetation including rushes and probably Phragmites. Wet soil conditions are indicated in the vicinity of the core, supporting a marsh flora including ferns and Compositae. Salix and possibly Vitis grew in this moist environment.

Frequencies of pollen representing mixed woodland species are sufficiently high in assemblage-zone A, to suggest that woodland areas existed within the lake-basin catchment, probably on the drier basin slopes. Deciduous and evergreen Quercus were the dominant tree species. Tilia was notably present in the vicinity of the core location.

Sediments of this zone have a fine, silty texture and contain negligible coarse minerals, suggesting that fine materials in the catchment were transported to the lake margin by surface runoff. High concentrations of charcoal were recorded from assemblage-zone 2, suggesting there was some human activity in the landscape involving the use of fire.

iii) According to the apparent carbon-14 dates, pollen assemblage-zone B1 and the lower part of B2 may represent the Bronze Age. Locally wetter conditions and the encroachment of lake water over the core location, are indicated by the presence of microfossils from aquatic organisms and pollen of lake-margin plants including Typha; rising lake level may suggest that climatic humidity had increased.

During the Bronze Age, mixed woodland became more prominent, at least in the south-eastern lake-basin catchment. Its composition included Quercus, Corylus, Ostrya/Carpinus orientalis and Oleaceae. Frequencies of Quercus pollen in subzone B1 suggest that both deciduous and evergreen species occurred within the basin, close to the core location. Evidence for Tilia is absent from this period and all subsequent periods represented by the core sediments. The presence of Hedera, Rhamnus and Pistacia is probably associated with woodland undergrowth, further suggesting the close proximity of this vegetation to the core location.

At the bottom of subzone B2, perhaps relating to the late Bronze Age, the occurrence of Quercus is substantially reduced, whilst relative proportions of herbaceous

vegetation dominated by Cruciferae and Gramineae are correspondingly increased. The appearance of Rumex, Plantago and Artemisia pollen suggest that parts of the basin or more distant parts of the study-area were reduced to grassland and perhaps cultivated.

At this time lake shore conditions existed at the core location, represented by coarse sediments in which pollen concentrations are markedly low. It is possible that sediments were eroded from the core location by waves at the lake margin during this phase, creating a hiatus in the sedimentary sequence of the core.

iv) Supposing a uniform sedimentation rate between the two dated levels, the central part of zone B2 would coincide with the establishment of the indigenous Messapian population of Salento, from the 8th century B.C. to the Roman era (4.5). Lake-level appears to have fallen once more during this period, as indicated by the accumulation of organic sediments above the shore deposit. During this time the core location coincided with marshy conditions at the lake-margin. It was suggested in 9.2.5 that increased proportions of pollen from evergreen oak species reflect an increased prominence of macchia in the lake basin. Increased presence of Ericaceae pollen, representing dwarf shrubs, support this interpretation. Sustained high frequencies of Cruciferae and Gramineae pollen, together with the continuing presence of Plantago, suggest that relatively dry, open ground existed in the south-eastern part of the lake basin. The presence of cereal-type Gramineae further suggest that areas of the basin were cultivated.

v) Sediments at 1.2 m, dated to 1765 ± 50 BP, apparently coincide with Imperial Roman times. Beneath this level, no significant change in the local or regional vegetation is evident from the Messapian period to early Roman times. At the core location a rising water-table and the return of lake waters of mixed salinity are indicated by the presence of microfossils from a range of aquatic organisms, including diatoms, dinoflagellate cysts, Botryococcus and Pediastrum.

Above this level, possibly in late Roman times, Quercus forms a conspicuously lower proportion of the pollen rain, perhaps reflecting further reductions in woodland and macchia remnants. Corylus and Ostrya/Carpinus orientalis were still present in the lake-basin catchment.

vi) The post-Roman period is represented by the upper 0.5 m of the core, coinciding with non-pollen microfossil zone 4; this zone represents the presence of a brackish water body over the core location, as exists today. During this time the lake shore existed to the east of the core location, where it remains.

Pollen frequencies of woodland taxa continue to decline in zone C, representing the post-Roman period, but dwarf shrub communities are consistently represented. Pollen of herbaceous species favouring disturbed ground are considerably more frequent in the upper 0.5 m of the core. As argued in 9.2.5, this suggests that arable farming became more prominent in the lake-basin catchment. Olive cultivation is indicated at the top of the core. It seems likely that the lake basin soils away from the marshy lake-margin, but close to a water source, provided good opportunities for arable cultivation, as they do today. Conditions of such quality would be scarce elsewhere in the study-area. Exploitation of these soils has, however, been severely impeded by malarial infestation of the marshy lake-margin, probably since Roman times and certainly until the early 20th century (2.9).

9.3 CORE 1AP

This core was extracted from marsh on the north-eastern margin of Alimini Piccolo (5.2.1iii). Depths in core stratigraphy are recorded in metres with respect to the present ground surface at the core location (0.39 m above lake-level at the time of core extraction). Core-sediment stratigraphy is illustrated in Fig. 9.5, and macrofossil distributions are presented in Table 9.3.

9.3.1 Core stratigraphy and macrofossils

(bottom of core)

6.67-5.38m Dense yellow-grey clay, contains some quartz sand.
(indistinct boundary)

5.38-4.02m Grey clay/lake-marl, includes some quartz sand. Shell fragments are present, including Cerastoderma and Scrobiculariidae.
(sharp boundary)

4.02-3.97m Grey-brown sandy clay composed mainly of calcium carbonate and fine quartz grains.
(sharp boundary)

3.97-3.15m Grey-yellow sandy clay, composed mostly of calcium carbonate in fine particles and nodules (< 1cm), and fine quartz grains. Ostracod carapaces are sparsely present. The upper 0.15 m of this layer has a higher water content than lower levels.
(sharp boundary)

3.15-3.0m Brown silt dense with shells, dominated by Cerastoderma. Hydrobiidae are also abundant. Ostracod carapaces and Foraminifera tests are present, together with sparse plant remains and charophyte oogonia.
(sharp boundary)

3.0-2.8m Grey silty mud. Includes more plant remains than layers beneath. Shells of Cerastoderma, Hydrobiidae, Scrobiculariidae, ostracod carapaces and Foraminifera tests are present.

(GAP 2.8-2.66m)

2.66-2.57m Dark-brown silt. Quartz sand and calcium carbonate are sparsely present. This layer contains many rootlets, charcoal fragments and charophyte oogonia. Ostracod carapaces and Foraminifera tests are present.
(sharp boundary)

- 2.57-2.48m Brown silt. Quartz sand and calcium carbonate are sparsely present. Plant remains, Hydrobiidae, ostracod carapaces and Foraminifera tests are present
(indistinct boundary)
- 2.48-2.31m Brown peaty silt. Quartz grains and calcium carbonate are sparsely present. Plant remains, abundant charcoal, sparse ostracod carapaces and Foraminifera tests are present.
(sharp boundary)
- 2.31-2.22m Dark-brown, humified organic layer. Plant remains, charcoal and ostracod carapaces are present.
(GAP 2.22-2.16m)
- 2.16-1.83m Brown silt, contains sparse quartz sand and calcium carbonate. Plant remains, charcoal, charophyte oogonia, Foraminifera tests and shells of Hydrobiidae and Cerastoderma are present. Ostracod carapaces are abundant.
(indistinct boundary)
- 1.83-1.56m Brown silt. The macrofossil content is similar to that of the layer beneath, but Cerastoderma and Foraminifera are fewer.
(sharp boundary)
- 1.56-1.46m Dark-brown organic-rich layer, with sparse calcium carbonate. Plant remains, Hydrobiidae and ostracod carapaces are present
(indistinct boundary)
- 1.46-1.17m Brown silt containing calcium carbonate. Plant remains, Hydrobiidae and ostracod carapaces are present. Foraminifera tests are present in the upper part.
(GAP 1.17-0.8m)
- 0.8-0.76m Grey-brown silty clay. Plant remains and ostracod carapaces are present.
(sharp boundary)
- 0.76-0.51m Brown finely laminated silt, containing quartz sand and calcium carbonate. Most laminations are less than 1 mm but some are up to 2mm thick. Plant remains, charcoal flecks and stones of Cornus mas (Cornelian Cherry) are present. Ostracod carapaces are abundant.
(sharp boundary)
- 0.51-0.48m Grey-white, finely laminated silty clay including quartz and calcium carbonate. Plant remains, abundant charcoal and ostracod carapaces are present.

- (sharp boundary)
- 0.48-0.46m Dark, grey-brown finely laminated silt, including quartz and calcium carbonate. Plant remains and ostracod carapaces are present.
(sharp boundary)
- 0.46-0.43m Grey-white finely laminated silty clay with patchy orange staining; it includes quartz sand and calcium carbonate. Charcoal flecks and ostracod carapaces are present.
(sharp boundary)
- 0.43-0.38m Many fine, black laminations, up to 1.5 mm thick, separated by grey-white laminations, containing quartz sand and calcium carbonate. Charcoal and Foraminifera tests are present, ostracod carapaces are abundant.
(sharp boundary)
- 0.38-0.37m Grey-white silty clay (thick lamination).
(sharp boundary)
- 0.37-0.25m Brown, laminated silt with patchy orange staining. Plant fragments, ostracod carapaces, Foraminifera tests and stones of Cornus mas are present.
(sharp boundary)
- 0.25-0.19m Brown silt, with a higher quartz sand content than the laminated layers beneath. Plant remains and Foraminifera tests are present, ostracod carapaces are abundant.
(indistinct boundary)
- 0.19-0m Brown-grey laminated silt, including quartz sand and calcium carbonate, disturbed by root penetration. Ostracod carapaces and shells of Hydrobiidae are present.
(top of core)

9.3.2 Discussion of stratigraphy and macrofossil content

The presence of ostracod carapaces within the dense grey clay, forming the lower 3.5 m of this core, suggests that this is a lake-marl formed from precipitated calcium carbonate. The marl incorporates abundant quartz grains, which may originate from the local calcarenite. Conspicuous numbers of black, green and orange sand grains are also present, and derive from the heavy mineral suite of volcanic origin deposited along

the coast of the study-area (3.6.6). Such minerals could enter Alimini Piccolo via Alimini Grande and the Strittu channel, or by aeolian transport. The green and orange grains are confined to the lake-marl in the core, but the presence of black grains continues into the dense shell layer above; some orange grains may derive from deposits of red earth (3.6.1). Quartz grains and calcium carbonate are present throughout much of the core.

The dense shell layer immediately above the lake-marl, probably represents a lake-shore environment at the core location, comparable to that observed in core AP88 (9.2.2). It implies that lake-level was reduced causing the shore line to shift westwards. Brackish water conditions are suggested by the presence of Foraminifera tests and shells of Hydrobiidae and Cerastoderma (see chapter 7, part 3). Plant remains are first apparent in the core within this layer, further indicating the proximate position of shore conditions.

The silt layers lying above this 'shore deposit', from 2.66 m to 2.31 m, contain less sand and markedly less mollusc remains; shells of Cerastoderma are absent. Charophyte oogonia are absent from the upper part of this layer, suggesting further lowering of lake-level. Consequent movement of the lake shore further westwards would have allowed marsh vegetation to encroach over the core location, thereby contributing to the higher content of plant material in this sediment. These silts may represent the margin of marsh soils or possibly the accumulation of soil material washed from adjacent land to shallow waters at the marsh fringe. The dark-brown humified layer above these silts predominantly contains plant remains, further suggesting that marsh soils accumulated at the core location and that the influence of lake-water was reduced.

In the silt layers above, from 2.16 m to 1.56 m, charophyte oogonia are again present, together with other macrofossils including shells of Cerastoderma and Foraminifera tests in the lower half of these sediments. Their presence suggests a rise in lake-level, relative to ground level, and a return to brackish lake-water conditions at the core location. The absence of such animal remains from the upper part of these sediments suggests a reversal in lake-level movement and a return to a marsh fringe environment. The overlying, distinct, dark-brown organic-rich layer (1.56m to 1.46 m) may represent a marsh soil. Above this layer, silts and silty clays (up to 0.76 m) and their macrofossil contents, suggest a continuation of marsh fringe conditions.

The laminated sediments constituting the upper 0.76 m of the core, must have been deposited under still water conditions over at least several decades. Such conditions are unlikely to have arisen naturally in the marginal lacustrine situation of the core location. Instead, it is probable that shallow water became ponded in this marshy

margin, following construction of the gabion wall which has circumscribed the lake waters since the 1940's (5.2.1i).

The laminations probably represent seasonal differences in sedimentation. The calcareous, grey/white laminae are most likely formed of precipitated calcium carbonate (5.2.1i), whilst the dark-coloured laminae represent allochthonous and autochthonous terrestrial silt and plant debris. Sediments excavated during construction of the wall, appear to have been piled on the landward side of the wall. It is likely, therefore, that some of this material has been redistributed over the adjacent marsh area by surface runoff, thereby contributing to sediment accumulation at the core location. This redeposited material, together with incorporated microfossils is expected to have confused the pollen and non-pollen microfossil record in the laminated core-sediments, post-dating construction of the wall.

9.3.3 Non-pollen microfossils

Core 1AP was sampled to a depth of 4.5 m for palynological analysis but samples below 3.0 m, within the grey clays and sandy clays, contained extremely sparse organic remains. The calcareous clays were deposited in a lacustrine environment (9.3.2) in which preservation conditions for organic material was poor. These deposits strongly resemble the lake-marl at the base of core AP88 (9.2.3).

Most microfossil types described in chapter 7(part 2), are present in sediments above 3.0 m in the core. Their distributions within the core are illustrated in Fig. 9.6. Five microfossil assemblage-zones are discerned in this diagram. Zone 5 represents the laminated sediments of the upper 0.8 m of the core, and is contaminated by redeposited, older microfossils, as explained in 9.3.2.

Assemblage-zone 1:

This zone corresponds to the calcareous clay layers in which preservation conditions are poor for organic microfossils. Some samples contain sparse fungal remains and siliceous microfossils of sponges and of the diatom, Campylodiscus.

Assemblage-zone 2:

The algal microfossil assemblage in zone 2 suggests that water of mixed salinity existed at the core location. Fresh to brackish water is represented by Pediastrum boryanum, Botryococcus, Cyanophyceae and sponge spicular remains, whilst brackish to saline water is represented by Spiniferites and the diatom genera Campylodiscus, Diploneis and Paralia; each of these diatoms occurred in modern mud-samples from brackish to

saline water-bodies in the study-area (8.4). Cladoceran remains suggest that freshwater was present, and together with Cyanophyceae, suggest that vegetated marginal waters existed over the core location (7.6.1 & 7.7.3). This evidence from microfossils supports the macrofossil evidence for a lake-shore environment (9.3.2).

The presence of dinoflagellate cyst 'Genus A' (7.7.2) within this assemblage, suggests that this genus may favour fresh to brackish water. Microfossils of 'Type A' (7.8.2) are most frequent in this zone of the core. It is possible that the organism from which it originates, favours a shallow, near-shore environment in water of mixed salinity.

Assemblage-zone 3:

Fungal spores are much more frequent in zone 3 than in zones 1 and 2, together with higher frequencies of charcoal and animal remains. This suggests that the input of soil material was significantly increased at the lake margin, in agreement with interpreted macrofossil evidence (9.2.3). In the lower 0.1 m of this zone, corresponding to the dark-brown silt layer (Fig. 9.5), the presence of Cladoceran remains and desmids suggests that freshwater influenced the core location. Brackish water is still represented throughout zone 3 by diatom frustules and by *Spiniferites* in the upper 5.5 m of the zone. *Botryococcus*, Cyanophyceae and *Pediastrum boryanum* reach peak frequencies in the upper part of zone 3. The latter two algae are often associated with vegetated margins of water bodies (7.7.3 & 7.7.5ii) as are Cladocera (7.6.1).

Assemblage-zone 4:

The algal microfossil assemblage of zone 4 is comparable to that of the upper part of zone 3, with the additional presence of the diatoms, *Surirella* and *Amphora*, and the desmid, *Cosmarium*, suggesting that water of mixed salinity continued to influence the core location (see 7.7.1 & 7.7.7).

Assemblage-zone 5:

This zone corresponds to the section of laminated core-sediments representing possibly the past 50 years (9.3.2). Water of mixed salinity continues to be represented throughout zone 5. Many algal microfossils are present, some in high frequencies.

The presence of *Mougeotia*, confined to this zone of the core, suggests that shallow, freshwater existed at the core location (7.7.6iii). Desmids also represent freshwater (7.7.7), and are more frequent in zone 5 of core 1AP than in any other fossil or modern assemblage analysed in this research. High frequencies of *Campylodiscus*, *Diploneis* and *Paralia* strongly suggest that brackish to saline water has also influenced the core location throughout the recent period represented by zone 5; in modern mud-

samples Paralia was frequent only in samples from the brackish environment of Alimini Grande (8.5). Evidence for saline water is further suggested by high frequencies of Spiniferites (7.7.2).

Zone 5 is divided into subzones 5a and 5b, according to the distribution of algae favouring different salinity levels. Subzone 5b appears relatively more saline than subzone 5a, because the former has higher frequencies of Spiniferites. Lingulodinium machaerophorum, a dinoflagellate-cyst genus favouring estuarine environments (7.7.2), is confined to subzone 5b. Dinoflagellate 'Genus A' is more frequent in subzone 5a, where desmids are also more frequent, suggesting a greater influence of freshwater in the lower part of zone 5.

The large increases in algal microfossil frequencies in zone 5 are possibly due to greater nutrient availability, provided by the increased input of soil materials to shallow water over the core location. Increased soil input is suggested by increased frequencies of charcoal and fungal spores, contributing to the dark laminae of this zone. The interjacent grey/white laminations of precipitated calcium carbonate were probably induced, at least in part, by algal depletion of carbon dioxide in the shallow waters (5.2.1i).

9.3.4 Evidence for local environmental conditions from spores and pollen of aquatic plants and marsh plants

Frequencies of spores and pollen from aquatic plants and plants of marshy ground are presented as absolute frequency estimates in Fig. 9.8.

The presence of Ruppia pollen in almost all samples from the core, suggests that brackish water has influenced the core location (see 9.2.4) throughout the period represented by the core sediments. Frequencies are particularly high at 2.0 m and 1.9 m, corresponding to part of microfossil assemblage-zone 3 (9.3.2), in which brackish, marginal lake waters are suggested at the core location. Spores of Filicopsida are present in the core above 2.0 m, coinciding with indications for increased input of soil material to the marginal lake waters.

Pteridium spores and Cyperaceae pollen are present throughout the core, and signify the local presence of dry to marshy land close to the core location. Typha pollen is also present in most samples, confirming that shallow, vegetated water or marshy ground has existed at the core location whilst the core sediments were deposited. Frequencies are highest at 2.6 m where many Typha grains occurred in clusters, indicating that rushes probably grew very close to the core location at the time of deposition (see 8.4.1).

9.3.5 Fossil pollen

i) Pollen concentration and preservation

Pollen concentration values in core 1AP vary from 3000 grains/ml to over 40000 grains/ml, as illustrated in Fig 9.8.

Although samples were processed to a depth of 4.5 m in the core, pollen preservation in samples below 3.0 m was very poor and few pollen grains were found.

ii) Pollen assemblage-zones

Three pollen assemblage-zones are discerned from the diagrams of percentage pollen frequency (Fig. 9.7) and absolute pollen frequency (Fig. 9.8).

Assemblage-zone A:

This zone corresponds to silty muds lying directly above the dense shell layer in the core. Arboreal and herbaceous taxa are represented in approximately equal proportions.

Arboreal component: Pollen of both deciduous and evergreen Quercus are relatively frequent in zone A, reaching 26% in total at 2.97 m. This suggests that mixed oak scrub or macchia existed on drier ground close to the core location. Frequencies of Fraxinus pollen are also significant, reaching 9% at 2.9 m; this genus could have grown locally in association with oak scrub. Corylus, Ostrya/Carpinus orientalis and Alnus are represented by low pollen frequencies, suggesting that they existed within the Alimini region, though they were not necessarily present within local vegetation (see 9.2.5, zone A). Similarly, low pollen frequencies of Pinus, Betula and Ulmus suggest that these taxa occurred within the region. The isolated occurrence of Tilia pollen at 2.97 m in core 1AP, could indicate that this taxon grew locally, since Tilia pollen is poorly dispersed (9.2.5, zone A).

Shrub component: The consistent presence of pollen of Rhamnus, Pistacia and Ericaceae, albeit at low frequencies, strongly suggests that a shrub community existed close to the core location; Rhamnus and Pistacia are commonly under-represented in modern surface-samples (8.4.1). The presence of Cistus, Helianthemum and Rosaceae pollen in zone A, further suggest that a dwarf-shrub community existed locally. This

community could have been associated with the local presence of Quercus, forming scrub undergrowth or macchia.

Herbaceous component: Cruciferae pollen is most frequent among the herbaceous taxa represented in zone A, reaching 28% of the pollen sum at 2.97 m. This suggests that open and perhaps disturbed ground existed close to the core location. The presence of Artemisia and Plantago pollen in the core may be similarly interpreted (see 9.2.5, zone B).

Assemblage-zone B:

Herbaceous pollen taxa are dominant in zone B. This zone corresponds to microfossil zones 3 and 4, from which increased input of soil material to the lake margin is suggested (9.3.2).

Arboreal component: Frequencies of Quercus and Fraxinus pollen are considerably lower in zone B than in zone A (Fig. 9.7 & Fig. 9.8), whilst frequencies of Pinus, Corylus, and Ostrya/ Carpinus orientalis and Ainus are comparable in both zones. This suggests that the local occurrence of mixed Quercus scrub or macchia, as interpreted in zone A, became reduced in extent; regionally occurring arboreal taxa continued to constitute similar proportions of the regional pollen rain at the core location. Pollen of Juglans regia occurs in the upper-most sample of zone B, pointing to human influence on the landscape in the north-eastern part of the lake basin.

Shrub component: The presence of Rhamnus, Pistacia and Ericaceae pollen throughout zone B, together with pollen of Cistus, Helianthemum and Rosaceae in some samples, suggests that a macchia type of shrub community continued to be present on drier land close to the core location.

Herbaceous component: Zone B is divided into subzones B1 and B2 on the basis of changes in the frequency of certain herbaceous pollen taxa (Figs. 9.7 & 9.8). Frequencies of Gramineae are high throughout zone B, whilst frequencies of Cruciferae, Rumex, Artemisia Chenopodiaceae and Plantago are significantly higher in subzone B2 than in B1. Each of these taxa may be associated with disturbed ground (Turner 1964b; Behre 1981). Cereal-type pollen (7.1.7) appears for the first time in the core, in subzone B2. This herbaceous assemblage and the frequencies of individual taxa, strongly suggest that areas of drier ground near to the core location were cleared for agricultural use, or for mixed arable and pastoral use.

Clearance of the previously existing Quercus scrub or shrub community, interpreted from zone A, and the disturbance of soils by agricultural practices, would promote runoff and the transport of soil material towards the lake margins. This could account for the increased deposition of soil material at the core location, interpreted from microfossil zones 3 and 4 (9.3.2).

Assemblage-zone C:

The pollen assemblages of samples within this zone, corresponding to the laminated sediments in the upper part of the core, are likely to contain redeposited pollen from older sediments excavated from unknown depths at the lake margin (9.3.2), besides pollen contemporary with the time of sediment deposition at the core location. Since pollen from the two sources cannot be differentiated, little interpretation can be made of assemblages in zone C.

The present author suspects that the higher frequencies of Quercus pollen in zone C, compared to zone B, are derived from sediments excavated from the lake margin at a depth comparable to, or below, the level of zone A in the core. Well drained land beside the marshy margin of Alimini Piccolo is intensively cultivated at present, and it is unlikely that a shrub community dominated by Quercus could have regenerated close to the core location during the past 50 years; no macchia exists in this part of the Alimini Piccolo basin today.

9.3.6 Summary of environmental change at the north-eastern end of Alimini Piccolo, represented by core 1AP

Four phases of change in the local environment are identified from the integrated evidence from sediments, macrofossils, microfossils and pollen within core 1AP.

Phase 1 (zone 1)

Fresh to brackish lake waters existed over the core location, in which calcium carbonate and some aeolian sand was deposited. During this time, the eastern shore of Alimini Piccolo existed to the east of the core location. Organic microfossils have not preserved within the sediment, leaving no record of contemporary local or regional vegetation communities.

Phase 2 (zone 2, zone A)

A lake-margin and shore environment is represented by silts dense with shells of Cerastoderma. This implies a lowering of lake-level had taken place, causing the lake-

margin to shift westwards. Waters of fresh to saline quality influenced the vegetated lake-margin, as suggested by pollen and microfossil evidence. Areas of shrub vegetation existed on dry ground close to the core location, including Pistacia, Rhamnus and Ericaceae, and also mixed Quercus and Fraxinus. Some open and perhaps disturbed ground is also suggested in the vicinity of the core location.

Phase 3 (zone 3 & 4, zone B)

Water of mixed salinity continued to influence the vegetated, marginal waters of the lake, at least in the vicinity of the core location. The microfossil content of silts in the core, including increased frequencies of fungal spores and charcoal, together with fern spores and increased frequencies of herbaceous pollen, suggest that 'phase 3' represents a period in which the amount of soil material transported to the lake-margin was significantly increased. This is probably consequential to a reduction in the extent of shrub vegetation, together with soil disturbance caused by agricultural practices on cleared land to the east of the core location, as interpreted from pollen assemblages of zone B.

Phase 4 (zone 5, zone C)

After the gabion wall was constructed around Alimini Piccolo, shallow, still waters existed over the core location which progressively filled with laminae of silts and precipitated calcium carbonate. These ponded waters, cut off from the natural lake-margin, have evolved into the seasonally marshy margin existing today.

9.3.7 Comparison of core 1AP with core AP88

i) Core sediments

At both core locations on the eastern margin of Alimini Piccolo, the depth of core obtainable was limited by dense, grey clay/lake-marl. This layer begins at comparable depths below lake-level in both cores, and probably represents a continuous deposit along the eastern side of the lake, if not basin-wide. It was deposited in a freshwater to brackish, lacustrine environment (9.2.2, 9.3.2).

A subsequent fall in lake-level is suggested from core 1AP, in which a silt layer dense with Cerastoderma shells occurs directly above the lake-marl, pointing to shallow water or lake-shore conditions at the core location. A fall in lake-level is also suggested from the occurrence of organic-rich sediments above the lake-marl in core AP88. Above

these deposits, a shell-rich layer similar to that in core 1AP, suggests that shallow water or lake-shore conditions existed over the location of core AP88.

Since the shell layer in core 1AP is 1 m lower, with respect to present lake-level, than that in core AP88, these are unlikely to be contemporary deposits; pollen evidence from the two cores suggests, however, that the shell layers may be of similar age (see 9.3.7iii). There are no further similar and distinctive layers in the two cores.

ii) Microfossils

Differences in sediment composition and sedimentary sequence between cores AP88 and 1AP will have arisen from their differing positions with respect to basin morphology. Likewise, microfossil assemblage-zones cannot be correlated between the two cores, as the originating organisms are closely associated with local environmental conditions.

Microfossil assemblages in both cores (9.2.3, 9.3.3) further suggest that lake-level fell at both locations subsequent to deposition of the lower lake-marl.

iii) Pollen

The pollen record in both cores is limited by poor preservation conditions in the lower lake-marl.

If the time period represented by core 1AP, above the lake-marl, coincides with all or part of the time period represented by core AP88, then similarities may be expected between spectra of well dispersed pollen taxa in the two cores. Quercus is the most frequent arboreal pollen genus in both cores. In zone B of core AP88 (Fig. 9.3), Quercus pollen frequencies exceed 20% of the pollen sum. Similarly high frequencies of Quercus pollen occur only in zone A of core 1AP (Fig. 9.7), excluding frequencies in zone C which are believed to be distorted by redeposited, older pollen (9.3.5). It is possible, therefore, that zone A of core 1AP correlates with the upper part of zone B2 in core AP88, and that zone B of core 1AP correlates with zone C of core AP88. Furthermore, the high Quercus frequencies in zone A of core 1AP occur in sediments directly above the layer with a high density of Cerastoderma shells (Fig. 9.7), and the upper part of zone B2 in core AP88 lies directly above the comparable shell layer in this core (Fig. 9.3).

Whilst comparisons between frequency distributions of other pollen types in these sections of cores 1AP and AP88 do not conflict with this proposed correlation between the cores, no other pollen taxa display strong similarities in frequency distribution in both cores.

It is concluded from this comparison between sediments, macrofossils, pollen and other microfossils, that core 1AP probably corresponds to only the upper metre of core AP88, despite the greater depth of the former. According to the proposed chronology for local environmental change represented by core AP88 (9.2.7), zone A of core 1AP may represent macchia vegetation of Roman age, on dry land beside the marshy lake margin. Macchia coverage subsequently dwindled as the extent of arable land, and perhaps pastoral land, increased on the eastern side of Alimini Piccolo.

9.4 CORES 2AP and 3AP

As explained in 5.2.1, these cores were collected from the north-western marshy margin of Alimini Piccolo, for stratigraphic comparison with cores AP88 and 1AP; palynological analyses were only carried out on specific samples from core 3AP, in order to test for stratigraphic correlation with core 1AG (9.5). Samples were processed and analysed across the boundary between the sand and the overlying organic deposits in core 3AP, but pollen preservation and concentration was too poor to allow useful comparison.

Depths in the cores are recorded in metres with respect to ground-surface level at the core locations. At the time of coring, ground-levels at the locations of cores 2AP and 3AP were 0.21 m and 0.17 m above lake-level respectively. The core sediments are illustrated in Figs. 9.9a & 9.9b.

9.4.1 Core 2AP stratigraphy

(bottom of core)

2.42-1.7m Grey/green sand, containing calcarenite clasts up to 4 mm large.
(sharp boundary)

1.7-0m Brown peat, with root penetration throughout.
(top of core)

9.4.2 Core 3AP stratigraphy

(bottom of core)

3.25-3.1m Dense, yellow sand with some clay.
(sharp boundary)

3.1-2.84m Grey sand
(sharp boundary)

2.84-2.33m Buff-coloured sand with high water content.
(sharp boundary)

2.33-1.66m Dark brown peat.
(indistinct boundary)

1.66-0.71m Brown silty mud. Shells of Lymnaeidae and Planorbidae are present.
(indistinct boundary)

- 0.71-0.47m Dark-brown silty peat. Shells of Lymnaeidae and Hydrobiidae are present.
(indistinct boundary)
- 0.47-0.18m Brown silt. Shell fragments are present, including a small shell of Cerastoderma.
(indistinct boundary)
- 0.18-0m Brown/black peat. Scattered shell fragments are present
(top of core)

9.4.3 Discussion of stratigraphy in cores 2AP and 3AP

Both cores reveal an accumulation of organic marsh-sediments above sands at their base. In core 3AP, a deeper section of sand deposits was obtained, within which three distinct layers were discerned on the basis of their colour and compaction.

Sands are exposed at the modern ground surface on shallow slopes beside the western marshy margin of Alimini Piccolo (5.2.1); according to De Marco *et al.* (1983) these are 'residual dune' sands. In the present study, samples were taken from the buff sand (at 2.75 m) and lower dense yellow sand (at 3.15 m) of core 3AP for comparison with a sample collected from the 'residual dune' sands adjacent to the marsh vegetation zone. The three samples were dry-sieved at $\frac{1}{4} \phi$ intervals from 0ϕ (1 mm) to 4ϕ (63 μm), according to the procedure given in Appendix A. Their resultant particle size distributions are illustrated in Fig. 9.10; also shown in Fig. 9.10 are particle size results for sand from core 1AG, discussed in 9.5.7. Fine sands (2ϕ - 4ϕ) predominate in each of the samples and their grain size distributions are similar, particularly those of the 'residual dune' and the lower sand from core 3AP. These grain size characteristics, combined with the fact that each sample contains grains of heavy minerals, suggests that all are of aeolian origin.

The buff sand from core 3AP exhibits a bimodal distribution, which is also faintly suggested in the other two samples, leading to the conclusion that aeolian sands were deposited in this location from probably more than one source. To examine this possibility, the particle size distributions from two distinct dune deposits in the study-area were compared (Fig 9.11). The first sample is from dunes along the low cliff-top between San Foca and the Cesine (grid ref: BK776664), the second is from a fossil dune deposit actively eroded by the sea at Torre San Stefano (grid ref: BK847521). As illustrated in Fig. 9.11, both samples are strongly sorted and display distinctly different modal particle sizes. In the first sample, sieved at $\frac{1}{2} \phi$ intervals, modal size is 0.5ϕ to 2ϕ , in the second sample modal size is 2.5ϕ to 2.75ϕ and reflects the modal size

of samples from core 3AP and the 'residual dune' (Fig. 9.10). The third histogram in Fig. 9.11 demonstrates that when the two dune particle size distributions are combined a bimodal distribution is produced, suggestive of those in Fig. 9.10.

Thus sand from at least two local sources were probably combined during aeolian transport and deposition on the west side of Alimini Piccolo. The evidence presented here suggests that the sands in core 3AP represent a continuation of the exposed 'residual dune' deposits on the north-west side of Alimini Piccolo, which have since been partially covered by accumulating organic sediments related to rising lake-level and groundwater levels. The core sand contains no evidence, such as silt or microfossils, to suggest that it was deposited in lake water. In order for the sands to accumulate on land at the location of core 3AP, lake-level would necessarily have been at least 3 m below its present level; that is below the level reached by the core. A possible age for these sands is discussed in 9.5.7, with respect to similar sands in core 1AG.

In both cores 2AP and 3AP, brown peat lies directly above the sands. In core 2AP, this peat continues to the present ground-surface, whilst in core 3AP, silts predominate above 1.66 m. Between 1.66 m and 0.71 m in core 3AP, the presence of shells of Planorbidae and Lymnaeidae signify the presence of stagnant, and probably vegetated, fresh to brackish waters at the core location (see 7.12.1). Between 0.7 m and 0.18 m, the presence of a Cerastoderma shell suggests that brackish-water has influenced this location. The stratigraphy of core 2AP shows no evidence of being influenced by lake-waters.

The stratigraphies of cores 2AP and 3AP, on the north-western side of Alimini Piccolo, do not correlate with the stratigraphies of cores AP88 and 1AP (9.2.1 & 9.3.1) on the eastern side. A lacustrine depositional environment has prevailed at the locations of the latter two cores, whilst a marsh environment has prevailed in the vicinity of cores 2AP and 3AP, having developed above an aeolian sand deposit. An aeolian sand layer is not evident in cores AP88 and 1AP. Basin asymmetry may account for this lack of correlation, together with spatial differences in sediment deposition within the lake basin (see 5.2.1).

9.5 CORE 1AG

9.5.1 Core stratigraphy and macrofossils

This core was extracted within the inland marsh-basin north of Alimini Grande (5.2.2). Depths in core stratigraphy are recorded in metres with respect to the present ground surface. The core sediments are illustrated in Fig. 9.12 and macrofossil distributions are presented in Table 9.4

(bottom of core)

- 5.1-4.18m Orange clay with dispersed sand. The clay is wet, incohesive and contains limestone clasts.
(indistinct boundary)
- 4.18-3.9m Orange clay, containing sand.
(indistinct boundary)
- 3.9-3.46m Orange sandy clay. Iron nodules were noted within the clay (< 1mm diameter) between 3.72 and 3.82m.
(sharp boundary)
- 3.46-3.3m Grey-brown sand. Charcoal fragments are present < 2mm).
(indistinct boundary)
- 3.3-3.19m Buff coloured sand, with humic staining towards its upper limit.
(sharp boundary)
- 3.19-3.1m Dark-brown/black coarse textured peat, incorporating sparse sand grains and charcoal.
(indistinct boundary)
- 3.1-2.56m Dark-brown/black silty peat, incorporating dispersed sand grains and charcoal. A 3cm deep band of dispersed quartz grains occurs, centred at 3.0 m.
(indistinct boundary)
- 2.56-0m Dark-brown peat. Charcoal fragments are abundant from 2.1 m to 1.8 m. Small, scattered fragments of mollusc shells were evident between 0.85 m and 0.76 m, and in the upper most 0.4 m of the core. A shell of Lymnaeidae was recorded at 0.36 m and Ostracod carapaces were recorded between 0.3 m and 0.2 m. Charophyte oogonia were present at 0.1 m and 0.2 m.

(top of core)

9.5.2 Discussion of core stratigraphy and macrofossils

The clay forming the lower part of the core, up to 3.46 m, is evidently a purely mineral deposit. The deposit's orange colour suggests it has been exposed to oxic conditions allowing ferric minerals to oxidise. The fact that aeolian sands overly this clay suggests that it was previously exposed at the ground surface, allowing oxidation *in situ*. Alternatively, ferric minerals were oxidised prior to, or during, their transport and redeposition at this location. Its texture and appearance are similar to that of the red earths exposed at the surface in parts of the study-area (3.6.1), suggesting that it is either a continuation of these deposits lining the marsh basin above bedrock, or it represents redeposited red earths from the basin; its origin is discussed in 9.5.7ii. Sand sized grains within this deposit are predominantly of quartz and orange coloured grains. Black and green heavy-mineral sand grains are present throughout this layer, and must derive from the coastal heavy-mineral sands (3.6.6); such rounded heavy-mineral grains are not found in the local calcarenite (De Marco *et al.* 1983). The present author believes it is an aeolian deposit, owing to its homogeneity, the dominance of aeolian sand grains and the lack of microfossils.

Quartz grains dominate the fine aeolian sands lying above the clay layer; the sands incorporate small fragments of plant material and charcoal. It is probable that the aeolian sand extended over slopes around the depressed marshy area, but it is no longer recognisable in the degraded soils. The abrupt change from aeolian deposits to highly organic deposits in this low depression, probably represents a significant rise in the local water-table, caused by increased climatic humidity. A hiatus in sedimentation is probable until vegetation became established on the sands. In fact some of the sand may have been lost through deflation prior to being fixed by plants and increased moisture.

Continuous organic and peaty sediments form the upper 3.1 m of the core, containing only dispersed sand grains. A relatively concentrated band of aeolian sand grains was revealed in the peat at 3.0 m by an X-ray radiograph of this core section. This isolated concentration may represent an episode of above average aeolian sand transport, or the sand may have been transported to the basin by sheetwash from surrounding slopes.

Indications for a marshy depositional environment are given by macrofossils only between 0.3 m and the top of the core, where ostracod carapaces and shells of Planorbidae are present (Table 9.4). The presence of sand-sized clasts of calcium carbonate between 0.9 m and 0.7 m and between 0.3 m and 0.1 m may also indicate wet phases at the sediment surface, permitting the precipitation of this mineral. The sparse presence of Foraminifera tests at 0.3 m could indicate the influx of brackish waters to the marsh basin from Alimini Grande, but no brackish water microfossils

were recorded to support this explanation (see 9.5.3). Their presence may therefore be misplaced, for instance by wind transport, as observed in surface-sample CS2 (8.2.2). Plant remains and charcoal are particularly abundant between 2.1 m and 1.8 m.

9.5.3 Non-pollen microfossils

The core was sampled to a depth of 4.0 m, but no organic remains or microfossils were present in samples below 3.4 m, coinciding with the orange clay section of the core; oxic conditions influencing the colour of this deposit would have had a deleterious effect on any organic materials originally within it.

The range of non-pollen microfossils present within this core (Fig. 9.13) is relatively limited when compared to that of cores from Alimini Piccolo (Figs. 9.2 & 9.6) or from the Cesine environment (Figs. 9.23,25,29,34). Plant, animal and fungal remains are well represented throughout the core above 3.4 m, but algal microfossils are restricted in both diversity and distribution within the core. Four assemblage-zones are distinguished in Fig. 9.13.

Assemblage-zone 1:

This zone coincides with the aeolian sand layer below the peat and above the orange clay. Low frequencies of fungal spores and the lack of algal remains conform with the dry conditions of this deposit. This assemblage and the microfossil frequencies are comparable to those of the surface-sample from dunes on the Cesine transect (8.3.2). It is possible, however, that these microfossils have filtered into interstices of the sand from the overlying peat.

Assemblage-zone 2:

Frequencies of mycorrhizae are highest in this zone of the core, and may correspond to a period in which herbaceous vegetation was predominant at the core location and around the basin (8.4.2). Fungal spores of type 1 are abundant, whilst the three other fungal spore-types are present in relatively low numbers. Concentricystes is present throughout zone 3, and reaches a maximum frequency in the core at 2.9 m.

This assemblage suggests that humid soil conditions existed at the core location during the period represented by this zone. The advent of wetter conditions towards the end of this period, at least locally, is indicated by the presence of Spirogyra in the upper 0.2 m of the zone.

Assemblage-zone 3:

This assemblage points to a marked change in the local environment, towards marshy conditions. Prevalently wet conditions at the core location are clearly suggested by the presence of Spirogyra and Mougeotia in all but the lower most sample of this zone, and of Pediastrum boryanum at 1.9 m. Pediastrum is a planktonic alga, and Mougeotia produces spores in shallow freshwater (7.7.6iii), signifying the seasonal, if not perennial, existence of standing water at the core location. Fungal spores reach maximum frequencies within this zone, probably associated with greater soil moisture, whilst mycorrhizae are sporadically present and less frequent than in zone 2. Concentricystes is absent from this zone.

Charcoal frequencies sharply reach a maximum in the core at 1.9 m, strongly suggesting that fire occurred in the vicinity of the core location; macroscopic charcoal fragments are also most abundant in this zone of the core (Table 9.4).

Assemblage-zone 4:

Wet and perhaps seasonally waterlogged conditions prevailed throughout the deposition of sediments constituting zone 4, as suggested by the continuing presence of Spirogyra and Mougeotia, and the occasional presence of Zygnema. Concentricystes reappears in this zone and is present in each sample; it is most frequent in the upper 0.4 m of the core. Fungal spores are well represented, though at overall lower frequencies than in zone 3. Charcoal fragments are present in relatively high frequencies in the upper 0.4 m of the zone, possibly reflecting regular use of fire in the local landscape.

The microfossil record in core 1AG indicates that marshy conditions have not always existed in the shallow depression north of Alimini Grande; causes and chronology for the development of marshy conditions in this location are discussed in 9.5.7. There is no evidence that brackish waters from the lake have influenced the environment of the depression.

9.5.4 Evidence for past local environmental conditions from plant spores and from pollen of marsh plants

Frequencies of spores and of pollen from marsh plants are presented as absolute frequency estimates in Fig. 9.15.

Pollen of Cyperaceae and spores of Filicopsida (ferns), together with sparse Pteridium aquilinum (bracken) spores were found within the aeolian sand layer, below the peat. These are taxa of dry ground as well as humid soils, whose presence do not contradict

the interpretation of dry environmental conditions based on the sediments and microfossil assemblage of zone 1. Some Cyperaceae grow on sands, for example Carex arenaria.

At 3.1 m, at the base of the peat, each of these taxa show a pronounced increase in absolute frequency, pointing to more favourable growth conditions locally. They are joined by Typha pollen, suggesting that wet ground conditions existed close to the core location (8.4.1). The microfossil record suggests that humid soil conditions, rather than wet conditions, existed actually at the core location until the top of assemblage-zone 2, at 2.2 m (Fig. 9.13).

Spores of ferns, bracken and Ophioglossum type reach their maximum frequencies in the core within the first 0.8 m of organic sediments above the sand. Spores identified as Ophioglossum type are restricted to this section of the core. Ophioglossum vulgatum (adder's tongue) is a herb favouring damp grassland, fen or scrub, whilst the sub-species Ophioglossum ambiguum favours sandy ground and coastal grassland areas (Clapham *et al.* 1962). The marked concentration of spores suggest that damp to dry ground conditions with relatively open vegetation cover existed at or close to the core location during the period represented by this core section. Above 2.3 m, bracken is consistently represented and ferns are sporadically represented throughout the rest of the core. The local presence of Phragmites is also suggested by sporadic, low pollen frequencies throughout the peaty core-sediments (Fig. 9.14).

This pattern concords with the suggested humid soil conditions at the core location during the period represented by microfossil-zone 2, succeeded by wetter conditions creating marshy ground and a suitable habitat for Zygnemataceous algae (7.7.6) in zones 3 and 4. Zone 2 appears to represent a period when silts and plant materials accumulated at the core location at a pace greater than or equal to the rising water-table. Above zone 2, however, rise in the water-table exceeded that of sediment accumulation, causing at least seasonal waterlogging at the ground surface.

9.5.5 Fossil Pollen

i) Pollen concentration and preservation

Throughout the dark-brown peat, forming the upper 2.56 m of the core, pollen concentrations generally vary between 2500 and 5000 grains per ml (Fig. 9.15); no absolute frequency estimates are calculated for sample 1.6 m, as part of the residue was lost during processing. A high pollen concentration of 9400 grains per ml was

recorded at 1.8 m, but no change in sediment composition was evident visually or on an X-ray radiograph.

In the under-lying dark-brown/black silty peat, pollen concentrations are consistently high, varying between 7000 and 10000 grains per ml. The higher pollen concentrations in these sediments may be attributed to slower rates of sedimentation during this evidently less humid phase; compaction of this sediment under the weight of later sediments, may also be a contributory factor.

Estimated pollen concentration in the buff-coloured aeolian sand is the lowest in the core, at 440 grains per ml, whilst the highest concentration within the core, 12000 grains per ml, occurs within the grey/brown sand beneath. It is possible that the upper sand layer has become impoverished of pollen by the vertical movement of grains through interstices of the sand, augmenting the concentration in the lower sand layer, above the less permeable orange clays.

ii) Pollen assemblage-zones

Six pollen assemblage-zones are discerned from the diagrams of percentage pollen frequency (Fig. 9.14) and estimated absolute pollen frequency (Fig. 9.15).

Assemblage-zone A:

This zone is defined by the dominance of herbaceous pollen in the assemblage. It incorporates the aeolian sands and the layer of coarse peat lying immediately above.

Arboreal component: Total frequencies of arboreal pollen taxa in this zone are the lowest in the core. Quercus is the most consistently represented tree genus in zone A, though its pollen frequencies do not exceed 5% of the pollen sum. Oleaceae pollen in zone A is exclusively of Fraxinus type (7.1.2), constituting 4% of the pollen sum at the top and bottom of this zone; frequencies of Oleaceae plotted in Figs. 9.14 and 9.15 represent total Oleaceae of Fraxinus and Olea type, excluding Ligustrum. Pollen of Corylus is present at 0.5% in the upper and lower parts of zone A, whilst Ostrya/Carpinus orientalis, Ulmus and Pinus pollen is present in just the upper part. Some pollen grains may have filtered into the aeolian sands from the overlying peat. These low percentages of arboreal pollen in samples with high pollen concentrations for the core, suggest that the represented taxa formed part of the regional vegetation, but did not grow close to the marsh basin, at the northern end of Alimini Grande.

Shrub component: Rhamnus and Rosaceae are represented by low pollen frequencies, of which the former probably occurred locally, as its pollen is poorly dispersed (8.4.1).

Vitis pollen is most frequent among the shrub taxa represented in zone A. Frequencies reach 4.5% at the top of the zone, suggesting that this climber grew close to the core location; in southern Spain, much higher frequencies of fossil Vitis pollen were attributed to early viticulture (Stevenson & Moore 1988). Bottema (1974a) has associated Vitis pollen in a fossil pollen-assemblage from Greece, with that of trees favouring wet ground. It grows naturally as a sun-seeking climber on moisture-loving trees and shrubs (Rivera Núñez & Walker 1989) and occurs in the understorey of some wet, Mediterranean woodlands (Polunin & Walters 1985; Beug 1961a). In northern Greece, Rivera Núñez & Walker (1989) observe that spontaneous Vitis is also associated with many shrubs of macchia, including Quercus coccifera and Pistacia terebinthus. Its representation in zone A of core 1AG may be naturally associated with locally growing Rhamnus and Rosaceae.

Herbaceous component: Zone A is distinguished from all other zones of the core by high pollen frequencies of Cynoglossum type and Spergularia type. Difficulties in the identification of Cynoglossum type pollen are explained in 7.1.5, but as species of Cynoglossum are predominantly associated with dry, open spaces (Polunin 1980), their strong representation in the aeolian sand deposits is congruous. Some species of Spergularia, for example Sand Spurrey, favour inland sands (Polunin 1980), whilst other species are common in coastal areas. Pollen of both types could have originated from plants growing on the aeolian sands at the core location, or it could have been transported to this location with the sands from a local coastal source.

Interestingly, high frequencies of Spergularia type pollen (14% to 24.5%) are confined to the sand layers of zone A, whilst Cynoglossum type pollen reaches its maximum frequency in the core (27.5%) in sample 3.1 m from the coarse peat layer immediately above the sands, reflecting the environmental preferences of these taxa. Some clusters of Cynoglossum type pollen occurred in sample 3.1 m, suggesting this taxon grew locally and therefore that dry ground conditions persisted throughout the period represented by zone A. Umbelliferae pollen are also most frequent in zone A. Many species of this family favour dry land and sometimes sands, for example Echinophora spinosa and Eryngium maritimum; the latter grows on coastal sands in the study-area (3.7.7).

Gramineae and both Compositae Liguliflorae and Tubuliflorae, each constitute more than 10% of the pollen sum in zone A, contributing further to the impression of open herbaceous vegetation at the core location. Clusters of Gramineae pollen and of Cyperaceae pollen occurred in sample 3.1 m, suggesting that their sources grew locally. Three of the five samples in which Malvaceae pollen was recorded in core 1AG, occur in zone A. This too is suggestive of prevalently dry open ground.

The presence of Phragmites-type pollen (7.1.7) in the sands, if correctly attributed, does not conform with the dry conditions generally represented by the herbaceous assemblage and by other non-pollen evidence from the sediments (9.5.2,3&4). Moister conditions are suggested in the overlying organic sediments (9.5.4), so it is possible that the small Phragmites-type grains have filtered down into interstices of the sand.

Assemblage-zone B:

Zone B lies within the dark-brown/black silty peat. Its lower limit is defined by an abrupt rise in total Quercus pollen frequencies (Figs. 9.14 & 9.15), and by the first appearance of Tilia, Alnus and a number of shrub taxa in the core sediments. The upper limit of zone B is marked most significantly by further large increases in Quercus pollen frequencies.

Arboreal component: Frequencies of total Quercus pollen vary between 14.5% and 21% in zone B. In all but sample 2.6 m, grains identified as Quercus robur/pubescens type (deciduous) are more frequent than those of Quercus ilex/coccifera type (evergreen) (7.1.1). These frequencies suggest that oaks grew locally, perhaps on slopes around the present-day marsh. Tilia pollen is present at up to 1% in zone B, suggesting that this taxon grew locally, as dispersal of Tilia pollen is poor (see 9.2.5, zone A).

Pollen of Corylus, Ostrya/Carpinus orientalis and Oleaceae continue to be present in low frequencies in zone B, suggesting that these taxa did not become any more prominent in the local environment. They may have been scattered among the more frequent oaks. Pinus pollen continues to be present at 6% or less, representing the probable regional, rather than local, presence of pine. The appearance of Alnus pollen may be associated with the establishment of more humid conditions in depressed areas of the region, as implied by the generation of organic-rich deposits at the core location.

Shrub component: Vitis pollen is consistently present in zone B, reaching 3.5% at 2.6 m, suggesting that this climber continued to grow locally, probably in association with oaks and other arboreal and shrub taxa. Frequencies of Rosaceae pollen are higher in this zone than in zone A. Included in the Rosaceae may be Rubus (bramble) for example, and other shrubs of woodland undergrowth and bush. The presence of Hedera helix pollen in zone B, adds support to the suggested local presence of woodland (see 8.4.1 & 9.2.5, zone B).

Pollen of Rhamnus is more frequent in zone B than in zone A, and pollen of Ericaceae appears for the first time in the core in zone B. This suggests that both taxa were present as components of shrub communities beneath or adjacent to wooded areas.

The isolated occurrences of pollen of Ligustrum, Rhus and Ephedra in zone B, may also originate from local woodland or bush vegetation.

The presence of Cistus pollen, even though at 0.5%, suggests that these shrubs of dry ground grew nearby. Cistaceae are common in areas of macchia and garigue in the study-area, yet their pollen rarely occurred in the modern surface-samples (chapter 8).

Herbaceous component: Frequencies of Cynoglossum type pollen abruptly fall to 1.5% at the bottom of zone B. Pollen frequencies of Umbelliferae and Spergularia type are similarly low in this zone (Fig. 9.14). Gramineae pollen are also markedly less frequent in zone B than in zone A (Figs. 9.14 & 9.15). A clear shift in the local herbaceous plant assemblage is indicated by these reductions and the contemporaneous increases in frequencies of Compositae and Chenopodiaceae. Artemisia appears for the first time in the core, at 2.8 m, whilst Plantago and cereal-type Gramineae are regularly represented at less than 1% in this zone. These possibly represent human disturbance in the basin catchment, though they may equally occur naturally at these frequencies (see 8.4.1).

That more humid conditions existed at the core location after deposition of the underlying aeolian deposits, is evident from the sediments themselves and the local establishment of ferns and bracken (9.5.4). The presence of Typha pollen in zone B further suggests that moist conditions existed locally.

High frequencies of Compositae pollen and fern spores could be considered a residual product following oxidation of a pollen assemblage (see 9.2.5, zone A). In this case, however, pollen concentrations in zone B are among the highest in the core (Fig. 9.14) and diverse pollen taxa are present in a well preserved state, suggesting that oxidation has had minimal effect in zone B.

Assemblage-zone C:

Zone C is primarily defined by maximum frequencies of Quercus pollen in the core (Fig. 9.14). In terms of estimated absolute frequencies, Quercus pollen concentrations in zone C appear generally no higher than in zone B (Fig. 9.15), but as overall pollen concentrations in zone C are considerably lower than those of zone B, the increased input of Quercus pollen to the core sediments is real, and not an artifact of relative frequency calculations. As suggested in 9.5.5(i), lower pollen concentrations in this zone may be attributed to higher rates of peat accumulation above 2.56 m. Oxidation is not suspected of biasing the pollen assemblage of zone C or creating low pollen concentrations, since grains appeared well preserved, and the resistant Ligulifloraceous pollen are relatively infrequent in this zone whilst certain other taxa show increased frequencies.

Arboreal component: Total Quercus pollen frequency in zone C rises from 24% to a maximum of 53% of the pollen sum at 2.2 m. It then declines to 29.5% at the top of zone C (Fig. 9.14). Deciduous type Quercus pollen constitutes between half and two thirds of total Quercus pollen in samples of this zone. These figures compare well with those for Quercus pollen frequency in the modern surface-sample from the Bosco S. Elia (8.2.2). Total Quercus pollen in this surface-sample constituted 41.5% of the pollen sum, of which three quarters (32.5%) were identified as deciduous type and one quarter (9%) evergreen type. Similarly high Quercus pollen frequencies were found only in the surface-sample from beneath planted Quercus ilex woodland in the Cesine reserve (8.2.2); here the pollen was almost exclusively of evergreen type, accurately reflecting the tree canopy.

This comparison of modern Quercus pollen frequencies with those of zone C, strongly suggest that both evergreen and deciduous oaks grew very close to the core location throughout the period represented by zone C. At its maximum extent this vegetation perhaps encroached over marginal areas of the present marsh. The prominence of deciduous type Quercus pollen suggests that a woodland rather than a shrub community is represented here, similar in composition perhaps to the Bosco S. Elia (4.4). Having said this, deciduous bush communities including Quercus pubescens do occur today in areas with sub-Mediterranean climates, where summers are hot and dry, and winters are cold and continental (Polunin & Walters 1985).

The marked decline in Quercus frequencies, represented in samples 2.1 m and 2.0 m of zone C, coincides with maximum charcoal frequencies in the core (Fig. 9.13) of both microscopic and macroscopic scale fragments (9.5.3). This peak, occurring after substantially lower charcoal frequencies in sediments beneath this level in the core, strongly suggests that arboreal and shrub vegetation around the core location was severely damaged by fire, perhaps as a deliberate action to clear land for economic use.

The probable local presence of Tilia is again suggested in zone C by the presence of its pollen. Corylus pollen is most frequent in this zone of the core, reaching 2.5% at 2.3 m. Pollen of Ostrya/carpinus orientalis continues to be represented at 1% or less of the pollen sum. Both could have existed locally within mixed woodland. Oleaceae pollen is slightly more frequent in zone C than in zone B, forming up to 2% of the pollen sum, except in sample 2.4 m where it contributes 6.5%; both Olea and Fraxinus type are represented.

Alnus pollen continues to be present at low frequencies. Pinus pollen frequencies are lowest in the core in zone C (Figs. 9.14 & 9.15). The proportion of regionally transported pollen deposited at the core location may have been reduced by aerodynamic effects of the proposed woodland community around the core location (see Tauber 1967).

Shrub component: Rhamnus pollen frequencies reach their highest levels in the core in zone C, coincident with peak Quercus frequencies (Fig. 9.14). Frequencies of between 3% and 3.5% are high for this taxon, which is under-represented in pollen rain (see 8.4.1), and suggest that Rhamnus grew close to the core location. Rhamnus alaternus often occurs in Mediterranean oak woods (Polunin & Walters 1985).

Vitis pollen continues to be present in zone C up to 2.2 m, coinciding with the maximum Quercus frequency. Its presence together with mixed arboreal species suggests that this climber continued to exist in the woodland undergrowth. Above 2.2 m, Vitis pollen is present only in samples 1.3 m, 0.6 m and 0.3 m, at less than 1%. Pollen frequencies of Hedera helix are also consistently high in this zone, at between 2% and 6.5%, the maximum coinciding with maximum Quercus frequencies; as noted from surface-sample analyses (8.4.1) this is an under-represented taxon in pollen assemblages. These frequencies strongly suggest that this climber grew very close to the core location. It would naturally favour a woodland environment for growth, such as is indicated by other shrub and arboreal elements of zone C.

High frequencies of Rosaceae pollen in this zone may also represent undergrowth vegetation, such as brambles, in close proximity to the core location. Rosaceae pollen was frequent in the surface-sample from Bosco S. Elia (8.2.2). The occurrence of Pistacia pollen at 2.1 m suggests that this taxon also existed close to the core location since its pollen is poorly dispersed and severely under-represented in pollen rain (8.4.1). Today, besides being a dominant element of macchia, Pistacia lentiscus grows beneath the mixed oak woodland of the Bosco S. Elia (8.2.2). Ericaceae pollen continues to be present at low frequencies in zone C, signifying their probable presence in the region.

Herbaceous component: Pollen of Compositae and Gramineae are markedly less frequent in zone C than in zone B (Figs. 9.14 & 9.15), whilst Chenopodiaceae and Caryophyllaceae pollen is 1% to 2% more frequent in zone C and continues to be so throughout the rest of the core. Other herbaceous taxa are sporadically represented in this zone at frequencies usually less than 1%. This overall reduction in the herbaceous component of local pollen rain during the period represented by zone C, suggests that the proposed woodland and shrub vegetation which dominates the period represented by this zone, existed within the basin area which today contains marsh vegetation (5.2.2). The exceptionally high Quercus frequencies in zone C support this reasoning.

Assemblage zone D:

The lower limit of zone D is defined by the decline of Quercus frequencies to levels comparable to and below those of zone B, together with concomitant decreases in

certain other arboreal and shrub taxa, and clear increases in frequencies of herbaceous taxa associated with disturbed ground. The upper limit of zone D is marked by increased Quercus frequencies, together with further increase in some herbaceous taxa of disturbed ground. The zone is divided into subzones D1 and D2, between samples 1.5 m and 1.4 m, where the downwards trend in Quercus pollen frequencies is reversed after reaching a minimum (Figs. 9.14 & 9.15). Pollen concentrations are more variable in this zone (Fig. 9.15) than in zones B and C. A conspicuously high concentration of 9500 grains per ml occurs in sample 1.8 m, but no change in sediment type or preservation conditions is apparent at this level.

Arboreal component: In subzone D1, total Quercus pollen frequencies are between 10.5% and 18%, suggesting that oaks remained in areas close to the core location, perhaps on slopes around the present-day marsh basin. Frequencies in subzone D2 suggest that areas with oak became further diminished in extent, but a slight increase in frequencies towards the top of zone D is indicated in Figs. 9.14 and 9.15.

Among the other arboreal pollen taxa, both Corylus and Oleaceae become sporadic in occurrence, at frequencies mostly below 1%. The presence of Tilia pollen is also more sporadic than in zones B and C. The apparent decline in these taxa appears to relate to the reduced extent, or degradation of mixed oak woodland in the environs of the core location. Pollen of Ostrya/Carpinus orientalis and Alnus continue to be present sporadically at 1% or less, and Pinus pollen frequencies remain low at 7%. The occurrence, at less than 1% of the pollen sum, of Ulmus at 1.5 m and 1.3 m, and the isolated occurrence in the core of Betula pollen at 1.8 m, can only be attributed to regional sources.

Shrub component: Rhamnus pollen is consistently present throughout zone D, suggesting that this shrub remained in the local environment. The more regular incidence of Pistacia pollen in this zone, especially in subzone D2, suggests that a shrub community remained close to the core location, succeeding the previously dominant woodland. This impression is supported by increased frequencies of Ericaceous pollen and the sudden fall in frequencies of Hedera helix pollen, closely correlated with that of Quercus (see Fig. 9.14). The presence of Hedera pollen in zone D is erratic, but the climber could have survived among the shrub community. Frequencies of Rosaceae pollen are maintained at up to 10% in subzone D1, but are markedly less in subzone D2, suggesting that represented species of this family were associated with woodland undergrowth.

Herbaceous component: Cynoglossum type pollen appears more consistently in subzone D1 than it does in zones B and C, but it is absent from the core above 1.5 m

(Figs. 9.14 & 9.15). It may originate from dry open land on nearby slopes cleared of woody vegetation. At the core location, perennial or seasonal wet ground conditions are strongly suggested by the presence of Typha and Phragmites-type pollen, and microfossils of freshwater algae (9.5.4).

Cereal-type Gramineae pollen is distinctly more prominent in zone D, especially in subzone D2 (Figs. 9.14 & 9.15). It is present in every sample in frequencies varying between 1% and 7.5%, suggesting that cereals were cultivated in cleared areas close to the marshy basin, although naturally occurring Gramineae could also be the source (7.1.7). Surface-sample analyses in the study-area showed cereal type pollen to be restricted to cultivated areas and garigue (8.2.3), suggesting clear links with anthropogenic activity. Gramineae pollen is markedly more frequent in zone D, as is Compositae Tubuliflorae, and in subzone D2, Compositae Liguliflorae. These point to a predominance of open ground in the vicinity of the core location.

Pollen of Plantago, Cruciferae and Labiatae are present in most samples from this zone, and probably originate from plants of open and disturbed ground. Artemisia pollen is consistently present in zone D from 1.6 m upwards. This genus favours dry habitats and some species occur as weeds of cultivation (Huntley & Birks 1983), but Artemisia maritima may occur within saltmarsh vegetation (Behre 1981) and possibly existed at the margin of Alimini Grande; no evidence was found from non-pollen microfossil analyses to suggest that saline waters influenced the sediments of core 1AG (9.5.4). Further evidence for disturbed ground in the locality is provided by Scabiosa (scabious) pollen in subzone D2.

Assemblage zone E:

This zone is defined by a secondary maximum of total Quercus pollen (Figs. 9.14 & 9.15), reaching 25.5% at 0.9 m; these frequencies imply a period of recovery in the oak woodland or shrub community.

Arboreal component: The frequencies of Quercus pollen, in which the deciduous type is predominant, imply that woodland or shrub areas with oak recovered or expanded towards the core location during the period represented by zone E. Pollen of Tilia and Ostrya/Carpinus orientalis appear in this zone for the last time in the core. Corylus and Oleaceae are also represented, suggesting that the composition of this woodland or scrub community persisted from zone B to zone E. Both Fraxinus and Olea type Oleaceae pollen were recorded from this zone. Pollen of Juglans regia is present in zone E, possibly suggesting human influence in the local landscape (see 9.5.7i).

Shrub component: Both Rhamnus and Pistacia pollen are present up to the top of zone E, but are absent from zone F above. This suggests that both shrub species, whose pollen are poorly dispersed (8.4.1), grew close to the core location either mixed with arboreal species or as part of a macchia type shrub community. Ericaceae are represented throughout this zone and probably existed in association with Pistacia and Rhamnus. Pollen of Hedera helix is present at 0.7 m, suggesting that this climber continued to exist locally amongst trees or shrubs. The odd occurrence of Cistus and Helianthemum pollen also point to the local existence of shrub or garigue type vegetation.

Herbaceous component: Compositae and Gramineae remain the dominant pollen taxa in zone E, suggesting that open vegetation prevailed at the core location. Cereal-type Gramineae continue to be present, at up to 3% of the pollen sum. Pollen of Plantago and Artemisia are present at their highest frequencies in the core of 6.5% and 3% respectively in this zone. It is conceivable that the increase in these genera, combined with higher Gramineae frequencies in zone E than in zone D, represent an increased area of open grassland, perhaps grazing land, on slopes around the core location. The presence of Scabiosa and Malvaceae pollen in this zone further suggests the continued local presence of cultivated or otherwise disturbed ground.

Assemblage-zone F:

Low total Quercus pollen frequencies define this zone (Figs. 9.14 & 9.15), which extends up to the modern ground surface; frequencies are mostly less than 4% of the pollen sum, comparable to levels in zone A. The zone is divided into subzones F1 and F2 between 0.4 m and 0.3 m, above which several significant changes occur in the pollen assemblage.

Arboreal component: The decline in percentage pollen frequencies of total Quercus from the bottom to the top of zone F (Fig. 9.14), is produced by relatively large increases in other pollen types; Fig. 9.15 shows Quercus frequencies to be low but consistent throughout zone F. Evergreen and deciduous type Quercus pollen are present in roughly equal proportions throughout the zone.

Other arboreal pollen is sparse in subzone F1; Corylus, Alnus and Oleaceae pollen are present at 0.4 m. This clear shrinkage of the arboreal pollen assemblage points to the removal of remnant woodland in the vicinity of the marsh basin north of Alimini Grande, and in much of the region.

In subzone F2, frequencies of Oleaceae pollen are many times more frequent than in subzone F1 (Figs. 9.14 & 9.15), especially in the surface-sample from the core

location (13.5%). All Oleaceae pollen in zone F were identified as Olea type (see 7.1.2). These abruptly higher frequencies in subzone F2 strongly suggest that olive cultivation occupied some land on dry slopes around the marsh during the period represented by subzone F2 up to the present.

Pinus pollen constitutes up to 9% of the pollen sum in subzone F1, suggesting that pines continued to be present outside the marsh basin catchment, probably towards the coast. Frequencies are substantially higher in sample 0.1 m and in the modern surface-sample, strongly suggesting the presence of pines within the marsh catchment during the period represented by the upper half of subzone F2. Pine planting began in coastal parts of the study-area mainly in the 1940's (Pagliara 1987) and today a pine plantation exists within 500 m of the core location (8.2.2). This suggests that the upper 10 cm of core sediments accumulated within the 20th century.

Shrub component: In zone F, shrub vegetation is only represented by pollen of Ericaceae and Rosaceae, both of which are more frequent in subzone F1 than in F2. These may represent remnants of macchia-type communities on dry slopes around the marsh basin, which may also be the source of Quercus pollen. Though the poorly dispersed pollen of Rhamnus and Pistacia are absent from zone F, this need not suggest that these shrubs were absent from the local landscape, as demonstrated by modern surface-sample analyses (8.4.1).

A pollen grain resembling Laurus pollen occurs in sample 0.6 m; this pollen is difficult to identify (Beug 1961a). Vitis pollen is present in samples 0.6 m and 0.3 m, probably originating from vine cultivation in the region. Two of the modern surface-samples contained odd grains of Vitis pollen, in areas distant from a source (8.2.2).

Herbaceous component: The herbaceous assemblage of zone F is again dominated by Compositae and Gramineae, though Compositae pollen is more abundant and Gramineae pollen less abundant than in zone E (Figs. 9.14 & 9.15). Pollen of Plantago and cereal-type Gramineae are consistently present in subzone F1, but are only once represented in subzone F2; Artemisia is absent from subzone F2. This evidence suggests that the extent of arable and perhaps grazing land in the catchment of the marsh basin was reduced during the period represented by zone F.

9.5.6 Synthesis of environmental information from core 1AG

The origins and possible ages of the aeolian sands and orange clay at the base of the core, are discussed in 9.5.7; following these discussions, a chronology for environmental change represented by core 1AG is put forward in 9.5.8. Both the pollen and non-pollen microfossil records begin in the core at 3.4 m, within the aeolian sands. Based on the combined analyses, a sequence of six phases are recognised in the core, describing local landscape evolution.

Phase 1 (zone A , zone 1)

Dry conditions are suggested to have prevailed at the core location during the period represented by the aeolian sand layer, in which algal remains are absent (zone 1) and herbaceous pollen are dominant in the pollen assemblage (zone A). Of special note in zone A are the high frequencies of Cynoglossum type and Spergularia type pollen, representing herbs which favour dry ground and sands. The predominance of open herbaceous vegetation cover is further suggested by high frequencies of Gramineae, Compositae and Cyperaceae pollen. Low frequencies of arboreal pollen, representing Quercus, Fraxinus and Corylus suggest that these taxa were present in the region when sands were deposited at and around the core location, but their presence was not significant on the surrounding basin slopes.

Phase 2 (zone B, zone 1/2)

As noted in 9.5.2, a hiatus in sedimentation at the core location may exist between the sands and the beginning of organic-rich sediment accumulation. Pollen of Cynoglossum type and Cyperaceae are most abundant in the coarse peat immediately above the sands, but throughout the rest of the period represented by microfossil zone 2, humid soil conditions are indicated at the core location. Under these conditions, autochthonous organic deposits accumulated together with silts and incorporated organic remains, probably transported to the basin by sheetwash from surrounding slopes. High frequencies of mycorrhizae in zone 2 coincide with high frequencies of pollen from herbaceous plants.

Herbaceous taxa favouring moister ground succeeded those of dry ground. Spores of ferns, bracken and Ophioglossum type are most frequent in the core in the lower silty peats, reaching maximum frequencies in zone B. These suggest that predominantly open ground with moist but well drained soils existed at the core location and probably on the nearest slopes of the depression. The presence of Typha points to the existence of locally wet ground.

These humid conditions appear to have favoured the expansion of mixed scrub or woodland. Relatively high frequencies of Quercus pollen, of both deciduous and evergreen types, suggest that oaks were present in the local landscape, perhaps on slopes bordering the depressed marshy area of today. The pollen assemblage suggests that Tilia also occurred locally, whilst Corylus, Ostrya/Carpinus orientalis and Oleaceae are present in the region. The first appearance of Alnus in the core (zone B) may reflect the establishment of wet ground conditions in parts of the region. Rhamnus and the climbers Vitis and Hedera helix are suggested to have grown locally; each could be naturally associated with locally occurring woodland or scrub.

Phase 3 (zone C, zone 2/3)

Coinciding with the change to more peaty sediments, above 2.56 m, a marked expansion is suggested in the local occurrence of deciduous and evergreen oaks. Frequencies of Quercus pollen reach a maximum at 2.2 m of such magnitude as to strongly suggest that a closed mixed-oak canopy encroached over the margins of the present marsh area. Corylus and Oleaceae were more prominent locally throughout this phase, whilst the regional or scattered local presence of Ostrya/Carpinus orientalis remained apparently unchanged. Tilia continued to be present locally.

Further support for the suggested presence of closed, mixed oak woodland close to the core location, is provided by increased frequencies of shrub pollen taxa associated with woodland undergrowth communities. Rhamnus and Rosaceae are most frequent during this phase and are likely to have occurred with Pistacia as undergrowth shrubs close to the core location. Vitis is well represented until the Quercus maximum. High pollen frequencies of Hedera helix suggest that this taxon grew close to the core location during this phase, adding support to the conclusion that mixed oak woodlands extended into the depressed area to the north of Alimini Grande. The woodland composition bears some resemblance to that of the extant Bosco S. Elia, believed to have derived from the ancient Bosco di Belvedere in Salento (4.4).

Overall reductions in frequencies of herbaceous pollen during phase 3, reflect the suggested closed nature of the woodland vegetation. Spores of ferns, bracken and Ophioglossum type decline in frequency with the apparent expansion in woodland. As ferns and bracken may favour a damp, woodland environment, their apparent decline at this time is difficult to explain; the recurrence of these spores throughout the overlying core sediments probably represents their residual survival from this phase.

Ophioglossum favours open herbaceous vegetation and generally drier ground conditions. It ceases to be represented in the core when wetter ground conditions at the core location are first suggested by the presence of the freshwater algae Spirogyra and Mougeotia (zone 3), at 2.1 m.

At this level in the core (2.1 m), Quercus pollen frequencies begin a marked decline. Coincident with this decline is the occurrence of maximum charcoal frequencies in the core, including the greatest concentration of macroscopic charcoal fragments. This evidence strongly suggests that fire affected the area close to the core location, and was at least partly responsible for the reduction or degradation of mixed oak woodland in this part of the study-area. Increasingly wet conditions at the core location may have contributed to this decline locally.

Phase 4 (zone D, zone 3/4)

Arboreal pollen frequencies suggest that woodland or scrub continued to exist close to the depression, which by this phase had become locally marshy. Frequencies of Quercus pollen continue to decline, however, until the latter part of this phase; other arboreal taxa associated with the oak woods, together with Hedera helix are similarly reduced, probably reflecting their decline in the local landscape. At the same time, macchia type shrub communities appear to have been more prominent locally. Rhamnus continues to be represented in zone D, joined by a regular representation of Pistacia and increased Ericaceae.

Increased frequencies of herbaceous pollen suggest that areas of open vegetation also existed in the vicinity of the core location. A distinct increase in the prominence of cereal-type Gramineae pollen, together with pollen from taxa favouring disturbed ground, suggest that economic activities, including arable cultivation, was practised in the local landscape throughout phase 4. This evidence suggests that anthropogenic activity was probably responsible for the burning and clearance of woodland areas which previously dominated the local landscape, and possibly the regional landscape.

Phase 5 (zone E, zone 4)

Oak woodland or scrub appears to have partially redeveloped or expanded towards the core location during this phase, retaining a similar composition to that of earlier woodland represented in phases 2 and 3. This apparent partial recovery coincides with a phase of relatively low charcoal frequency, between 0.9 m and 0.5 m in the core, in zone 4. Burning and clearance activities were possibly less widespread or less frequent during this phase.

Pollen of Pistacia, Rhamnus, Ericaceae and Cistaceae suggest that shrub communities, possibly macchia and garigue, continued to occupy well drained areas close to the core location. Areas of open ground in the landscape are still represented by the continuing presence of cereal-type pollen and pollen taxa representing plants of disturbed ground. Since frequencies of Plantago, Artemisia and Gramineae pollen are especially prominent during this phase, areas of open, dry grassland may have existed on slopes

around the marshy depression. This possibly indicates that both pastoral and arable landuse existed in this area during phase 5.

Phase 6 (zone F, zone 4)

Consistently low frequencies of arboreal pollen, including evergreen and deciduous Quercus, imply that remnant woodland areas were removed from the environs of the marsh basin, and probably from much of the region by this phase; Tilia and Ostrya/Carpinus orientalis are absent from the pollen assemblage of zone F. High charcoal frequencies throughout this phase suggest that burning was possibly regularly employed, at least locally, to control vegetation. Shrub vegetation was also apparently less prominent in the local environment, though macchia often fails to be represented in fossil pollen assemblages (8.4.1).

Decline in the occurrences of cereal-type pollen and pollen from herbaceous plants of disturbed ground, suggest that arable land and grassland was reduced in extent on slopes around the marsh basin during phase 6. In the latter part of this phase, abruptly higher frequencies of Olea type pollen strongly suggest that olives were cultivated on dry slopes surrounding the marsh. This practice continues to the present day. The odd occurrence of Vitis pollen may signify the presence of vine cultivation in the region. Large increases in Pinus pollen in the upper 10 cm of the core are interpreted to represent 20th century pine planting in the region.

9.5.7 A discussion of chronology for environmental change represented by core 1AG

In the absence of radio-carbon dates for core 1AG, attention is focussed on the origin of the core's sediments, and on the comparison between the pollen record of core 1AG and that of core AP88 (9.2) in order to establish a chronology for landscape evolution in the vicinity of core 1AG.

i) The pollen spectra of cores AP88 and 1AG compared

In the upper-most samples of cores AP88 and 1AG, marked increases in Oleaceae pollen are attributed to olive cultivation within the catchments of both cores (AP88 zone C, 1AG zone F2), representing modern time. High Pinus pollen frequencies, representing 20th century planting, are not however registered at the top of core AP88.

Below the surface sediments, comparison of the percentage pollen diagram for core AP88 (Fig. 9.3) with that for core 1AG (Fig. 9.14) reveals similarity in the curves of

total Quercus pollen. The Quercus curve of core AP88 is similar in pattern and frequencies represented, to that of the upper 1.5 m of core 1AG. Alternatively the curve of core AP88, including two Quercus maxima, could represent in condensed form the complete curve of core 1AG, excluding zone A. These two hypotheses are evaluated by further comparison between the pollen spectra of the two cores.

In core AP88, Tilia pollen ceases to be present above zone A, when Quercus frequencies are greatest, whilst in core 1AG it is present until the top of zone E. In core 1AG the consistent presence of Tilia pollen in zone C, suggests that this taxon was a constituent of local mixed woodland (phase 3, 9.5.6). Similarly, Corylus and Oleaceae are suggested to be associated with woodland during phase 3, but in core AP88 their distribution appears less related to the Quercus curve.

Pollen of shrub taxa further suggest that the woodland phase represented by zone C of core 1AG is not represented in core AP88. A woodland undergrowth including Vitis, Hedera, and Rhamnus is well represented in zone C of core 1AG, where their pollen frequencies are highest in the core; relatively high frequencies of Vitis pollen also occurred in the preceding zones B and A. In no part of core AP88, however, are these taxa so strongly and consistently represented. Their frequencies are comparable instead to corresponding frequencies in zones D2, E and F of core 1AG. Having said this, these taxa are unlikely to have grown as close to the marginal lacustrine location of core AP88, as they might in the case of core 1AG, and their poorly dispersed pollen may consequently be less well represented.

Pollen of Pistacia is present in zone B of core AP88 although this taxon is usually also under-represented (see 8.4.1). In core 1AG, Pistacia pollen is not present until after the Quercus maximum in zone C, suggesting that a macchia type shrub community succeeded woodland in the vicinity of core 1AG (phase 4, 9.5.6). Similarity between the pollen curves of Ericaceae in both cores further favours the hypothesis that the pollen record of core AP88 relates to the upper 1.5 m of core 1AG. Frequencies of Ericaceae pollen only exceed 1% of the pollen sum at 1.7 m and above in core 1AG, suggesting that Ericaceae formed part of a shrub community succeeding the woodland phase represented by zone C. This community persisted in the local landscape throughout the secondary Quercus maximum. In core AP88, Ericaceae pollen constitutes 1% to 2% of the pollen sum throughout zones B2 and C, suggesting a shrub community was established locally throughout this time.

Thus the pollen assemblages and frequencies of arboreal and shrub taxa from core AP88 resemble most closely those of the upper 1.5 m of core 1AG, supporting the first correlative hypothesis. The mixed woodland phase represented by zone C in core 1AG has no closely matched counterpart in core AP88. It is possible, however, that the Quercus pollen maximum constituting zone B1 of core AP88 represents this woodland

in the vicinity of Alimini Piccolo, prior to the disturbance of sediments by changes in lake-level over the core location (zone 3, 9.2.3), and the existence of a lake shore environment at the core location represented by the dense sand and shell layer in the core. Under these conditions it is possible that sediments were eroded from the core location by the wave energy of marginal lake waters, creating a hiatus in the sedimentary record, thereby shortening the fossil record. The second correlative hypothesis, that the spectra of core AP88 represent those of core 1AG in condensed form, cannot therefore be rejected.

On the basis of this comparison, the radiocarbon dates of core AP88 may be tentatively transferred to core 1AG. According to the first hypothesis, that core AP88 corresponds to the upper 1.5 m of core 1AG, the apparent age at 1.2 m in core AP88 of 1765 ± 50 BP may be transferred to 0.5 m in core 1AG. The apparent age of 3675 ± 55 BP may be transferred to 0.9 m in core 1AG. Extrapolating this date downwards in the core, the organic sediments of core 1AG could represent the entire Holocene period. This is improbable since climatic conditions and surface hydrology are unlikely to have been sufficiently humid for peat formation during the early Holocene in southern Italy, as discussed below in 9.5.7ii & iii. Due to the possible influence of older carbon, however, the sediments from core AP88 may be younger than their apparent radiocarbon ages (9.2.6). Therefore, the correlation between core AP88 and the upper 1.5 m of core 1AG may be valid if the dates are 'too old'.

According to the second possible correlation between the two cores, allowing for a hiatus in the sediments of core AP88, the radiocarbon date of 3675 ± 55 BP may be transferred to the lower part of zone C in core 1AG, at around 2.4 m. This date, when extrapolated downwards in core 1AG, places the lower boundary of organic sediments in the mid-Holocene, which accords with current views on Holocene climatic change and peat initiation in southern Europe (see 9.5.7ii & iii).

Under both hypotheses, the upper date of 1765 ± 50 BP at 0.5 m in core 1AG could be 'too old' to represent 0.5 m of peat accumulation. If the correlation between the *Quercus* pollen spectra of cores AP88 and 1AG is correct, it seems that this date has been rendered 'too old' by the influence of older carbon. Pollen assemblages in neither core contain exotic taxa which would serve as historic time markers, against which the radiocarbon dates could be compared. The occurrence of *Juglans regia* (walnut) pollen, however, in zone E of core 1AG and zone C of core AP88 suggests that sediments of these zones might be not more than three millennia old; this date does not conflict with the radiocarbon dates. *Juglans regia* is widely believed to have been imported to Holocene Europe by man (Bottema 1980a) becoming palynologically evident in north-western Greece at around 3200 BP (Bottema 1974a) and on the Dalmatian coast in association with Roman activities (Beug 1967). In Italy, however, Kelly & Huntley

(1991) found pollen of Juglans regia in sediments dated to the early Holocene at Lago di Martignano.

ii) The orange sandy clay and the origin of red earth

If the orange clay at the base of core 1AG is of aeolian origin and similar to exposed red earths in the study-area, as put forward in 9.5.2, it may be possible to approximate an age for the deposit. In 3.6.1, red earths are identified as the earliest unconsolidated deposits in the study-area, lying directly above the calcarenites from Miocene to Pleistocene age. Beneath core 1AG, Pleistocene calcarenites form the depression now occupied by marsh. Limestone clasts were incorporated within the lower-most core sample (9.5.1), suggesting that the orange clay is in contact with the calcarenite. The orange colour of this clay, rather than deep red, is very similar to that of sandy, red earth which fills karst solution pipes exposed by a quarry in the Pleistocene rock near San Foca, for example. Mesolithic artefacts have been found within such fill in the vicinity of San Foca, suggesting that it was partly deposited or redeposited during or after the Mesolithic (3.6.1).

To test this apparent similarity, particle size distributions of the sand fraction of two samples collected from fill exposed by the quarry (grid ref: BK770649), were compared with that of a sample taken from the core at 3.8 m. Also for comparison, samples of red earth were collected from fill exposed by a new road cutting (in 1990) between Melendugno and Borgagne (grid ref: BK755601), and from red earth exposed at the surface at the south eastern side of Alimini Grande (grid ref: BK828528). Histograms illustrating the particle size distributions of these samples are given in Fig. 9.16, together with pie charts illustrating the ratio of sand to the silt and clay fraction of each sample. As illustrated by Fig. 9.16, the particle size distributions of the quarry fill samples and the sample from core 1AG, are similar.

The appearance of these red earths (described in 3.6.1) compare well with the description of red earth from Kokkinopilos, across the Adriatic in Epirus, north-west Greece (Dakaris *et al.* 1964). Here red earths also lie above a karst limestone surface. Particle size analyses of samples from different levels within the deposit revealed a consistent sand content of 20% (Tippet 1964). This is comparable to the sand content from red earth at the surface near Alimini Grande, but is considerably lower than that from core 1AG or the exposed quarry sections (Fig. 9.16). The higher sand content in these samples is explained by the admixture of locally derived aeolian sands with the red deposits, suggesting the entire composite deposit is of aeolian origin.

The origins of red earth has long been a controversial matter (Rapp 1983). As red earths of the Mediterranean characteristically overly limestones, they are commonly believed to be a residual weathering product of the limestone. In Puglia, Grassi *et al.* (1975) recognise three groups of 'terra rossa', including one Quaternary group, but all are considered to derive from insoluble residues of the local carbonate rocks. Whilst Moresi & Mongelli (1988) acknowledge that 'terra rossa' from Puglia incorporates aeolian dusts, they too conclude from geochemical analyses that the deposits derive from the local rocks. The present author feels this evidence is still inconclusive. After dissolving 50g samples of the Pliocene and Pleistocene calcarenites from the study-area in weak hydrochloric acid, the insoluble residue of each amounted to between 0.5% and 1% of the original sample volume; it follows that to produce a residue 0.5 m deep, for example, would require dissolution of a 50 m thickness of calcarenite.

In Epirus, Macleod (1980) found that acid insoluble residues constituted only 0.15% of original sample volumes from the Pantokraton limestone beneath red earths. From this it was calculated that 130 m of limestone would have to be weathered to produce 0.4 m of red earth. When considering the origin of 'terra rossa' in Grotta Romanelli, south-east Puglia, Blanc (1921) found that the acid insoluble residue from the cave limestone was such that 'hundreds of thousands' of cubic metres of the limestone, exceeding the cave's volume, would be needed to produce the volume of red deposit currently within the cave. Blanc (1921) rejected the hypothesis that the deposit was brought into the cave by water, and concluded that it is of aeolian origin, probably from a desert source in Africa.

Further evidence favouring a predominantly aeolian origin of red earth in the Mediterranean region is provided from Israel, where Danin *et al.* (1983) observed weathering patterns of endolithic lichens and cyanobacteria on karst surfaces beneath the 'terra rossa'. If the deposit was a residual product of the underlying dolomite, the distinctive weathering patterns would also have dissolved (Danin *et al.* 1983). Many now support the hypothesis that Mediterranean red earths are aeolian deposits from a north African source (Rapp 1983; Macleod 1980; Yaalon & Ganor 1973). Saharan dust is frequently transported to Europe, especially to peninsular Italy (Prodi & Fea 1979) and areas affected by the Scirocco from north Africa (Macleod 1980). Pollen analysis of an aeolian dust fall in southern France, for example, confirmed its African origin (van Campo & Quet 1982).

Dust falls from Africa are likely to have been more frequent and of greater magnitude at times during the Quaternary (Rapp 1983), for example during the late Pleistocene when deflation rates in the Sahara were high (Parmenter & Folger 1974). Blanc (1928) proposes that the 'terra rossa' in Grotta Romanelli was deposited during a relatively warm and dry interstadial of the last (Würm) glaciation; red earth elsewhere in Salento

may be of similar age. Within the 'terra rossa', Blanc (1928) records faunal remains indicative of warm climatic conditions, including elephant and rhinoceros, together with horse, bustard and grassland-hen characteristic of steppe. The deposit also contains a lithic industry of Upper Palaeolithic character.

Similarly, Upper Palaeolithic industries were found in association with red earths at Kokkinopilos in Epirus (Dakaris *et al.* 1964) and on Corfu (Sordinas 1983). Mousterian artefacts have been found within the alluvial 'Red Beds' of Epirus (Higgs & Vita-Finzi 1966), suggesting that the red earths in the region are of Middle Palaeolithic or earlier age. Further evidence for this age determination is provided in the southern Argolid, Greece, where samples of the 'Red Beds' and Mousterian lithics within them were dated, using Uranium series methods, to 50000 BP (Pope *et al.* 1984).

In conclusion, the orange clay at the base of core 1AG shares characteristics of the red earths. It is a distinctly yellow-red, aeolian deposit overlying a karst surface and has a high fine-particle fraction. Evidence from Grotta Romanelli and other parts of the Mediterranean suggest that the red material is of north African origin, and accumulated mostly towards the end of the Pleistocene, including episodes within the last glacial.

iii) The sand layer

Since the sand content of the orange clay increases towards the boundary with the overlying sand deposits in core 1AG, it appears that the sand continued to be deposited at a perhaps increased rate after the supply of red aeolian material ceased; the distinct boundary between the two deposits suggests that some of the red material was removed from the core location, perhaps by deflation, as an abrupt end to the deposition of this material is unlikely.

The particle size distribution of a sample from the sand, taken at 3.4 m within core 1AG, is illustrated in Fig. 9.10 (in section 9.4.3). The sample is mostly comprised of fine sand (2 ϕ -4 ϕ) in a distribution which closely reflects those of the lower sample from core 3AP (Fig. 9.10), the residual dune from the west side of Alimini Piccolo (Fig. 9.10) and the combined dune particle size distribution (Fig.9.11). According to the argument put forward in 9.4.3, this particle size distribution probably represents material from two or more local sand sources combined during aeolian transport and deposition; each of the core samples contain heavy mineral grains indicating a local, littoral source. As in core 1AG, the sands in cores 2AP and 3AP lie directly below uninterrupted organic sediments (9.4.3) suggesting that these core sands and the

residual dune on the west side of Alimini Piccolo, all date from the same phase of aeolian deposition.

As concluded in the previous section, the red aeolian deposits are likely to have been deposited in the study-area during the last glacial, when aridity was widespread in equatorial areas, promoting the deflation of soils on a large scale (Parmenter & Folger 1974). Climatic change following the last glacial most probably terminated this significant supply of red material to the Mediterranean region. According to pollen and lake-level data, moister conditions prevailed in north Africa between 12000 BP and 6000 BP (COHMAP Members 1988; Rossignol-Strick *et al.* 1982) allowing vegetation to stabilise former areas of deflation. During the same period, it is widely held that eustatic sea-level rise proceeded at an estimated average rate of 5 m per millennium (as reviewed by Kidson 1982).

The transgressing sea would have disturbed littoral sediments as it advanced landwards, providing fine source material for aeolian transport. It is widely believed that since 5000 BP, eustatic sea-level has continued to rise at a rate of around 1 m per millennium (see 12.5.1). Hence, between 6000 BP and 5000 BP, sea-level may have been 5 m below its present level. With reference to nearshore bathymetry in the vicinity of the Alimini (IGM 1:50000 maps), the coastline since 5000 years ago probably existed within 200 m of the present shoreline (see 12.5.3).

On both the Adriatic and Ionian coasts of Salento, two Holocene dune deposits have been recognised and dated (2.4.5). According to radiocarbon dates, the earlier dunes accumulated between 6780 BP and 3900 BP (Magri & Zezza 1970) and are undercut by the present sea-level. In places these dunes lie directly above the calcarenite surface, but often red earth lies between the two (Magri & Zezza 1970; Cotecchia *et al.* 1969). It is possible, therefore, that sands overlying red earth in core 1AG, originate from this phase of aeolian sand transport and dune accumulation, associated with a coastline hypothetically situated within 200 m eastwards of its present position near the Alimini.

Since the maximum depth of Alimini Grande, when measured in 1868, was 3.82 m below the contemporary sea-level (De Giorgi 1895), sea water may not have entered the lake basin during the Holocene until sea-level had reached say 4 m below its present level. Little more can be said at present on this point, as many factors relating to both the past and present situation are unknown, including the depth of sediment in Alimini Grande, the depth of the inlet to the lake from the Adriatic and the degree to which littoral dune sands blocked this inlet. Until sea-level was sufficiently high to enter the basin, any water body within the basin would have been supplied by groundwater reserves and/or by surface runoff. The assemblages of pollen and other microfossils within the sand of core 1AG suggest that dry conditions prevailed in the vicinity of the core location while the sand deposit accumulated (phase 1, 9.5.6). The groundwater

level at the core location was therefore probably at least 3.5 m below the present ground surface.

Following this argument on the origin of the sand layer in core 1AG, a maximum date of between 6700 BP and 3900 BP is proposed for the initiation of peat accumulation at the core location.

iv) The organic sediments and peat

Humid conditions are necessary for the accumulation of organic sediments and peat. Peat initiation can result from a complex combination of factors including climatic change, mire hydrology and forest clearance (Cruise 1990). As pointed out by Cruise (1990) the early Holocene is frequently not represented by peats from valleys and low altitude sites in the Mediterranean region; the bottom of many peat deposits, including those from the Ligurian Alps and Ligurian Apennines, are dated no earlier than 5000 BP. Cruise (1990) suggests that climatic change during the mid-Holocene is most likely to have been a common cause of peat initiation in north-western Italy, where few early Holocene organic sediments are known. Following the Holocene thermal maximum between 9000 BP and 6000 BP (COHMAP Members 1988) a change to widespread cooler and perhaps moister conditions is suggested by the initiation of peats and by pollen evidence for major forest changes in south-western Europe. At a lowland site in south-west Spain, however, the initiation of peat at 4500 BP is attributed to hydrological consequences of vegetation destruction in the catchment (Stevenson & Moore 1988).

To the present author's knowledge, there has been no previous investigation into the chronology and circumstances of Holocene peat accumulation in low altitude areas of southern Italy. Peaty sediments formed the upper 1.0 m of a core from the coastal plain beside Lago di Varano on the Gargano Peninsula (Pasa & Pasa Durante 1962), but no dates were put forward for the sediments or the pollen spectra from the core. The location of this core is geographically and geomorphologically the closest to those of the present research, known to the present author. Unfortunately the pollen diagram (Pasa & Pasa Durante 1962) lacks sufficient detail to permit a conclusive comparison with core 1AG, however some similarities are identified in 12.2.1.

On the basis of available evidence, it is probable that the organic sediments in core 1AG began to accumulate in the mid-Holocene, when moister, cooler climatic conditions succeeded a dry, warm early-Holocene period. This hypothesis accords with the suggested period of sand accumulation at the core location, related to sea-level in the mid-Holocene (9.5.7iii). Pollen and microfossil evidence from the sediments

(9.5.3 & 4) support the argument that climatically induced changes in surface hydrology led to peat initiation in this location, but some anthropological influence on the catchment hydrology cannot be discounted.

Thus a chronology is put forward for environmental change represented by core 1AG, based upon geomorphological and palynological analyses. The origins of the core's sediments, as discussed, strongly favour the second proposed correlation between the pollen diagrams of cores AP88 and 1AG (9.5.7i). According to this hypothesis, the extrapolated radiocarbon dates place the base of the organic core-sediments in the mid-Holocene, at around 5000 BP to 4500 BP. This agrees well with the earliest date of peat accumulation at the location of core 1AG, proposed after an evaluation of the source of underlying mineral deposits, and the mechanisms by which they arrived at the core location. The orange deposit at the base of the core is attributed to aeolian deposition during arid conditions of the last glacial (9.5.7ii). The accumulation of aeolian sands of local origin probably relates to a phase of dune formation between 6900 BP and 3900 BP associated with a mid-Holocene stage of post-glacial sea-level rise (9.5.7iii).

Dry ground conditions prevailed at the core location during this period of sand deposition. Similar conditions are indicated in the vicinity of core 3AP on the north-western side of Alimini Piccolo, where comparable sands underlying organic deposits suggest that the lake-level of Alimini Piccolo was at least 3 m below its present level during their deposition (9.4.3). Given that the Strittu channel joins Alimini Piccolo to Alimini Grande, which in turn connects to the Adriatic, this evidence further suggests that sea-level was several metres lower than its present level when the sands were deposited.

A climatic change to moister and perhaps cooler conditions in the mid-Holocene, combined with further rise in sea-level, would have promoted vegetation growth at the core location and the development of organic sediments. Human disturbance of the catchment's vegetation and soils may have contributed to changes in local surface hydrology, but the sediments and incorporated microfossils betray little evidence for such.

9.5.8 Chronological interpretation of environmental change represented by core 1AG

With reference to the environmental information from core 1AG (9.5.6) and the discussion of sediment chronology (9.5.7), an interpretation of environmental change in the vicinity of the northern end of Alimini Grande is presented here.

i) Dry conditions prevailed in the middle to late Neolithic period, during which sands from local coastal sources accumulated in the depression north of the Alimini Grande basin and perhaps in other depressed areas, including the western side of Alimini Piccolo. Open herbaceous vegetation was predominant within and around the depressed area, but trees were present in the region, including Quercus, Fraxinus, and Corylus (phase 1). The coastline in the vicinity of the Alimini at c. 5000 BP, is estimated to have been around 200 m seawards of its present position. As sea-level was probably insufficiently high to enter the basin of Alimini Grande, both lakes would have been fed only by groundwater and surface runoff, forming smaller, unconnected water bodies. Brackish lacustrine conditions are suggested to have existed at the location of core AP88 in the middle Neolithic period (9.2.7).

ii) Towards the end of the Neolithic, ground surface conditions became moister and were locally suitable for the accumulation of plant materials, possibly as a result of increased climatic humidity. Open herbaceous vegetation was still predominant in and around the depression, but an increased presence of mixed scrub or woodland is indicated in the local landscape (phase 2). Limited mixed woodland is also suggested to have existed within the catchment of Alimini Piccolo during this period, whilst aquatic plants and marsh vegetation became established on silts deposited at the lake margin, represented in core AP88 (9.2.7).

iii) In the early Bronze Age, beginning at around 3700 BP, a marked expansion of mixed woodland, dominated by deciduous and evergreen oaks, is strongly suggested. The closed canopy, with a well developed undergrowth probably impinged on the depression to the north of Alimini Grande (phase 3). Sea-level may be estimated at between 3 m and 4 m lower than present, but sufficiently high to enter and partially fill the lake basin of Alimini Grande. By penetrating increasingly higher levels of the karsified calcarenite (3.4), sea-level rise will have caused groundwater levels to rise in places, contributing to the development of marshy conditions in depressed areas. A rise in the level of Alimini Piccolo is indicated during the corresponding phase in core AP88, together with a notable increase in mixed woodland in the basin catchment (9.2.7).

Beginning in the mid-Bronze Age, c. 3300 BP, a major decline in the extent of mixed woodland is attributed to deliberate clearance involving the use of fire (phase 3). This episode has probably been lost from the fossil record of core AP88, due to the existence of lake shore conditions at the core location and consequent disturbance of sedimentation (9.5.7i).

iv) In the late Bronze Age some mixed woodland or scrub existed in the vicinity of the depression, but *macchia* type shrub vegetation was probably more prominent, interspersed with areas of open herbaceous vegetation. As cereal-type pollen and taxa characteristic of disturbed ground are consistently represented during this period of the fossil record (phase 4), arable cultivation was probably practised in some local, cleared areas of the catchment. Conditions within the lower part of the depression had become marshy by this time.

v) During the period in which the indigenous Messapian population and culture was established (8th century), leading into the early Roman period, it appears that woodland or scrub dominated by oaks recovered or expanded to some extent in the local landscape (phase 5); an increase in *macchia* coverage is suggested in the catchment of Alimini Piccolo (9.2.7). Lower charcoal frequencies during this phase in the core possibly suggest that clearance by burning was less widespread, allowing *macchia* or scrub to re-establish in some areas. The appearance of *Juglans* in the fossil record during this phase, may represent one element of increasing trade contact with Greece, and the Hellenistic influence on Salento in this period (see 9.5.7i).

It is possible that during the latter part of the first millennium B.C., the marshy conditions of the depression created an increasingly unhealthy environment for the local human population. Malaria is believed to have arrived in southern Italy between the 5th and 2nd centuries B.C. (2.9), corresponding to the early Roman period in Italy. This may partly explain why no Messapian or Roman population centres are known between locations well inland and the coast (4.5). Archaeological evidence further suggests that early Roman presence in the region led to conflict with the indigenous population, resulting in the destruction and abandonment of many Messapian settlements (D'Andria 1988). The incomplete attempts to fortify Roca Vecchia in the 4th or 3rd century B.C. (4.5), then a major settlement within the study-area, imply that many aspects of life, including economic practices, would have been disrupted during this time.

vi) By the late Roman period, any remaining mixed woodland or scrub was removed from the local environment, and probably from much of the region. Some arboreal elements, including *Tilia*, cease to be represented in the fossil record since the beginning of this phase (phase 6); the fossil record may have failed to represent any locally remaining areas of *macchia* (8.4.1).

Archaeological evidence implies that most Imperial Roman activity in the study-area was directed towards port operations and contact with the eastern Mediterranean (4.5). Even so, Novembre (1979) suggests that the agricultural organisation of this period in

Salento persisted until Medieval times. The presence of cereal-type pollen and disturbed ground taxa in the fossil record, decrease between this period and modern times, pointing either to change in economic practice or reduced usage of land around the present-day marsh. This may again be explained by the persistence of malaria in this coastal-margin zone. Olive cultivation is suggested to have begun on dry slopes of the catchment in the Medieval period (phase 6). This corresponds well with historical information for the expansion of olive cultivation in Medieval Salento (4.5).

9.6 CORE PP1

This core was extracted from a marshy depression within the former 'Paludi Pozzelle', for the purpose of examining sediment stratigraphy (5.2.3). Core stratigraphy is illustrated in Fig. 9.17a; depths in the core are recorded with respect to the modern marsh soil-surface.

9.6.1 Core stratigraphy

(bottom of core)

1.09-1.04m Calcarenite granules.
(indistinct boundary)

1.04-0.94m Dark-grey/brown silty clay, incorporating sand, granular calcarenite and organic matter.
(indistinct boundary)

0.94-0.88m Peaty clay, contains granular calcarenite.
(indistinct boundary)

0.88-0.48m Dark-brown peaty silt, contains sparse fragments of mollusc shells.
(indistinct boundary)

0.48-0m Dark-brown, well humified peat.
(top of core)

This exploratory core reveals that predominantly organic deposits lie above the calcarenite base of this shallow depression. The core contains no sand or clay deposits comparable to those of core 1AG, despite similarities in the geomorphological situations of the two cores. It is possible that aeolian sands of probable local coastal origin, which form distinct layers in cores 2AP, 3AP and 1AG (9.4 & 9.5), were not deposited in this more sheltered, inland depression.

The silt, clay and granular calcarenite content of the lower 0.56 m of the core, suggests that sediments from surrounding slopes were deposited in the basin by sheet wash, together with autochthonous organic remains; organic deposits predominate in the upper 0.48 m.

9.7 CORE RV88

This core was extracted from the cultivated depression west of Roca Vecchia (5.2.4). Core stratigraphy is illustrated in Fig. 9.17b; depths in the core are recorded with respect to the modern ground-surface.

9.7.1 Core stratigraphy

(bottom of core)

0.95-0.90m Buff coloured sand
(sharp boundary)

0.90-0.43m Mid-brown silt and organic deposit, mottled by iron staining. Contains charcoal.
(indistinct boundary)

0.43-0.07m Dark brown peat.
(top of core)

This exploratory core has been disturbed by ploughing to a depth of at least 0.5 m. Fine textured sand at the base of the core is probably of local aeolian origin; the basin in which this core is located is closed off from the coast, at its northern end, by dunes. Above this layer, silts and organic material represent allochthonous sediments from the basin catchment and autochthonous organic remains. Oxic conditions are indicated by iron staining in the silty organic deposits between 0.9 m and 0.43 m. This factor, combined with disturbance of the sediments due to cultivation practices, renders this core unsuitable for palynological analysis.

9.8 CORES SF88 and SF1

As explained in 5.2.5, both cores were extracted at the eastern margin of the marsh basin to the north-west of San Foca. Core SF1 provides a longer sediment sequence than core SF88, and was sampled for palynological analysis. Depths in the cores are recorded in metres with respect to the present ground surface at the core locations. Core-sediment stratigraphy is illustrated in Figs. 9.18a and 9.18b, and macrofossil distributions within core SF1 are presented in Table 9.5.

9.8.1 Core SF88: stratigraphy

(bottom of core)

- 1.3m Calcarenite bedrock.
 (sharp boundary)
 - 1.3-1.2m Dark-brown sand, stained by humic acids from overlying peat.
 (indistinct boundary)
 - 1.2-0.85m Dark-brown/black peat. Specks of calcarenite and mollusc shell are present.
 (indistinct boundary)
 - 0.85-0m Brown peat.
- (top of core)

9.8.2 Core SF1: stratigraphy and macrofossils

(bottom of core)

- 2.87m Grey/buff sand, comprised predominantly of quartz grains and including heavy mineral grains.
 (sharp boundary)
- 2.87-2.4m Dark-brown, organic-rich silt. Contains shells of Planorbidae.
 (sharp boundary)
- 2.4-2.33m Buff sandy silt, comprised predominantly of calcium carbonate. Shells of Planorbidae are present.
 (sharp boundary)

- 2.33-1.66m Dark-brown silt, containing dispersed quartz sand grains. Shells of Planorbidae and shell fragments are frequent.
(indistinct boundary)
- 1.66-1.0m Dark-brown peat. No shell fragments are present.
(indistinct boundary)
- 1.0-0m Dark-brown peat. Dispersed shell fragments are present.
(top of core)

9.8.3 Discussion of stratigraphy and macrofossil content

The fine textured sand at the base of both cores is of aeolian character and lies directly above the calcarenite. In the overlying silts of core SF1 (up to 1.66 m), the virtually continuous presence of charophyte oogonia, shell fragments and shells of Planorbidae, suggest that shallow water conditions prevailed during the deposition of these sediments (see chapter 7, part 3)). Whilst charophyte oogonia continue to be present above 1.66 m, shells of Planorbidae cease to be present and shell fragments are rare, suggesting that standing water conditions no longer occurred at the ground surface in this part of the basin. The homogenous layer of buff-coloured calcareous silt between 2.40 m and 2.33 m, was deposited in stagnant or slow-moving water, as suggested by the presence of shells of Planorbidae. It most likely originates from a phase of sheet-wash off exposed calcarenite slopes around the eastern part of the basin, possibly within localised rills.

9.8.4 Non-pollen microfossils in core SF1

The range of microfossils recorded from this core is similar to that recorded from core 1AG (9.5.3), reflecting the comparable depositional environments at the two core locations. In core SF1, however, the additional presence of microfossils from more water-dwelling algae testify to the local existence of shallow water during two phases of sediment accumulation represented by the core. Five assemblage zones are discerned in Fig. 9.19.

Assemblage-zone 1:

The consistent presence of Spirogyra, Mougeotia and the planktonic algae Botryococcus and Pediastrum in the lower dark-brown silt and buff coloured silt, indicate that shallow water was present during their deposition; the latter two algae are especially

frequent in the lower organic-rich silt. Further evidence for a shallow freshwater environment is provided in parts of this zone by the presence of chydorid head-shields, sponge sclere, Zygnema and Euastrum (chapter 7, part 2). This assemblage thus provides complementary evidence to that of microfossils in these sediments.

Concentricystes occurs only once within this core, in the buff, calcareous silt layer. It may have been transported together with the silt from higher ground above the shallow waters.

Assemblage-zone 2:

Microfossils representative of shallow water conditions continue to be present in zone 2, though occurrences are sporadic. Most notable is the scarcity of Botryococcus and Pediastrum, in contrast to their frequencies in zone 1. It is possible that continuing input of silty sediments to this location, progressively reduced the depth of standing water, thereby constricting the habitat of certain algae. The upper limit of this zone coincides with the upper limit of Planorbidae within the core (Table 9.5), confirming the cessation of standing water at this location.

Fungal remains and charcoal are more frequent in zone 2 than in zone 1, and may be associated with increased input of silts from the basin margin, as well as of allochthonous organic materials.

Assemblage-zone 3:

All microfossil evidence for standing water is absent from this zone. Spirogyra is the only alga represented, suggesting that moist soil conditions existed at the core location during the period represented by this zone (7.7.6i).

Assemblage-zone 4:

The re-appearance of Mougeotia at 0.9 m, and of Pediastrum, Cosmarium, sponge sclere and chydorid head-shields between 0.5 m and 0.3 m, suggests that standing water existed again at the ground surface; some scattered fragments of mollusc shell were detected in this zone of the core by X-ray radiography.

Assemblage-zone 5:

As in zone 3, zone 5 is distinguished by the absence of evidence for shallow water, and by the sole algal presence of Spirogyra. At the top of this zone, coincident with the modern ground surface, charcoal frequency is many times greater than at any other level within the core, and reflects modern burning of reed communities at the marsh fringe to clear land for cultivation. It appears therefore, that similar practice has not

previously affected the core location during the period represented by the core sediments.

9.8.5 Fossil pollen

Samples from the lower 0.5 m of this core, including the buff-coloured silt, were examined for fossil pollen in order to investigate possible changes in local vegetation-cover associated with the abrupt change in sediment. The results, presented in Fig. 9.20, reveal no significant change in the pollen record. Pollen assemblages are dominated by consistently high percentages of Compositae and Gramineae.

Quercus and Tilia pollen are present in most samples, but never exceed 2%. Whilst this indicates the probable local presence of Tilia, the source of Quercus pollen could be remote. The arboreal and shrub pollen frequencies do not suggest that woodland or macchia existed close to the core location during the period represented by these core sediments.

Relatively frequent pollen of Phragmites-type (see 7.1.7), contributing up to 6% of the pollen sum, suggests that Phragmites grew locally during the deposition of both the lower organic-rich silt, and the buff, calcareous silt. Phragmites would have favoured the shallow, stagnant water conditions indicated by macrofossil and microfossil analyses. Clusters of both Typha pollen and Epilobium pollen occur at 2.0 m, suggesting that the standing water was locally vegetated.

Fern spores are present in most samples from this section of the core, and probably originate from marsh vegetation fringing the areas of standing water. It is probable that the abundant Compositae pollen also originate from a local marsh community similar to that postulated for pollen assemblage-zone A in core AP88 (9.2.5).

Pollen assemblages in this lower section of core SF1 differ little from the modern surface-sample assemblage at the core location, presented in chapter 8, Table 8.12. The interjacent core sediments contain similarly high proportions of pollen representing local herbaceous and marsh vegetation, and infrequent arboreal pollen. Hence the pollen record of this core appears to represent the local environment in recent history.

9.8.6 Summary of local environmental conditions interpreted from core SF1

Relatively open, shallow, stagnant water existed at the core location during deposition of the lower 0.5 m of sediment, but water depth was progressively reduced by the input of silts from surrounding slopes. Wet conditions and stagnant water existed at the core location, at least seasonally, up to 1.66 m in the core. These conditions were succeeded by a drier phase, corresponding to microfossil assemblage-zone 3, followed by a second wet phase, as indicated by the algal remains of zone 4. Within less than 0.2 m of the top of the core, drier conditions were resumed at the core location, continuing until the present day.

Thus the sedimentary and fossil evidence from core SF1, broadly reflects the conditions of 'La Longa' marsh as interpreted in 4.3, from the report by Orlando (1885). 'La Longa' was described as a seasonally inundated marsh, in which standing water reached a maximum depth of 0.5 m. The lower silty core-sediments confirm that rainwater runoff from surrounding slopes contribute at least part of the water collected in the basin. There is no evidence, however, from macrofossils and microfossils to suggest that marine water influenced the part of the basin represented by core SF1.

9.9 CORES C1 and PG

The analyses presented in sections 9.9 to 9.14, are of cores from the Cesine region of coastal lagoons and marsh (see 5.2.6). A synopsis of environmental change in the Cesine region, interpreted from these analyses, is given in 9.15.

As described in 5.2.6, exploratory core C1 was extracted from mudflats at the northern-most shore of Pantano Grande, whilst core PG was extracted from the western shore of this lagoon and samples the entire sediment sequence above the calcarenite in this location.

Depths in both cores are recorded with respect to the modern shore or mud-surface; core stratigraphy is illustrated in Figs. 9.21a and 9.21b. Sediments and mollusc-shell content of core C1, described below, change little over the short core sequence. Macrofossil distribution in core PG is illustrated in Table 9.6. In core PG, sediments revealed distinct changes in the local depositional environment, and were subject to palynological analyses; pollen preservation and concentration was poor throughout the core.

9.9.1 Core C1: stratigraphy and macrofossils

(bottom of core)

0.78-0.58m Dark-grey silty clay. Shell fragments, including shells of Cerastoderma, are present.

(indistinct boundary)

0.58-18.8m Grey/brown sandy clay. Complete bivalve shells of Cerastoderma are present.

(sharp boundary)

18.8-0m Mid-brown sandy clay.

(top of core)

9.9.2 Core PG: stratigraphy and macrofossils

(bottom of core)

- 2.25m Calcarenite.
(sharp boundary)
- 2.25-2.03m Dark-grey/brown sandy silt.
(indistinct boundary)
- 2.03-1.82m Dark-brown silt with dispersed sand grains.
(sharp boundary)
- 1.82-1.48m Greenish yellow/grey sand. Contains charcoal fragments and charophyte oogonia.
(sharp boundary)
- 1.48-0.02m Dark-brown peaty silt. Sand grains are very sparse. Sparse shell fragments are scattered between 1.25 m and 1.05 m, as revealed by an X-ray radiograph, otherwise mollusc shells in this layer are confined to the upper 0.07 m of sediment; shells include Hydrobiidae and Cerastoderma. Charophyte oogonia are discontinuously present from 0.7 m to 0.3 m.
(sharp boundary)
- 0.02-0m Modern, sandy shore deposit, dense with shell fragments, shells of Hydrobiidae and Cerastoderma, ostracod carapaces and Foraminifera tests. Charophyte oogonia are also present.

(top of core)

9.9.3 Discussion of stratigraphy and macrofossil content in core PG

The lower sandy silt, in contact with the calcarenite, contains no macrofossils and is probably of aeolian origin. The dark colour and silty texture of the overlying layer suggests that wet conditions subsequently developed at the core location, encouraging local plant growth. Wet conditions may have continued at the core location during deposition of the second fine-sand layer, as charophyte oogonia are incorporated in the lower part of this deposit. The particle-size distribution of a sample from this sand closely resembles those of sands from cores 3AP and 1AG (Fig. 9.22), which represent aeolian sands from more than one local source, as argued in 9.4.3; also shown in Fig. 9.22, is a particle size distribution of sands from core CM within the Cesine environment (see 9.14).

Peaty silts lying above the sand layer and forming most of the remainder of the core, suggest that moist conditions prevailed at the core location, permitting the establishment of marsh vegetation. Wet surface conditions are suggested only by the presence of mollusc shell fragments in the upper 0.07 m of the core. Proximity to the modern saline lagoon is not indicated until the upper 0.02 m of the core, where sand and mollusc shells form the modern shore deposit.

It appears, therefore, that the encroachment of saline lagoon waters over the core location has influenced only the upper 0.07 m of the core sediments; a shoreline depositional environment has developed here in modern times.

9.9.4 Non-pollen microfossils

Microfossil distributions within core PG are illustrated in Fig. 9.23, within which seven assemblage-zones are distinguished.

Assemblage-zone 1:

This zone contains no fossils of planktonic or moisture loving algae, suggesting that dry conditions existed at the core location during deposition of the lower sandy silt above the calcarenite. Concentricystes is notably present in this zone.

Assemblage-zone 2:

Large increases in the frequencies of charcoal and fungal spore-type 1 occur in this zone, which corresponds to the dark silt layer between the two sand layers. This possibly represents in-washed soil material from nearby soils, perhaps disturbed by human activity. A change to locally moist or wet conditions is suggested by the presence of sponge sclere (7.6.2) and Spirogyra (7.7.6i).

Assemblage-zone 3:

The presence of Spirogyra and the planktonic alga, Botryococcus, in the aeolian sands which correspond to zone 3, suggest that these sands were deposited under wet conditions at the core location, influenced by fresh to brackish water. Fungal remains and charcoal fragments are markedly less frequent in this zone, reflecting the influx of sand rather than of eroded soil material.

Assemblage-zone 4:

Prevalently wet conditions, of fresh to brackish water quality, are suggested by the presence of sponge sclere, Botryococcus, Spirogyra, and Zygnema in peaty silt overlying the aeolian sands. The presence of a dinoflagellate cyst of Genus A (7.7.2) at 1.4 m, further suggests that a water body influenced the core location at this stage. Since other algae of this zone are tolerant of fresh to brackish water, it is probable that this dinoflagellate shares similar tolerance of low salinity, as also suggested from its occurrence in core AP88 (9.2.3), core 1AP (9.3.3) and in the modern-mud sample from Alimini Piccolo (8.4).

Mycorrhizae and fungal spores are more frequent in zone 4, and may be associated with the influx of soil material and possible development of local herbaceous vegetation during the period represented by this zone. A large increase in charcoal frequency at 1.3 m, and sustained high frequencies until the level of the modern shore deposit, suggests that fire regularly occurred in the vicinity of the core location.

Assemblage-zone 5:

This zone is distinguished by the presence of chydorid head-shields and remains of other Cladocera, together with Mougeotia and Cyanophyceae. All except the Cyanophyceae are considered freshwater organisms (chapter 7, part 2), and are confined to this zone of the core. Cyanophyceae tolerate some salinity, but favour ponds and weedy margins of water bodies (7.7.3), as do the Cladocera (7.6.1) and Mougeotia (7.7.6iii). Their presence, combined with the continued occurrence of sponge sclere, Botryococcus, Spirogyra and Zygnema suggest that standing water, perhaps at the fringe of a water-body, existed at the core location. Water quality was predominantly fresh, with possibly some brackish influence; mixing of saline water and freshwater occurs on the west side of Pantano Grande today, as indicated by the modern microfossil assemblage (8.5).

Mycorrhizae are conspicuously less frequent in this zone of the core, possibly reflecting locally wetter conditions and perhaps reduced input of soil material to the core location during this period.

Assemblage-zone 6:

Zone 6 is distinct from all lower zones of the core, in that diatoms appear for the first time, represented by frustules of Campylodiscus, a planktonic genus tolerant of low to high salinity. This genus was dominant in microfossil assemblages of modern-mud samples from Pantano Grande (8.5). The probable existence of a water body over the core location is further suggested by the presence of sponge sclere, Cyanophyceae and

Botryococcus, together with Spirogyra and Zygnema. Mycorrhizae and spore-type 1 reach their highest levels in the core in zone 6, probably signifying the input of soil material to the water body from adjacent, possibly disturbed ground.

Assemblage-zone 7:

Modern shore conditions at the top of the core are marked in the microfossil assemblage by frustules of additional diatoms, including the genera Diploneis and Amphora, tolerant of saline water. The absence of Zygnemataceae from this zone probably reflects recent increase in salinity levels at the present lagoon shore (3.7.6).

9.9.5 Interpretation of local environmental change represented by core PG

Environmental information deduced from the microfossil record in core PG, agrees with and supplements information derived from the core sediments and macrofossils (9.9.3). From the combined data, the following phases of environmental change are proposed.

Phase 1: Prevalently dry conditions existed at the core location whilst aeolian sands were deposited above the calcarenite surface, which lies 2.25 m below the present ground surface. Relative sea-level was therefore probably at least 2 m below its present level, since it did not influence sediments at the core location directly, or indirectly by raising groundwater levels. According to generally accepted views on the pattern of glacio-eustatic sea-level rise in the Holocene (12.5.1), sea-level may have been around 2 m below its present position at c. 2000 BP, attributing a Roman or earlier age to the aeolian deposits. In this region, however, some degree of neotectonic subsidence may have contributed to relative sea-level change (4.2), but as yet, any such subsidence has not been quantified.

As noted in 2.4.5, the lower levels of the youngest dune cordons on both the Adriatic and Ionian coasts of Salento, have been dated to around 2110 BP (Magri & Zezza 1970). The current dune cordon lying between the Cesine lagoons and the Adriatic probably originates from the same phase of dune accumulation. It is possible that aeolian sands a short distance inland, such as those in cores PG, CS2 (9.12) and CM (9.14), are also related to this early phase of sand movement. This adds support to the suggestion that sea-level contemporary with the core sands, was approximately 2 m below its present level.

Phase 2: Moist to wet conditions developed after the first phase of aeolian deposition, in which organic materials accumulated at the core location. Allochthonous inputs to this silty sediment were possibly promoted by human activity in the locality, as suggested by high microscopic charcoal frequencies. Rising groundwater levels, floating on rising sea-level penetrating the calcarenite, probably accounts for this change to moister local conditions; as indicated in 5.2.6, fresh to brackish groundwater presently mixes with saline water on the western side of Pantano Grande.

Phase 3: A further phase of aeolian sand deposition occurred whilst fresh to brackish wet conditions persisted at the core location, as suggested from charophyte oogonia and planktonic algae incorporated by the sands. The movement of such a significant amount of sand, suggests that coastal dune sands were unstable at this time, perhaps due to sea-level reaching a sufficiently high level to undercut the bases of the dunes.

Phase 4: Continued groundwater rise, most likely governed by sea-level rise, is suggested by the algal microfossil- assemblage in the peaty silt overlying the sands. A water body probably existed by this time in the depression that now contains Pantano Grande, whilst marsh vegetation developed at its margin. At the core location, water quality was fresh to brackish within the marshy fringe.

Phase 5: Indications for standing water at the core location are provided by microfossils at an earlier stage than by macrofossils. While organic sediments accumulated between 0.7 m and 0.4 m below the present ground level, standing water existed at the core location, suggesting that sediments at this stage were submerged by a water body, which was locally of predominantly freshwater quality.

Phase 6: The influence of saline water over the core location becomes apparent in the core at 0.3 m and above, suggesting that sea-level was approaching its present level and influencing the water body by seepage through the dunes and calcarenite, and perhaps by breaching the dune cordon. On the western margin of the water body, the influx of freshwater and eroded soil materials continued.

Phase 7: Shore conditions developed at the core location only in recent times. As observed in 3.7.6, dead roots of Phragmites at the present western margin of the lagoon testify to less saline water conditions in the recent past. The salinity of Pantano Grande has increased as a result of an imbalance between freshwater and saline water supply, arising in part from artificial drainage of marsh areas (5.2.6) and exacerbated by a recent series of dry years (3.7.6).

Thus core PG represents the development of a marshy environment at the margin of a water-body, which has changed in quality from being predominantly fresh on its western margin, to predominantly saline. The pattern of sediment accumulation is satisfactorily explained in terms of relative sea-level rise over probably the past two millennia. According to this hypothesis, and on the basis of sedimentological and fossil evidence from the core, dry conditions prevailed at the core location for a period within and prior to Roman times, during the Holocene.

9.10 CORE C2

This core was extracted from exposed mudflats on the western shore of the largest of the Salapi lagoons, as described in 5.2.6. Core depths are recorded with respect to the modern mud-surface, lying within 0.5 m of sea-level. Core-sediment stratigraphy is illustrated in Fig. 9.24 and macrofossil distributions are presented in Table 9.7.

9.10.1 Core stratigraphy and macrofossils

(bottom of core)

1.0-0.1m Dark grey/brown sandy silt. Complete bivalve shells of Cerastoderma are present throughout, and are particularly concentrated between 0.52 m and 0.25 m.

(indistinct boundary)

0.1-0m Dark grey/brown sandy silt.

(top of core)

9.10.2 Discussion of stratigraphy and macrofossil content

Quartz and calcium carbonate are predominant in the sand fraction of this lagoon-margin deposit; grains of black and green heavy minerals (3.6.6) are also frequent, and may have been transported from the Adriatic littoral to the core location by wind or water. As shown in Table 9.7, macrofossils from water-dwelling animals are abundant throughout the core, except in the sample at 1.0 m. Ostracod carapaces are sparsely present in this sample but mollusc shells and Foraminifera tests are absent, possibly indicating that relatively dry conditions existed at this stage of deposition.

Shells of Lymnaeidae are present in the core between 0.9 m and 0.6 m, suggesting that slow-moving, vegetated water of low salinity (7.12.1) existed at the core location during the period represented by this section of core; supporting evidence is provided by the presence of charophyte oogonia throughout the core. The additional presence of Foraminifera tests and shells of Hydrobiidae and Cerastoderma sp. suggest that brackish to saline water also influenced the core locality throughout its depositional history above 0.9 m in the core. Ostracod carapaces are abundant above 0.9 m, further suggesting the continuous presence of a water body at the core location.

9.10.3 Non-pollen microfossils

The presence of diatoms throughout core C2, together with dinoflagellate cysts and other microfossils of water-dwelling algae, suggest that a water body has continuously influenced the core location during the period represented by the core. Differences in microfossil distribution with core depth, however, point to changes in the local aquatic environment. Three assemblage-zones are distinguished in the diagram of microfossil distribution in core C2 (Fig. 9.25).

Assemblage-zone 1:

Water of mixed salinity is suggested by the range of microfossils in this zone. Freshwater is represented by Mougeotia, Zygnema and Cladoceran remains, low salinity by Spirogyra, Pediastrum, Botryococcus, dinoflagellate Genus A and sponge sclere, whilst some influence by low to high salinity water is suggested by Cyanophyceae, Spiniferites and the diatom assemblage (see chapter 7, part 2). Mougeotia is confined to zone 1 of the core, suggesting that a shallow, freshwater environment prevailed at the core location; this alga requires such conditions to produce the observed fossil spores (7.7.6iii).

Frequencies of the genera Campylodiscus and Surirella, tolerant of saline water, together with unidentified diatom genus (1) (7.7.1), greatly increase towards the top of zone 1. These diatoms together with Cyanophyceae, which also reach high frequencies in the upper part of zone 1, may have flourished in the shallow, possibly vegetated and nutrient-rich water on the water-body margin; as noted in 7.7.1, however, many factors influence diatom populations.

Charcoal and fungal remains are most frequent in zone 1 of core C2, further suggesting that the core location was situated at the water-body margin, where it could also receive eroded soil material.

Assemblage-zone 2:

Although Mougeotia is absent from this zone, fresh- to low salinity water is still represented by Cladocera and Zygnema, amongst other microfossils. Campylodiscus, Surirella and the unidentified diatom genus (1) reach peak frequencies in zone 2, though Cyanophyceae are less frequent than in zone 1 and Spirogyra are absent. This possibly suggests that water depth had increased and become less vegetated at the core location, with the relative increase in distance from the water's edge. Marked reductions in fungal frequencies in this zone may be similarly explained.

Assemblage-zone 3:

A water body of mixed salinity is again indicated over the core location by microfossils of zone 3. Freshwater is represented by the presence of desmids and Cladocera, whilst many microfossils representing organisms tolerant of some salinity are also present. Diatoms are less frequent than in zones 1 and 2, apart from Craticula. The diatom genus Hantzschia occurs in zone 3, and its association with littoral lake areas and damp soil (Barber & Haworth 1981) may suggest that water-level was lowered during the period represented by this zone; it may equally have been washed in from nearby soils. A lowering of water-level may explain the absence of dinoflagellate Genus A from this zone, after having been present in all samples of zones 1 and 2.

Frequencies of fungal remains increase again in zone 3, suggesting that littoral soil material could reach the core location, perhaps due to the proposed lowering of water-level.

9.10.4 Evidence for local environmental conditions from spores and pollen of aquatic plants and marsh plants

Frequencies of spores and pollen from plants of wet ground and aquatic plants in core C2 are presented as absolute frequency estimates in Fig. 9.27.

The proposed presence of a fresh to brackish water body at the core location throughout the period represented by the core sediments (9.10.2), is confirmed by relatively high frequencies of Ruppia pollen (see 9.2.4) in all but the upper-most core sample. Proximity of the core location to a vegetated fringe, during the period represented by microfossil zone 1, is strongly suggested by the presence of Typha pollen; as noted in 8.4.1, Typha is under-represented in modern surface-samples from marsh in the study-area.

This agrees well with evidence for shallow freshwater, interpreted from the distribution of Mougeotia in the core, and supports the proposed existence of vegetated marginal waters interpreted from Cyanophyceae and diatom frequencies in zone 1. The much reduced and sporadic occurrence of Typha pollen above 0.5 m in the core, suggests that local water conditions became perhaps too brackish or too deep for continued growth. The proximity of moist to dry land is indicated by relatively high frequencies of Cyperaceae pollen throughout the core, and by the occurrence of Pteridium and Filicopsida spores mostly within core sediments corresponding to zone 1.

9.10.5 Interpretation of local environmental change represented by core C2

Combined evidence from macrofossils, microfossils and pollen of aquatic plants, strongly suggests that a water body of mixed salinity influenced the core location throughout the period represented by the core sediments, as is the situation today. While sediments were deposited between 0.9 m and 0.6 m below the present ground surface, slow-moving and shallow, vegetated water of predominantly freshwater quality existed at this location, as particularly suggested by the fossil distributions of *Lymnaeidae*, *Mougeotia* and *Typha*. Between 0.6 m and 0.3 m in the core, the absence of *Lymnaeidae* combined with changes in the microfossil assemblage and reductions in *Typha* pollen frequencies, suggest that the water body became more saline overall and perhaps deeper at the core location. Above 0.3 m, a reduction in water depth is suggested, which may be attributed to the accretion of silt at the core location, combined with a reduced water supply resulting from artificial drainage of marsh around the Salapi during the past century (5.2.6).

9.10.6 Fossil pollen

i) Pollen concentration and preservation

As illustrated in Fig. 9.27, estimated pollen concentration fluctuates mostly between 2000 grains/ml and 12500 grains/ml; the bottom-most sample, at 1.0 m, has the greatest pollen concentration in the core, of 18000 grains/ml. Pollen grains were generally well preserved and changes in pollen concentration are not associated with changes in core-sediment type.

ii) Pollen assemblage-zones

Three assemblage-zones are discerned from the diagrams of percentage pollen frequency (Fig. 9.26) and estimated absolute pollen frequency (Fig. 9.27).

Assemblage-zone A:

This zone is defined by high frequencies of herbaceous pollen and relatively low frequencies of arboreal and shrub pollen.

Arboreal component: Total, arboreal pollen frequency in zone A is the lowest in the core. Of the taxa represented, total *Quercus* pollen is most frequent (8.5%), suggesting that both evergreen and deciduous members of this genus were present within the

Cesine area in tree or shrub form. Pinus pollen is present in similar frequencies, suggesting that pine possibly occurred locally, but as noted in chapter 8, pine was considerably over-represented in pollen-assemblages from surface-samples within the study-area. The low percentage of Oleaceae pollen at 0.9 m is of Fraxinus type (see 7.1.2), and may originate from trees or shrubs growing in association with Quercus. Also represented, possibly as part of a local wood or scrub community, are Corylus, Ostrya/Carpinus orientalis and Castanea-type (see 7.1.5). The presence of Juniperus pollen is probably associated with coastal macchia. Abies pollen occurs in this zone of the core, but the bisaccate grain is most likely to have arrived by long-distance transport from higher altitudes in southern Italy, or from across the Adriatic.

Shrub component: The presence of poorly dispersed Hedera pollen (8.4.1) suggests that scrub or shrub vegetation was growing close to the western Salapi margin, in the vicinity of the core location. Further indication for the local presence of a shrub community, is provided by the presence of Rhamnus and Pistacia, both of which are poorly represented in modern surface-samples from the study-area (8.4.1). Ericaceae pollen constitutes 3% of the pollen sum of this zone, and similarly suggests that a shrub community existed nearby.

Herbaceous component: Compositae pollen dominates zone A; the Ligulifloraceous type is particularly frequent. As acknowledged in 9.2.5(zone A), high relative proportions of Compositae pollen may result from differential preservation within a pollen assemblage. Such bias is not apparent in zone A of core C2, since pollen of normally poorly represented shrub taxa are also present. In this case the high Compositae pollen frequencies suggest species of Compositae grew close to the core location, perhaps within marsh vegetation. Pollen of Chenopodiaceae is also frequent at the top of zone A, and is likely to represent salt-tolerant species growing around the water's edge. Other herbaceous pollen taxa present in zone A have low frequencies, and may be associated with marsh vegetation or open vegetation on dry ground.

Assemblage-zone B:

This zone is defined primarily by high frequencies of Quercus pollen in the core.

Arboreal component: Frequencies of Pinus pollen steadily increase to 25% of the pollen sum at the top of zone B, suggesting that the presence of pine increased within the Cesine area, either as individual trees or as part of a macchia community; Pinus halepensis favours dry, coastal situations (Polunin & Walters 1985). These frequencies do not necessarily signify the presence of pine close to the core location, since pine pollen constituted between 30% and 40% of the pollen sum in surface-samples more

than 140 m distant from a source, along the Cesine transect (see 8.3, Fig. 8.1). High frequencies of Quercus pollen, varying between 14% and 19% in zone B, are of more significance locally, and suggest that oak trees or shrubs grew close to the western Salapi margin.

A small local or regional presence of Alnus, Corylus and Ostrya/Carpinus orientalis is also represented. Oleaceae pollen is more frequent in zone B than in zone A, suggesting that some species of Oleaceae expanded locally, possibly associated with Quercus wood or scrub. The occurrence of Juglans regia pollen suggests that a source existed close to the core location, and may signify human activity in the local landscape (see 9.5.7i). A grain of Picea pollen, another bisaccate type capable of travelling long distances, most likely originates from high land outside Salento; according to Pignatti (1982), Picea is absent from southern Italy today.

Shrub component: The range of shrubs represented in zone B strongly suggest that a well developed shrub community existed close to the core location, either as undergrowth beneath a mixed evergreen and deciduous, open woodland, or as macchia. Hedera, Pistacia and Ericaceae continue to form a significant part of the pollen assemblage, whilst Rhamnus and Rosaceae are more strongly represented than in zone A. The additional presence of Tamarix, Myrtus and Ephedra pollen in zone B further supports the proposed local existence of a shrub community. The solitary occurrence in the core of Vitis pollen, at 0.6 m, may originate from vine cultivation elsewhere in the study-area.

Herbaceous component: Frequencies of Compositae pollen are greatly reduced in zone B (Figs. 9.26 & 9.27). This may be explained by the local expansion of shrub communities over open land close to the western Salapi margin. Certain other herbaceous species of open ground, however, become more significant in zone B, especially those associated with disturbed ground, including Cruciferae, Artemisia and Plantago. Human economic activities within the Cesine landscape may be responsible for increases in these pollen taxa (see 8.4.1), but Artemisia and Plantago occur naturally in coastal areas (Behre 1981), and Cruciferae are naturally represented at present, for example, on dunes along the Cesine coastline (8.3.3 and Appendix B). Chenopodiaceae pollen dominates the assemblage at 0.4 m, and most likely represents salt-tolerant species at the water-body margin, close to the core location.

Assemblage-zone C:

This zone is defined by substantial reductions in Quercus pollen frequencies and significant increases in some pollen taxa, pointing to anthropic influence over local vegetation patterns.

Arboreal component: As shown in Figs. 9.26 and 9.27, frequencies of Quercus pollen are considerably lower in zone C than in zone B. Pine pollen frequencies are similarly reduced, apart from in the upper-most core sample where pine constitutes 50% of the pollen sum, representing the development of pine plantations in the Cesine area since the 1940's (Medagli 1980). Ostrya/Carpinus orientalis continues to be represented in the lower part of zone C, above which it possibly disappears from the local landscape. Oleaceae, Corylus and Alnus continue to be represented throughout zone C. Frequencies of Juniperus are higher and more consistent in this zone of the core, suggesting the continuing presence of coastal macchia.

Shrub component: The local presence of a shrub community is suggested by the continued presence of Tamarix, Pistacia and Ericaceae pollen. Previously significant frequencies of Rosaceae and Rhamnus pollen are greatly reduced in zone C, whilst Hedera pollen is absent from this zone, suggesting that these shrub genera were associated with the formerly more extensive Quercus growth locally. The assemblage suggests that a macchia community, including Pistacia and Ericaceae, existed close to the core location on the western side of the Salapi.

Herbaceous component: In sample 0.3 m, pollen of Cruciferae, Plantago and Gramineae sharply increase to frequencies of between 13% and 17%. Such high frequencies occur in modern surface-samples from areas of open vegetation in the Cesine (see 8.3, Fig. 8.1). Their occurrence in zone C of the core suggests that areas of open vegetation increased in extent, possibly as a result of scrub and macchia clearance for agricultural landuse.

Combined pollen and microfossil analyses from core C2 are interpreted together with corresponding analyses from core CS1, in 9.11.7. A chronology for environmental change in the vicinity of the Cesine Salapi, as represented by cores C2 and CS1, is discussed in 9.11.8.

9.11 CORE CS1

As explained in 5.2.6, this core was extracted from a point close to the Bronze Age archaeological feature described in 3.6.2, in order to investigate environmental change in the vicinity of this site and the possible local environmental impact of human activity. The core was extracted from marsh beside the northern-most edge of the smallest Salapi water body (5.2.6). Depths in core stratigraphy are recorded in metres with respect to the present ground surface. Core sediments are illustrated in Fig. 9.28 and macrofossil distributions are presented in Table 9.8.

9.11.1 Core stratigraphy and macrofossils

(bottom of core)

- 1.53m Calcarenite bedrock.
(sharp boundary)
- 1.53-1.25m Brown/grey silty clay. Present are charophyte oogonia, shells of Planorbidae, Hydrobiidae and Cerastoderma type.
(indistinct boundary)
- 1.25-0.69m Buff/grey sandy clay. Precipitated calcium carbonate is responsible for the buff colouring. Charophyte oogonia, ostracod carapaces and shells of Hydrobiidae and Cerastoderma type are present throughout. Foraminifera tests, shells of Planorbidae and Scrobiculariidae are sparsely present.
(indistinct boundary)
- 0.69-0.55m Grey/brown silty clay. Charophyte oogonia, Foraminifera tests, ostracod carapaces and shells of Hydrobiidae and Cerastoderma are present.
(indistinct boundary)
- 0.55-0.21m Buff-coloured silty clay. Charophyte oogonia, ostracod carapaces and shells of Hydrobiidae and Cerastoderma are present.
(sharp boundary)
- 0.21-0.1m Coarse calcarenite sand/granules. Shells of Hydrobiidae are present.
(indistinct boundary)
- 0.1-0m Dark-brown silt with high content of plant remains. Shells of Planorbidae and Hydrobiidae are present at the bottom of this layer. Sparse shells of Cerastoderma type and ostracod carapaces are present near the surface.

(top of core)

9.11.2 Discussion of core stratigraphy and macrofossils

The consistent presence of charophyte oogonia, ostracod carapaces and mollusc shells including Hydrobiidae and Cerastoderma type, from the bottom of the core to 0.3 m, indicates that a water body with some degree of salinity existed over the core location, throughout the deposition of these sediments. The absence of charophyte oogonia above 0.3 m and the sporadic presence of mollusc shells suggests that the core location ceased to be perennially inundated by the water-body, perhaps permitting marsh vegetation to establish.

These two phases are separated by a layer of coarse calcarenite sand, between 0.21 m and 0.1 m, which resembles broken down calcarenite bedrock. The granular texture of this deposit suggests it was produced by anthropological working of the calcarenite, possibly associated with cutting the drainage channel 'Canale Colletore Cesine', which passes through the calcarenite within 27 m of the core location (5.2.6). The local introduction of artificial drainage would also explain the apparent reduction in the influence of a water body over the core location, as suggested by macrofossil distributions above 0.3 m in the core. If the granular layer is correctly linked with drainage works, which were completed within the 1940's (5.6.2), then the upper 0.2 m of the core sediments are little more than 50 years old. No pottery shards were found within the core sediments to correlate with the eroding horizon observed at the channel edge (see 5.2.6).

9.11.3 Non-pollen microfossils

The five assemblage-zones distinguished in the diagram of microfossil distribution in core CS1 (Fig. 9.29), correspond closely to sediment stratigraphy in the core.

Assemblage-zone 1:

Frequencies of charcoal and fungal remains are highest in zone 1 of the core, which coincides with the brown/grey silty clay above the calcarenite, and probably represent locally eroded soil material. Freshwater runoff or seepage may have transported this material to the core location, where it was probably deposited in water of low salinity. Freshwater or water of low salinity is suggested by the presence of sponge sclere, Cyanophyceae, Botryococcus, Euastrum and Spirogyra, while brackish water is suggested by the diatom assemblage and Spiniferites (see chapter 7, part 2).

Assemblage-zone 2:

In this zone, freshwater and the input of soil material are less well represented; algal microfossils present, including diatoms, Botryococcus and Cyanophyceae, suggest that a water body of brackish water quality or low salinity was present over the core location.

Assemblage-zone 3:

An increased diversity among microfossils representative of freshwater in zone 3, including Cladoceran remains, Cosmarium and Mougeotia, suggests that freshwater input contributed significantly to the water body, at least locally, during the period represented by this zone. The presence of Mougeotia may also signify shallow water depth at the core location (7.7.6iii). Botryococcus and the diatoms Campylodiscus and unidentified genus (1) (7.7.1) reach high frequencies in zone 3, and possibly favour the proposed shallow water environment. In core C2, frequencies of these two diatom genera similarly reach high frequencies in zone 1, where Mougeotia is also present (9.10.3).

Assemblage-zone 4:

Between 0.7 m and 0.6 m in the core, frequencies of Campylodiscus and unidentified diatom genus (1), greatly decrease in frequency, strongly resembling their distribution pattern in core C2 (Fig. 9.25). Many factors could contribute to this marked population change (7.7.1) but the similarity between distributions in cores CS1 and C2 suggests that a widespread change in the Salapi environment took place at the time represented by samples 0.7 m and 0.6 m in core CS1. Water of mixed salinity is represented by the algal microfossil assemblage of zone 4. Mougeotia is absent from this zone, but desmids and Cladoceran remains suggest there was some freshwater input. Among microfossils representing water of low salinity to saline quality, are dinoflagellate genus A and Spiniferites.

Assemblage-zone 5:

Algal microfossil frequencies are greatly reduced in zone 5, whilst mycorrhizae and fungal spore-types 3 and 4 increase in frequency. This supports the interpretation based upon macrofossil evidence (9.11.2), that water-level was lowered by artificial drainage works close to the core location, allowing vegetation to become established and organic sediments to develop at the core location.

9.11.4 Evidence for local environmental conditions from spores and pollen of aquatic plants and marsh plants

Frequencies of spores and pollen from plants of wet ground and aquatic plants are presented as absolute frequency estimates in Fig. 9.31. *Ruppia* pollen is present in two sections of the core, roughly corresponding to microfossil assemblage-zones 2 and 4. Its absence from core samples corresponding to zones 1, 3 and 5 appears to reflect changes in salinity and water depth at the core location, as interpreted from the microfossil assemblages. The presence of *Typha* pollen between 1.4 m and 0.6 m in the core suggests that rushes grew close to the core location throughout much of the core's depositional history. Consistent presence of Cyperaceae pollen in the core, and the presence of *Pteridium* and Filicopsida spores in some samples (Fig. 9.31), suggest that moist to dry land existed close to the core location throughout the period represented by sediments of core CS1.

9.11.5 Interpretation of local environmental change represented by core CS1

Both macrofossil and microfossil evidence suggest that a water body of mixed salinity influenced the core location throughout the period represented by the core sediments. The microfossil assemblages, together with pollen representative of aquatic and marsh plants (9.11.4) suggest that until the past century, when drainage works lowered groundwater levels, a vegetated margin of the Salapi water body existed at the core location.

9.11.6 Fossil pollen

i) Pollen concentration

In the granular calcarenite layer, pollen concentration was too poor to achieve the pollen sum. Pollen concentrations generally increase with depth in the core, from 3800 grains/ml at 0.3 m, to 18000 grains/ml at 1.5 m (Fig. 9.31). This pattern could result from steadily increasing rates of sedimentation at the core location, or from increasing compression of the lower core sediments with depth, but without dated levels within the core the cause cannot be determined.

ii) Pollen assemblage-zones

Three pollen assemblage-zones are discerned from the diagrams of percentage pollen frequency (Fig. 9.30) and estimated absolute pollen frequency (Fig. 9.31).

Assemblage-zone A:

This zone is defined by high frequencies of Compositae pollen. Strong similarities exist between the assemblage and relative frequencies of this zone and that of zone A in core C2 (9.10.6).

Arboreal component: Quercus pollen of both evergreen and deciduous type are present in equal proportions in zone A, but together form less than 10% of the pollen sum, suggesting that mixed oaks were present in the Cesine area but were not dominant locally. Low frequencies of Pinus pollen suggest that pines did not exist close to the core location, though they may have been present in the Cesine area. Oleaceae pollen of both Fraxinus and Olea type occur in zone A at low frequencies, suggesting that trees or shrubs of Oleaceae existed within the Cesine vegetation. Pollen identified as Castanea (see 7.1.5) is confined to zone A of core CS1, and is likewise confined to zone A of core C2.

Shrub component: The presence of Hedera helix pollen in zone A, whilst arboreal pollen frequencies are low, suggest that this climber was growing close to the core location, in association with a shrub community. The occurrence of Vitis pollen in zone A may be similarly associated (see 9.5.5, zone A). Significant frequencies of Ericaceae pollen, together with Rosaceae, suggest that a shrub community did exist locally. The absence of pollen from other typical macchia genera, need not indicate their absence from the local landscape (8.4.1).

Herbaceous component: High frequencies of Compositae pollen in zone A are likely to represent the local occurrence of Compositae species. The argument against differential preservation accounting for high relative frequencies of Compositae pollen, put forward in explanation of assemblage zone A in core C2 (9.10.6), also applies in this case, where under-represented genera including Hedera helix are present. Some herbaceous taxa of open ground are represented by low pollen frequencies in zone A, including Malvaceae and Plantago, whilst other pollen taxa including Labiatae, Umbelliferae and Gramineae may be associated with either dry open ground or with locally marshy ground.

Assemblage-zone B:

High frequencies of Quercus pollen distinguish zone B from the rest of the core. The pollen assemblage and relative pollen frequencies closely resemble that of zone B in core C2 (9.10.6).

Arboreal component: Combined frequencies of evergreen and deciduous type Quercus pollen greatly increase to 34% of the pollen sum at the base of zone B, and remain above 20% until 0.7 m; estimated absolute frequencies of Quercus pollen are similarly highest in zone B of the core (Fig. 9.31). These sustained high frequencies suggest that mixed oaks in tree or shrub form existed close to the core location, throughout the period represented by zone B. Relative frequencies of Pinus pollen steadily increase in zone B to 16% at 0.7 m, although these frequencies are insufficiently high to suggest that pine occurred close to the core location, as explained in the description of zone B, core C2 (9.10.6). Consistently present in this zone are pollen of Corylus and Ostrya/Carpinus orientalis together with Oleaceae pollen, which reaches a peak frequency in the core at 0.9 m. These taxa could naturally associate with Quercus, forming mixed woodland or scrub at the northern end of the largest Salapi lagoon.

The presence of Alnus pollen throughout zone B may be of little local significance, as it frequently exists in assemblages far from its source (8.3.1). Higher frequencies of Alnus pollen, however, in the top three samples of zone B, and continuing into zone C, suggests that Alnus did exist within the Cesine area, most likely associated with the western margins of the water bodies where issuing freshwater created damp ground. The sporadic occurrence of Juniperus pollen most likely represents coastal macchia. Pollen of Juglans regia occurs at 0.1 m, possibly signifying human activity in the local landscape (9.5.7i); its occurrence is more pronounced in zone B of core C2.

Shrub component: Although Hedera helix is only represented in the upper and lower-most samples of zone B, this suggests that the climber continued to grow locally amongst the wood or shrub community beside the core location. Surface-sample analyses demonstrated that the presence of Hedera is not always represented in pollen samples (8.4.1). Pistacia is unusually well represented in zone B, and Rhamnus pollen is consistently present in all but sample 1.2 m, strongly suggesting that a shrub community existed close to the core location, forming undergrowth or macchia. Ericaceae, Rosaceae and Cistus are each represented throughout zone B, and may naturally occur within macchia vegetation.

Herbaceous component: Frequencies of Compositae pollen are greatly reduced in zone B, as they are in zone B of core C2 (9.10.6), possibly as a result of the local expansion

of shrub vegetation over areas close to the water-body margin. Chenopodiaceae pollen is relatively frequent in the lower 0.3 m of zone B, probably representing salt-tolerant species on muds at the water-body margin. The diversity of the herbaceous assemblage in zone B is wider than in zone A, and several pollen taxa significantly increase in frequency in this zone. As in zone B of core C2, pollen frequencies of disturbed ground taxa, including Cruciferae, Artemisia and Plantago are greater in zone B, possibly suggesting that areas within the Cesine had been cleared of shrubby vegetation. These taxa could, however, expand without human disturbance of natural or semi-natural vegetation (see 8.4.1).

Assemblage-zone C:

This zone is defined by greatly reduced frequencies of Quercus pollen and large increases in some disturbed ground taxa, suggesting that human activity in the Cesine region increased during the period represented by zone C. Marked changes in the pollen assemblage closely resemble those of zone C in core C2 (9.10.6).

Arboreal component: Frequencies of Quercus pollen do not exceed 6% in zone C, suggesting that oaks no longer occurred in the vicinity of the core location. Pollen of Corylus and Ostrya/Carpinus orientalis are still represented in low frequencies, signifying their regional presence. Oleaceae pollen frequencies steadily decline to 1% at 0.1 m, in contrast to the 10% frequency at the top of zone C in core C2 (9.10.6). This may suggest that widespread occurrence of Oleaceae declined with the decline in oak wood or scrub, but scattered specimens remained. Pine pollen frequencies also decline in zone C, apart from in the upper-most sample, where frequencies exceed 30% of the pollen sum. As in core C2, this high frequency represents the development of pine plantations in the Cesine area since the 1940's.

Shrub component: Shrub pollen is least diverse and least frequent in zone C of the core. Hedera helix is no longer represented, Rhamnus pollen occurs only at 0.6 m and Pistacia and Ericaceae pollen occur irregularly and are less frequent than in zone B. This assemblage suggests that the extent of shrub vegetation was greatly reduced with the decline in coverage by arboreal taxa, but a macchia type community including Pistacia continued to exist close to the core location.

Herbaceous component: Chenopodiaceae pollen reaches peak frequencies in the core at the bottom of zone C, probably representing salt-tolerant species on the water-body margin, close to the core location. Cruciferae pollen frequencies increase to a maximum in zone C, of over 30% at 0.3 m. To a lesser extent, Plantago and Gramineae pollen also become markedly more frequent in the lower 0.4 m of zone C,

strongly suggesting that areas of open, herbaceous vegetation expanded locally, and possibly throughout the Cesine, until areas were planted with pines. The occurrence of Rumex pollen in the lower half of zone C, coinciding with peak frequencies in open ground taxa, further suggests that open vegetation and disturbed ground increased in the Cesine region at the expense of shrubs and macchia, during the period represented by zone C. As in zone C of core C2 (9.10.6), these changes are attributed to deliberate clearance for agricultural purposes.

9.11.7 Comparison of cores C2 and CS1

Strong similarities exist between the pollen and microfossil records of core C2, from the western margin of the largest Salapi lagoon, and respective records of core CS1 from the northern margin of the smallest Salapi lagoon (see 5.2.6ii, Fig 5.3). It is concluded from these similarities that the sediments of cores C2 and CS1 represent approximately the same time period.

i) Non-pollen fossil remains

In both cores, macrofossil and microfossil remains suggest that both locations were influenced by a water body of mixed salinity throughout their sedimentary history. A similar range of microfossils was found in the two cores, within which the frequency and distribution of charcoal and of the diatoms Campylodiscus, Diploneis and unidentified genus (1), are respectively similar. Charcoal frequencies are greatest at the base of both cores (Figs. 9.25 and 9.29) in samples where macroscopic charcoal is also most frequent (Tables 9.7 and 9.8). Fungal remains are also most frequent at the base of the cores, suggesting that eroded soil material was deposited in water above the calcarenite at the beginning of the existing sedimentary sequence.

Assemblage-zone 1 of core C2 (Fig. 9.25) correlates well with zones 1 to 3 of core CS1 (Fig. 9.29), whilst zones 2 and 3 of core C2 correlate with zones 4 and 5 of core CS1 respectively. The microfossil record in both cores suggests that a distinct change occurred in the Salapi environment, represented by zone 2 in core C2 and by the boundary between zones 3 and 4 in core CS1, causing a synchronous decrease in diatom populations. In both cores, a decrease in water depth at the core locations could be inferred from reductions in overall algal frequencies in the cores' upper-most zones. Sedimentary evidence in core CS1 (9.11.2) suggests that drainage works within the past century caused local water-level to fall.

ii) Pollen and spores of aquatic plants and marsh plants

Pollen and spores in both cores suggest that both core locations were covered by vegetated marginal waters during the period represented by microfossil zone 1 in core C2 and zones 1 to 3 in core CS1 (9.10.4 & 9.11.4); this confirms the suggested marginal vegetated conditions interpreted from the microfossil assemblages. The marginal location of both cores is further suggested by the presence of Pteridium and Filicopsida spores and Cyperaceae pollen in many of the core samples. The presence of Ruppia pollen in both cores confirms that brackish water has influenced both locations throughout much of their sedimentary history.

iii) Pollen

Three pollen assemblage-zones are discerned in the pollen diagrams of both cores (Figs. 9.26, 9.27 & 9.30, 9.31). As observed in the description of pollen assemblage-zones for core CS1 (9.11.6), strong similarities exist between frequency distributions of certain pollen taxa in core C2 and respective distributions in core CS1; taxa displaying similar frequency distributions in both cores are Pinus, Quercus, Ostrya/Carpinus orientalis, Alnus, Hedera helix, Rhamnus, Pistacia, Ericaceae, Rosaceae, Cruciferae, Rumex, Artemisia, Compositae, Plantago, Ranunculus and Gramineae. The cores may be correlated on the basis of pollen assemblage-zones, strengthening the correlation based upon microfossil distributions and further suggesting that both cores represent approximately the same time period.

The pollen diagrams of cores C2 and CS1 reflect changes in vegetation composition common to the landward margins of two of the Cesine water bodies, besides recording elements of the regional Cesine vegetation. Interpreted vegetation changes are summarised as follows.

Zone A core C2/CS1: Open herbaceous or marsh vegetation was prominent at the water-body margins. A shrub community existed on drier ground close to the core location, as indicated by the presence of pollen of Hedera helix and Ericaceae, and by the additional presence of Pistacia and Rhamnus pollen in core C2. Low frequencies of total arboreal pollen suggest that the local Cesine landscape was predominantly open. Pollen in both cores suggest that deciduous and evergreen Quercus, together with Fraxinus and Pinus, were present but sparse in the local landscape; in core C2 the presence of Corylus and Ostrya/Carpinus orientalis is also suggested.

Zone B core C2/CS1: A marked expansion in the local occurrence of both evergreen and deciduous Quercus is interpreted from zone B; increased frequencies of Oleaceae may be associated with this expansion. A well developed macchia-type shrub

community, including Ericaceae, Pistacia, Rhamnus and Hedera helix is strongly suggested to have existed locally, either as undergrowth beneath oak wood or scrub, or as macchia. Quercus could naturally have been a component of macchia, as could Pinus whose pollen frequencies are also increased during the period represented by zone B.

In both cores, pollen of Juglans regia first appears during the period represented by this zone, pointing to human activity within the local landscape. Further impact of human economic practices in the Cesine is suggested by increases in pollen from taxa characteristic of disturbed ground, including Cruciferae, Artemisia and Plantago, although these may be naturally abundant in a coastal environment.

Zone C core C2/CS1: Continued representation of shrub taxa suggests that a macchia-type shrub community persisted in the vicinity of both core locations, though somewhat reduced in extent. Frequencies of Quercus and Pinus pollen are considerably lower in this zone, suggesting that their presence was diminished close to the Salapi, but they continued to occur within the broader Cesine landscape, together with Corylus, Ostrya/Carpinus orientalis and Alnus.

In both cores, Cruciferae, Plantago and Gramineae become markedly more frequent in zone C, strongly suggesting that areas of open herbaceous vegetation and disturbed ground expanded at the expense of macchia and scrub in the Cesine. The cause of these changes is probably deliberate vegetation clearance for agricultural landuse, though charcoal frequencies in both cores (Figs. 9.25 & 9.29) are not so great as to suggest that large areas were cleared by fire.

9.11.8 Chronology for environmental change represented by cores C2 and CS1

As indicated in 9.11.2, the upper 0.2 m of sediment in core CS1, which correlates with the upper 0.1 m to 0.2 m of core C2, most likely represents sedimentation over little more than the past 50 years. In neither core was pollen found from exotic plants introduced to the Cesine in the past century (see 5.2.6ii), such as pollen of Carpobrotus acinaciformis found in certain surface-samples along the Cesine transect (8.3.2), or other exotic pollen grains described in 7.2. Only pollen of Juglans regia, occurring in zone B of both cores may, provide an age marker, possibly suggesting a maximum age of 3000 years BP for the base of zone B (9.5.7i), though Juglans may be native to Holocene southern Italy (9.5.7i).

No radio-carbon dates are available for the Cesine core sediments, but further chronological context for the environmental change represented by cores C2 and CS1,

is gained by comparing the pollen diagrams of these cores with those of cores AP88 (9.2) and 1AG (9.5). Two hypotheses were put forward for correlating core AP88 with core 1AG (9.5.7) based upon strong similarities between frequency distributions of arboreal and shrub pollen in the two cores. Highly comparable similarities exist between many distributions of percentage pollen frequency in cores C2 and CS1 (Figs. 9.26 & 9.30) and respective frequency distributions in core AP88 (Fig. 9.3) and in the upper 1.5 m of core 1AG (Fig. 9.14).

Of the arboreal pollen, the frequency distribution of the dominant genus, *Quercus*, is similar in all four cores. The pollen frequency distributions of *Pinus* and *Juglans regia* in cores C2 and CS1 are similar to respective distributions in the upper 1.5 m of core 1AG, whilst the frequency distributions of *Ostrya/Carpinus orientalis* and Oleaceae are comparable in cores C2, CS1 and AP88. The distribution of *Rhamnus* pollen is similar in each core, and appears to be closely related to high frequencies of *Quercus* pollen. Distributions of Ericaceae pollen are also similar in each core, and further demonstrate the similarity between the upper 1.5 m of core 1AG and cores C2, CS1 and AP88; below 1.5 m in core 1AG, frequencies of Ericaceae pollen are significantly lower than they are above this level (9.5.5ii).

Similarities also exist between frequency distributions of certain herbaceous pollen taxa. Cruciferae pollen is similarly distributed in each core, whilst distributions of *Artemisia* pollen are similar in cores C2, CS1 and 1AG, possibly reflecting a regional expansion of these genera with increased clearance of shrub vegetation and the disturbance of soils by agricultural practices.

Based upon these summarised similarities between pollen diagrams, the pollen assemblage-zones A, B and C, discerned in cores C2 and CS1, may be correlated with zones D2, E and F respectively in core 1AG. If there is no hiatus in the sediment sequence of core AP88, then these same assemblage-zones may be correlated with zones A, B and C in core AP88, according to the first hypothesis for correlating core AP88 with core 1AG put forward in 9.5.7i. Discussion of the origin of sediments in core 1AG (9.5.7), however, favours the second proposed correlation between cores 1AG and AP88, allowing for a hiatus in core AP88; this second correlative hypothesis does not alter the proposed correlation between pollen diagrams of the Cesine cores and that of core 1AG. Fig. 9.32 illustrates schematically the correlation between assemblage-zones in cores C2, CS1, AP88 and 1AG. Further discussion of the significance of this correlation, in terms of regional vegetation patterns and the changing environment of the study-area, is given in 11.2.2.

On the basis of this proposed correlation between the cores, the radio-carbon date of 1765 ± 50 BP at the base of zone C in core AP88, may be transferred to the base of zone C in cores C2 and CS1. If correct, both cores could represent approximately the

past 4000 years, but as pointed out in 9.5.7i, this date may be 'too old' due to the possible influence of contaminating carbon. Since the upper 0.2 m of core CS1 has been attributed to sedimentation over the past 50 years, it is improbable that the upper 0.6 m of the core could represent 1765 years. It is probable, however, that compression of the core's sediments increases with depth, as suggested by pollen concentration values in the core (9.11.6i), producing a non-linear relationship between depth in the core and sediment age.

A constraint on the maximum age of sediments at the base of both cores may be inferred from the macrofossil and microfossil evidence throughout the cores, for brackish water. This implies that sea-level was sufficiently high for saline water to reach the core locations directly, or indirectly by penetrating the calcarenite and mixing with fresh groundwater. As the maximum depth of core CS1 is 1.5 m below present sea-level, it follows that during the Holocene, saline water could have initially influenced the core location when sea-level was between 1.5 m and 2 m below its present level. Since the glacio-eustatic element of relative sea-level rise has proceeded at no more than 1 m per millennium over the past 5000 years (see 12.5.1), it is unlikely that the sediments of cores C2 and CS1 represent more than the past 1.5 to 2 millennia. This argument invalidates the transfer of the radio-carbon age of 1765 ± 50 BP from AP88 to the two Cesine cores. It further brings into question the accuracy of this date in core AP88, since strong similarities have been indicated between the pollen diagrams of cores C2, CS1, AP88 and the upper 1.5 m of core 1AG.

9.12 CORE CS2

Core CS2 was extracted from a marshy depression landwards of the second largest Salapi lagoon (5.2.6). A continuous sedimentary sequence above calcarenite bedrock is represented by the core and grab samples, and is important to the investigation of environmental change in the northern Cesine. Depths in core stratigraphy are recorded in metres with respect to the present ground surface. Core stratigraphy is illustrated in Fig. 9.33, and macrofossil distributions are presented in Table 9.9.

All samples were analysed for pollen and other microfossils, but pollen concentrations were generally poor and the pollen sum was reached in only samples 1.4 m and 1.2 m; the pollen assemblages of these samples are discussed in 9.12.4.

9.12.1 Core stratigraphy and macrofossils

(bottom of core)

- 2.37m Calcarenite bedrock .
(sharp boundary)
- 2.37-1.76m Dense green/yellow sand. Quartz grains are dominant .
(indistinct boundary)
- 1.76-1.56m Dense grey/green sandy silt. Quartz grains are dominant and fine roots penetrate from above.
(indistinct boundary)
- 1.56-1.33m Grey/brown sandy silt. Sand content decreases with height in this layer. Charcoal is present.
(indistinct boundary)
- 1.33-0.97m Grey/brown silty clay. A low amount of sand is present. Shells of Planorbidae are dispersed throughout this layer, and Acroloxus cf. lacustris is present at 1.0 m. Charophyte oogonia are present above 1.2m.
(indistinct boundary)
- 0.97-0.87m Black silty clay. Fine plant roots are frequent.
(sharp boundary)
- 0.87-0.61m Buff-coloured sandy silt. Charophyte oogonia and shells of Planorbidae are present.
(sharp boundary)

- 0.61-0.12m Grey/brown silty clay. Charophyte oogonia, ostracod carapaces and shells of Acroloxus cf. lacustris and Planorbidae are present.
(indistinct boundary)
- 0.12-0m Grey/brown silt, constituting the present marsh soil. Charophyte oogonia, shell fragments and ostracod carapaces are present.
(top of core)

9.12.2 Discussion of core stratigraphy and macrofossils

The absence of macrofossils in fine sands overlying the calcarenite, suggest that the sands were not deposited in water. Their appearance and fine texture are comparable to that of aeolian sands overlying the calcarenite in core PG (9.9.3); grab samples from this sand layer in core CS2 were insufficiently large to apply particle-size analysis (see Appendix A).

Above 1.3 m, the presence of charophyte oogonia and shells of Planorbidae in most samples, together with shells of Acroloxus cf. lacustris in some, indicates that freshwater or water of low salinity has existed continuously or ephemerally at the core location during the time in which these sediments were deposited (see chapter 7, part 3). Precipitated calcium carbonate in samples above 1.1 m further suggest the presence of surface water. The presence of ostracod carapaces in the upper 0.4 m of the core may reflect an increase in salinity of waters affecting the core location, however Foraminifera tests and shells of brackish water molluscs are absent from the core sediments.

9.12.3 Non-pollen microfossils

Six assemblage-zones are discerned in the diagram of microfossil distribution in core CS2 (Fig. 9.34), most of which correspond closely to sedimentary units within the core.

Assemblage-zone 1:

The green/yellow sands overlying the calcarenite only contain low frequencies of fungal spore-type 1. This compares closely with surface-sample 1 from the Cesine transect (8.3.5 & Fig. 8.2), and supports the proposed aeolian origin of the sands.

Assemblage-zone 2:

The appearance of charcoal and mycorrhizae within the sandy silts, corresponding to zone 2, suggest that silts and microfossils from the vegetated margin of the present marshy depression were deposited together with aeolian sands at the core location. At the top of this zone, the presence of sponge sclere, Botryococcus, Spirogyra and Mougeotia suggest that environmental conditions became moister (see chapter 7, part 2), at least locally.

Zone 2 is particularly distinguished from the rest of the core by the presence of Concentricystes. High frequencies of this microfossil in samples 1.4 m and 1.5 m imply that the prevailing environment was conducive to the production of this microfossil by the originating organism (7.8.1); the present author notes that in core PG, Concentricystes similarly occurs only in the sands above the calcarenite (9.9.4), suggesting there is some determining environmental factor in its distribution.

Assemblage-zone 3:

Algal microfossils of increased diversity and frequency define this zone. Locally moist conditions are suggested by the presence of Spirogyra and Zygnema, whilst the presence of Mougeotia, Botryococcus Cyanophyceae and sponge sclere suggest that shallow water of fresh to brackish quality existed at the core location (chapter 7, part 2). The appearance of animal remains together with increased frequencies of mycorrhizae and fungal spores suggest that soils from surrounding slopes were transported to the basin and perhaps that vegetation was established at the core location under marshy conditions.

Assemblage-zone 4:

Zone 4 corresponds to the black, silty layer of the core, within which algal microfossils are conspicuously absent (from sample 0.9 m), whilst frequencies of charcoal and mycorrhizae reach their highest levels in the core. High charcoal frequencies point to the local incidence of fire. The presence of sponge sclere suggest that moist conditions persisted at the core location, but there is no supporting evidence for this.

Assemblage-zone 5:

The presence of sponge sclere, Cyanophyceae, Botryococcus, Spirogyra, Zygnema and Mougeotia suggest that moist conditions with perhaps some standing water, were resumed at the core location, creating marshy ground.

Assemblage-zone 6:

Zone 6 extends up to the present ground-surface and is distinguished from the rest of the core by the presence of diatoms frustules, including the genera Diploneis and Amphora which are tolerant of some salinity (7.7.1). Sponge sclere and algal microfossils, including Cyanophyceae and Spirogyra continue to be present in the core. Together, these microfossils probably represent seasonally waterlogged ground; at the core location today, ground beneath the marsh vegetation is mostly dry in summer months. Frequencies of mycorrhizae and fungal spore-type 1 greatly increase towards the top of zone 6. This suggests that the apparent reduction in standing water at the core location has favoured their production, perhaps in association with the establishment of more herbaceous vegetation and soil conditions (see 8.4.2).

9.12.4 Interpretation of local environmental change represented by core CS2

Phase 1: The absence of macrofossils and microfossils from the fine sands above the calcarenite base of this depression, further suggests the sands are of aeolian origin. Dry conditions would have prevailed during their accumulation. Relative sea-level was probably at least 2.0 m below its present level in order not to influence the core location during this period. As argued in the case of similar sands at the base of core PG (9.9.5), the aeolian deposit may be attributed to the Roman period or earlier. The present author believes that the sands at the base of cores PG and CS2 are of similar age and composition.

Phase 2: Organic sediment accumulation at the core location may have been initiated by the disturbance of vegetation and soils on land around the depression. At 1.3 m below the present ground surface, the onset of moist and locally wet ground conditions is suggested by the presence of freshwater mollusc shells and charophyte oogonia, and by the appearance of algal microfossils (zone 2). This evidence points to the existence of stagnant, fresh or low-salinity water at the core location.

At 1.4 m, pollen concentration was sufficient to achieve the pollen sum. The pollen assemblage of this sample from sediments previous to the development of moist ground, is dominated by Compositae pollen (70%) and Gramineae pollen (13%), suggesting that open, herbaceous vegetation was dominant in the vicinity of the core location; ferns, bracken and sedges are also well represented by pollen and spores in this sample. Also significant is the presence of Ericaceae pollen (6%), implying that a shrub community existed locally. Both Pinus and evergreen type Quercus pollen

constitute 4% of the pollen sum, suggesting that they existed within the Cesine region, but were not prominent locally.

Phase 3: The occurrence of Planorbidae shells throughout the sediments between 1.3 m and 1.0 m, supports the interpretation of microfossil assemblage-zone 3 that shallow, vegetated water existed either perennially or seasonally at the core location. The pollen assemblage at 1.2 m suggests that Compositae remained locally dominant (28%) during this phase, together with Gramineae (8%). Ericaceae pollen also remains at a significant frequency (5%), whilst an increase in the local prominence of evergreen oak is suggested by a higher frequency of *Quercus* pollen (10%). The pollen sum was not reached in sample 1.0 m, but pollen of *Quercus* accounted for 20% of the 90 grains counted, suggesting continued local expansion of evergreen oak, possibly associated with macchia in this part of the Cesine.

Phase 4: High charcoal frequencies in the black layer immediately above 1.0 m, imply that fire occurred locally, perhaps as a means of deliberate vegetation control or clearance. Pollen concentrations in this layer, and in sediments above it, were too poor to investigate possible vegetation management.

Phase 5: Above the black silt, both macrofossils and microfossils suggest that moist conditions and seasonal waterlogging have existed at the core location until the present. At no point in the core sediments is there any indication that saline water has directly influenced the local environment. Occasional Foraminifera test-linings were, however, noted in microfossil assemblages above 1.2 m in the core, although the tests themselves were lacking from macrofossil assemblages. The test-linings may have been displaced by wind; such an explanation was given for the presence of test-linings in the modern surface-sample from the location of core CS2 (8.2.2), which is over 50 m distant from a saline water body.

The presence of pyrite framboids in most samples above 1.6 m in the core, suggests that sulphur was available in groundwater at the core location, implying that fresh groundwater has been influenced by sea water penetrating the calcarenite (see 7.9.1). As put forward in the interpretation of sediment accumulation represented by core PG (9.9.5), the development of moist conditions at the core location is related to rising groundwater level, which in the Cesine region is likely to be associated with late Holocene sea-level rise.

9.13 CORES C3 and C4

These exploratory cores were collected in order to examine the sediment sequence in an enclosed, marshy depression at the southern end of the Cesine reserve (5.2.6iii). The depression does not border any of the existing water bodies. Depths in core stratigraphy are recorded in metres with respect to the present ground surface. Core-sediment stratigraphy is illustrated in Figs. 9.35a & 9.35b.

Palynological analyses were carried out on one sample from core C4, at 0.57 m, in order to investigate the origin of a black silt layer. Samples from the lower 0.5 m of core C4 were sieved for macrofossil content; macrofossil distributions are illustrated in Table 9.10.

9.13.1 Core C3: stratigraphy

(bottom of core)

- 1.53-1.49m Granular calcarenite.
(sharp boundary)
- 1.49-1.10m Dark-brown silt, penetrated by coarse plant roots.
(indistinct boundary)
- 1.10-0.75m Black silt. Plant roots, small shell fragments and shells of Planorbidae and Lymnaeidae are present.
(indistinct boundary)
- 0.75-0.08m Dark-grey/brown sandy silt. Contains plant roots and shell fragments. Shells of Lymnaeidae occur sporadically below 0.43 m, and are frequent between 0.66 m and 0.61 m.
(indistinct boundary)
- 0.08-0m Dark-grey/brown silt. Fine plant roots are present.
(top of core)

9.13.2 Core C4: stratigraphy

(bottom of core)

- 1.0-0.63m Reddish-brown silt. Charophyte oogonia and shells of Planorbidae and Lymnaeidae are present in the lower 0.1 m.
(sharp boundary)
- 0.63-0.57m Dark-grey/brown sandy silt, finely laminated into lighter and darker layers. Charophyte oogonia, ostracod carapaces and shells of Lymnaeidae, Planorbidae and *Acroloxus* cf. *lacustris* are present.
(sharp boundary)
- 0.57-0.55m Black, humified silt. Charophyte oogonia, ostracod carapaces and shells of Lymnaeidae and Planorbidae are present. Charcoal fragments are abundant.
(sharp boundary)
- 0.55-0.51m Dark-grey/brown sandy silt. Charophyte oogonia, ostracod carapaces and shells of Lymnaeidae and Planorbidae are present. A small pottery fragment (2.5 cm long) was present within this layer.
(indistinct boundary)
- 0.51-0.42m Grey/brown sandy silt. Charophyte oogonia and ostracod carapaces are present, together with sparse shells of Lymnaeidae and Planorbidae.
(indistinct boundary)
- 0.42-0.10 Dark-grey silt. Plant roots and shells of Lymnaeidae and Planorbidae are present.
(indistinct boundary)
- 0.10-0m Dark-grey/brown silt. Fine roots and shells of Lymnaeidae and Planorbidae are present.

(top of core)

9.13.3 Discussion of stratigraphy and macrofossils in core C4

The presence of charophyte oogonia and shells of Lymnaeidae and Planorbidae, favouring shallow, freshwater environments (see 7.12.1), suggest that standing water existed at the core location while the lower 0.2 m of sediments were deposited. The absence of these macrofossils between 0.8 m and 0.66 m suggests that drier ground conditions prevailed during this phase. Standing water or marshy ground at the core

location, is again indicated between 0.66 m and the top of the core. The core sediments contain no evidence for saline or brackish water intrusion into the marsh; fine sand grains incorporated by the silty core sediments are of aeolian origin.

Of particular interest in this core is the black silt layer between 0.57 m and 0.55 m, and the pottery fragment lying above it. The abundance of charcoal fragments associated with this sediment points to particularly intense fire events in the local landscape, possibly deliberately used for vegetation control or clearance. The pottery fragment has been weathered and has no distinct form, but analysis of the material matrix would possibly indicate its age, and therefore provide a minimum age for the black layer upon which it rests; this has not been possible within the present research.

Palynological analyses were carried out on a sample at 0.57 m, within the black silt. Herbaceous pollen taxa dominate the assemblage, which largely consists of Compositae Liguliflorae (55%) but includes Gramineae and Artemisia. Total Quercus pollen constitutes 12% of the pollen sum, whilst Pinus, Ostrya/Carpinus orientalis and Oleaceae are represented at low frequencies. Rhamnus pollen is present and Ericaceae is well represented at 3% of the pollen sum. Spores of Filicopsida and Pteridium are also present. This assemblage suggests that open, herbaceous vegetation dominated the environs of the core location, whilst a shrub community existed on drier ground nearby, possibly including scattered, mixed deciduous and evergreen trees.

The non-pollen microfossil assemblage is dominated by abundant charcoal fragments and fungal hyphae. Fungal spore-type 1 are frequent in this sample, as are mycorrhizae, supporting pollen evidence for the local prevalence of herbaceous vegetation (see 8.4.2). Marshy to wet conditions at the core location are suggested by the presence of sponge spicular remains, Spirogyra, Zygnema and Mougeotia (see chapter 7, part 2).

9.14 CORE CM

Core CM was extracted from an enclosed marsh basin, landwards of existing water bodies in the Cesine area, in order to examine sediment stratigraphy in an interior location (5.2.6iii); no palynological analyses were carried out on this core. Core stratigraphy is illustrated in Fig. 9.36; depths in the core are recorded in metres with respect to the present ground surface.

9.14.1 Core stratigraphy

(bottom of core)

- 1.43m Granular calcarenite
(sharp boundary)
- 1.43-0.90m Green/yellow fine sand. Charred organic material, less than
1 mm thick, lies between the sand and the calcarenite beneath.
(indistinct boundary)
- 0.90-0.78m Dark-brown/black peaty silt, grades into sand below.
(indistinct boundary)
- 0.78-0.68m Dark-grey silt. Shells of Planorbidae are present.
(indistinct boundary)
- 0.68-0.59m Buff/grey silty clay. Shells of Planorbidae are present.
(indistinct boundary)
- 0.59-0.16m Dark-grey/brown silt. Shells of Planorbidae and Lymnaeidae are present.
(indistinct boundary)
- 0.16-0m Dark-brown silty peat. Shell fragments including Planorbidae are
present.

(top of core)

9.14.2 Discussion of core stratigraphy

Fine sand overlying the calcarenite at the base of the core is of similar appearance and particle-size distribution to that in core PG (9.9.3). The particle-size distributions of sands from both cores are illustrated in Fig. 9.22 (9.9.3) and resemble those from sands in cores 3AP and 1AG (Fig. 9.22); similar sands occurred at the base of core CS2 (9.12.2). These are believed to be aeolian sands from mixed, local sources (see

9.4.3, 9.9.3). In core CM, unlike the other cores however, a thin layer of charred, unidentifiable organic material (less than 1 mm thick) was observed between the calcarenite and the overlying sands, suggesting that in this location the calcarenite surface was not entirely exposed when aeolian sands were deposited.

The sand grades into an organic silt layer above, with no evident macrofossils, possibly representing the establishment of vegetation and the development of a soil at the core location, or inwashed soil material. The occurrence of shells of Planorbidae and Lymnaeidae in silts between 0.78 m and 0.16 m in the core, suggests that stagnant and possibly vegetated freshwater existed at least seasonally over the core location (see 7.12.1), whilst these sediments were deposited. Mollusc shells are fragmentary in the upper 0.16 m of the core and include Planorbidae, suggesting that seasonally marshy conditions have persisted at the core location until the present.

9.15 Synopsis of environmental change represented by cores from the Cesine region

9.15.1 Sedimentary environments

Comparable sediment sequences occur in cores PG, CS2 and CM. At the base of each of these cores is a Holocene aeolian sand, which was deposited above the Pleistocene calcarenite surface under dry conditions, when sea-level was around 2 m or more below its present level. These Holocene, aeolian sands may therefore have been deposited 2000 years ago, or more, and are possibly associated with the most recent phase of dune accumulation along the study-area coastline (9.9.5).

Evidence from macrofossil and microfossil remains in cores PG, CS2 and CM suggest that organic sediments began to accumulate at the core location with the development of moist ground conditions; sediments accumulated as water-levels became higher. In cores CS2 and CM, the saturation of sediments by groundwater produced phases of standing water at the ground surface. In core PG, fossil evidence suggests that water-level rise caused a water body, Pantano Grande, to impinge upon the core location. Sediments accumulated in mixed fresh and brackish water at the vegetated fringe of the water body. Artificial drainage excavated in the Cesine region within the past century, has caused water levels to fall. Standing water now exists only seasonally at the locations of cores CS2 and CM, and a lake-shore environment now exists at the location of core PG.

The cause of rising water-levels throughout the low-lying Cesine area has been attributed to sea-level rise over approximately the past two millennia (see 9.9.5); Holocene sea-level rise is discussed in 12.5.3, with respect to the changing coastline of the study-area. The level of sea-water penetrating the calcarenite will have risen relative to sea-level rise, forcing freshwater levels to rise above it. Water-levels within the Cesine will also have risen as a consequence of the coastal dune-cordon developing and impeding drainage from land to the sea; the position of the dune cordon is itself related to sea-level.

An early dry phase is not represented in cores C2, CS1, C3 and C4. Macrofossil and microfossil evidence suggests that these locations have always been influenced by freshwater or fresh to brackish water, throughout the period represented by the core sediments. Sediments sampled by cores C2 and CS1 accumulated in shallow waters of mixed salinity at the margins of the Salapi water-bodies. Recent reductions in water-level caused by artificial drainage works, have caused marshy conditions to develop at the location of core CS1, and muds are seasonally exposed at the location of core C2. Since evidence for brackish water exists throughout cores C2 and CS1, and the

maximum depth of sediments in core CS1 is 1.53 m, these cores may represent a shorter time period than cores PG, CS2 and CM, which probably does not exceed 1.5 to 2 millennia (9.11.8).

9.15.2 Vegetation patterns

Pollen in cores C2 and CS1 were sufficiently well preserved for a record of vegetation change in the central Cesine area to be interpreted from pollen analyses. Strong similarities exist between the pollen records of both cores (9.11.7iii), from which it is concluded that both represent approximately the same time period, which probably does not exceed the past 1.5 to 2 millennia (9.11.8).

During the first phase of sediment accumulation, open herbaceous vegetation was predominant locally, and a macchia type shrub community existed close to the landward side of the Salapi water bodies. Scattered, mixed evergreen and deciduous tree species existed within the Cesine area, but were not significantly present locally. Subsequent pollen evidence suggests that a woody macchia community, including and perhaps dominated by *Quercus* species, expanded close to both core locations. Human activity in the local landscape is signified during this period by the presence of *Juglans regia* pollen in the pollen record of both cores.

In the final phase, macchia remained in the local landscape, but it was reduced in extent and *Quercus* was a far less significant component. Areas of open, herbaceous vegetation and disturbed ground are suggested to have expanded during this phase, until the past 50 years in which large areas of the Cesine have been planted with pines (Medagli 1981), as registered in the pollen diagrams of cores C2 and CS1 (see Figs. 9.26 & 9.31). Since the upper 0.2 m of core CS1 has been attributed to the past 50 to 100 years, this final phase of the pollen record may represent up to the past 300 years, suggesting that large-scale disturbance of the woody macchia in the Cesine area possibly began in the 16th century. This interpretation concurs with historical information stating that cultivated land and pastoral land progressively encroached on coastal macchia and marshlands in Salento, between the 16th and 18th centuries (4.5). Maps and accounts compiled in the late 18th and the 19th centuries, however, suggest that extensive areas of macchia, incorporating *Quercus* species, still existed in coastal parts of the study-area (see 4.4).

The first phase of open vegetation represented by the pollen record of cores C2 and CS1, suggests that the growth of macchia and scrub vegetation had been inhibited during a period previous to medieval impact on the Cesine landscape; charcoal frequencies are highest at the base of both cores (9.1.7i), possibly suggesting that fire

was used to control or clear areas of regenerating semi-natural vegetation during this early phase. It is probable that this phase represents the impact of Roman activities in the Cesine area. The coastal area was certainly of importance in Imperial Roman times, as evidenced by constructions at San Giovanni, at the northern end of the Cesine, and at San Cataldo (4.2).

On the basis of the strong similarities that exist between the pollen diagrams of cores C2 and CS1 and those of cores AP88 and the upper 1.5 m of 1AG (9.11.8), the present author concludes that comparable vegetation changes occurred in the landscape around the Alimini lakes, probably during the same time period.

Chapter 10

**RESULTS OF SAMPLE ANALYSES
FROM ARCHAEOLOGICAL CONTEXTS****10.1 Roca Vecchia**

The archaeological importance of the study-area within Salento, over at least the past three millennia, is exemplified by the site of Roca Vecchia (4.5). Situated on the coast towards the most northern exposure of the Pliocene calcarenite (see 3.2, Fig. 3.2), this site incorporates remains of late Bronze Age, Messapian, Roman and Medieval age (Pagliara 1987). Chemical and palynological analyses were applied to samples of deposits from specific archaeological contexts of the site, with the purpose of deriving information on local environmental conditions to complement archaeological findings and results of the core analyses.

10.1.1 Principal features of the site

The site is bounded to the north-east by the cliff coastline, and to the north-west, south-west and south-east by the foundations of a wall, and beyond it a double ditch (Fig. 10.1). The ditches are believed to post-date the 'wall', though the age of these features is not certain. Foundations for the wall are believed to have been laid in the 3rd and 4th centuries B.C. (Pagliara 1987), towards defending the Messapian settlement against increasing Roman presence in the region (D'Andria 1988). Construction of the wall itself appears to have been abandoned; on the southern side, foundations terminate several metres from the present cliff-edge, whilst partially hewn blocks exist nearby in the exposed calcarenite.

In parts of the enclosed area, but relating to earlier settlement at this site, archaeological investigations have located prehistoric hut foundations cut into the calcarenite. Some have stones positioned around their bases (Pagliara 1987), resembling those at Otranto which have been dated to the 9th century B.C., and attributed to contact with Mycenaean culture in the late Bronze Age and early Iron Age (D'Andria 1988).

Much of the later constructions of the site are concentrated in the northern part of the 30 hectares enclosed by the 'wall' (Pagliara 1987). Remains of medieval walls bound

parts of this 'peninsular' area, but many sections have been lost through cliff-collapse. Recent excavations, directed by Prof. C. Pagliara of the Dipartimento di Scienze dell'Antichità, Università degli Studi-Lecce, are located within this part of the site, as indicated in Fig. 10.1. Samples were selected for analysis by the present author, from deposits exposed by excavated sections and features in this zone.

10.1.2 Sample locations and archaeological context

Sampling was concentrated around part of a Medieval roadway (Fig. 10.2). On the eastern side of the roadway is a well, dated possibly to the 15th or 16th century A.D. (Pagliara pers. comm.), and foundations of a church of later date. A vertical section excavated directly below part of the south-west facing side of the roadway, has exposed a sequence of deposits which include a charcoal-rich layer of possible Bronze or Iron Age, above bedrock at 1.4 m below the road level. Deposits in this section were sampled stratigraphically for chemical analyses. A comparable charcoal-rich layer from a trial pit on the site, and dated possibly to the 8th century B.C. by the inclusion of Greek geometric decorated-ware in the deposit, was also included in the analyses. Deposits were systematically sampled from other exposed sections close to the roadway, but none of these extended to bedrock or included a comparable charcoal-rich layer.

10.1.3 Summary results of the chemical analyses

Quantities of some chemical and material components of a deposit are partially determined by local environmental conditions at the time of deposition. High concentrations of phosphates may occur, for example, in areas where organic matter has been allowed to accumulate and decay as a result of human practices (Dauncey 1952; Proudfoot 1976). Other components, such as calcium and nitrogen may be similarly concentrated in a deposit (Cook & Heizer 1965). Among the analyses carried out on 53 samples from the site, contents of phosphorous, calcium and magnesium, organic matter and sodium were measured; the sodium content of a deposit may be increased by exposure to sea water and sea-spray, and so is of interest in samples from Roca Vecchia.

From the resultant data set, several samples were identified with relatively high values for a combination of these components. The charcoal-rich layer of possible late Bronze Age, at the base of the section beneath the roadway (10.1.2), has a high content of organic matter, calcium and magnesium. Also at 1.1 m below the top of this section,

high values for organic matter, calcium, magnesium and sodium were recorded. The charcoal-rich layer of possible 8th century B.C. date (10.1.2), has the highest content of organic matter, calcium and magnesium of all the samples, together with high sodium content. Results from these deposits suggest that they were associated with surface sediments during periods when human settlement and economic activities influenced the local environment. The highest phosphorous value in all samples analysed, occurred in a deposit 1.1 m below the level of the church ruins (10.1.2), close to tombs.

10.1.4 Pollen analyses

i) Dry archaeological deposits

The archaeologically dated samples, identified as probable occupation layers from their material and chemical composition (10.1.3), were processed for pollen analysis. No pollen or other microfossils were found in their residues. It is likely that highly oxic conditions within these deposits are inimical to pollen preservation. Carbonised grains of *Hordeum* sp. were, however, recovered from the charcoal-rich layer of possible 8th century age B.C.. This suggests that cereals were perhaps cultivated locally, for consumption by the inhabitants of the early settlement at Roca Vecchia.

ii) Sediments from wells

Successful palynological analysis was carried out on wet sediments contained by the remains of a basket, excavated from a well dated to the 3rd or 4th century B.C. (Fig. 10.2; see 5.5); the basket is thought to be of similar age to the well construction (Pagliara pers. comm.).

A 5 ml sample of the sediment was processed according to the procedure in Appendix A. Pollen within the residue was well preserved, and 300 grains were identified. The non-pollen microfossil assemblage consists of fungal spores, fragments of plant cell-walls and animal fragments.

As shown in Table 10.1, herbaceous pollen dominates the pollen-assemblage. Only 4.5% of the pollen sum originates from arboreal species, of which *Quercus* and Oleaceae pollen are present in equal proportions. This suggests that trees or shrubs were present but not particularly prominent in the local landscape. Gramineae pollen constitutes 71% of the pollen sum, suggesting that open grassland existed around the site during the 3rd/4th centuries B.C.; some of the Gramineae grains are sufficiently large to represent cereal species (see 7.1.7), implying that areas in the vicinity of the

site were used as arable land. It is possible, however, that grasses grew around the top of the well, providing direct input of pollen to the well sediments. Gramineae pollen was found to be abundant in sediments from two Roman wells, in Britain and Germany (Dimbleby 1985), but it was not suggested that vegetation associated with the wells themselves may have influenced the pollen assemblage.

Similar analyses were carried out on sediments from a well dated to the 15th or 16th century A.D. (10.1.2), but no pollen was found in the sample residue.

POLLEN	PERCENTAGE
Quercus	2.0
Oleaceae	2.0
Alnus	0.5
Gramineae	71.0
Compositae (Tubuliflorae)	10.0
Compositae (Liguliflorae)	6.0
Umbelliferae	4.0
Chenopodiaceae	1.0
Cruciferae	0.5
Cyperaceae	3.0

Table 10.1: Pollen-assemblage of sediment from the 3rd/4th century well B.C., Roca Vecchia.

10.2 Archaeological feature in the Cesine reserve

As described in 3.6.2, a circular arrangement of calcarenite blocks exists embedded in soil beside the modern drainage channel between the Salapi water bodies in the Cesine reserve. The feature is attributed to possibly the late Bronze Age, and may be similar to hut foundations found at Roca Vecchia (Pagliara 1987) and at Otranto, dated to the 9th century B.C. (D'Andria). Soil directly beneath the blocks may be of similar age to the feature. A sample was taken from beneath a block at the channel side, and processed for pollen analysis.

Pollen preservation in the sample was generally poor. Most grains appeared degraded, suggesting that the pollen-assemblage of the sample has been distorted by differential preservation. Odd grains of Oleaceae, Compositae, Cruciferae and Gramineae pollen occurred in the sample, but pine pollen comprised 75% of total identifiable grains; according to Haviga (1964), pollen of *Pinus* is included amongst pollen types least susceptible to corrosion and oxidation. Pine pollen also comprised 74% of the pollen sum in the modern sample collected from surface-soil within the feature (see 8.3.3, Fig. 8.1); such a high frequency is attributed to the proximity of present pine plantations. In the case of the buried deposit, it is possible that insects have deposited pollen beneath the block, and that the high numbers of pine pollen may originate, at least in part, from modern pines.

It was concluded from analyses of pollen from core CS1, located close to the feature, that the core-sediments represent no more than the past 2 millennia (9.11.8). Local environmental conditions contemporary with the feature, during the late Bronze Age or early Iron Age, are not therefore represented in the pollen diagram for core CS1.

Part 3

Conclusions

Chapter 11

SUMMARY OF THE GEOMORPHOLOGICAL AND PALYNOLOGICAL RESULTS AND CONCLUSIONS ON LATE QUATERNARY ENVIRONMENTAL CHANGE IN THE STUDY-AREA

Much of the study-area is now partially or completely denuded of Holocene, unconsolidated sediments above the Pliocene and Pleistocene calcarenite surface. Zones of sediment accumulation are largely confined to the coastal margin and depressions in the Pleistocene calcarenite surface (chapter 4). Sediment cores were obtained from selected lacustrine, marsh and lagoon locations within these low-lying depositional areas (chapter 5).

Integrated analyses of the sediments and their macrofossil, microfossil and pollen contents have provided detailed information on the evolution of both local environmental conditions and regional vegetation patterns in the study-area, as a consequence of natural processes and human impact on the landscape (chapter 9).

11.1 Late Quaternary sedimentary environments**11.1.1 Early mineral deposits**

Red earths are the earliest unconsolidated sediments in the study-area (3.6.1). Remnants of this deposit lie directly above the calcarenite in sheltered karst features and at the surface, where protected by dense vegetation from erosion. Of all the cores extracted from the study-area, only core 1AG contained red earth (9.5). Particle-size analyses of this red deposit from the core, and of comparative samples from exposed red earths in the study-area, showed that each contains locally derived aeolian sand. This suggests that the sampled red earths are of aeolian origin (9.5.7ii). Findings of this study are in agreement with those of Blanc (1921) concerning red earths in Grotta Romanelli, and with similar analyses of red earths around the Mediterranean (9.5.7ii).

Red earths in the study-area may be of similar age and origin to that within Grotta Romanelli, 22 km south of Alimini Grande, which Blanc (1921) concludes is from a desert source in north Africa. From analyses of faunal remains and lithic artefacts within the red earth, Blanc (1928) suggests that it was deposited during a warm, dry interstadial of the Würm glaciation, within the Upper Palaeolithic period, in which a

steppe environment prevailed in Puglia. Piccinno (1978) does not note whether the analogous Upper Palaeolithic industries from rock shelters beside the Alimini lakes (4.5) were excavated from red sediments. Mesolithic artefacts were found within red earth fill near San Foca (Ingravallo 1980; 4.5), but faunal remains or other environmental indicators were absent.

A stalagmitic layer directly above the red earth in Grotta Romanelli, is interpreted by Blanc (1928) to indicate cool, pluvial conditions, corresponding to possibly the last Würm glacial advance in northern Europe. No evidence exists in core 1AG for pluvial conditions following deposition of the red earth. Upper levels of the red deposit in core 1AG could be redeposited red earth, transported to the depression by runoff from the basin catchment during a pluvial period, but the deposit contains no sedimentary or fossil evidence to support this.

Faunal and pollen analyses from Upper Palaeolithic levels of the Grotta Paglicci, at the south-western foot of the Gargano promontory, suggest that cool, humid conditions in Puglia were succeeded between 15500 BP and 14000 BP, by a warm, continental steppe environment (Satta & Renault-Miskovsky 1985). Dry conditions are suggested to have prevailed at the location of core 1AG during deposition of the fine aeolian sands above the red earth; herbaceous pollen taxa were predominant and algal remains were absent in this sand layer (9.5.6). The composition and particle-size of the sand, suggests that it was deposited by wind from local littoral sources (9.5.7iii).

Strong similarities between the particle-size distribution, composition and stratigraphic position of this sand and sands in cores 2AP and 3AP, associated with a 'residual dune' on the north-western side of Alimini Piccolo, suggest that they may be of similar origin and age (9.4.3 & 9.5.7). For sands to accumulate under dry conditions at the locations of cores 2AP and 3AP, sea-level would probably have been at least 3 m below its present level (9.4.3). It is argued in 9.5.7iii, that the distinct sand deposit in all three cores is associated with a phase of dune accumulation around the Salento coast, dated to between 6700 BP and 3900 BP, probably resulting from the mobilisation of fine sands by the transgressing mid-Holocene shoreline.

In cores RV88 (9.7) and SF1 (9.8), between the Alimini lakes and the Cesine reserve, aeolian sands were found to lie directly above the calcarenite. Similarly in cores PG (9.9), CS2 (9.12) and CM (9.14) from the Cesine reserve, aeolian sands of local source form a layer upon the calcarenite. Microfossil analyses of cores SF1, PG and CS2 suggest that the sands were deposited under locally dry conditions.

Each of these five cores are from low depressions which would be accessible to marine ingressions if the littoral dune cordon was absent. It is possible that prior to the development of the dune cordon, dated probably to c. 2110 BP (9.9.5), sea water was

able to penetrate these depressions and remove any sediments from the calcarenite surface; that is with the possible exception of the more inland location of core CM, where thin remnants of organic material occurred between the calcarenite surface and the sand layer (9.14.2). For this to happen, sea-level would necessarily have been within 2.5 m of its present level. This implies that sand deposition occurred at the core locations within the past 2 to 3 millennia, and was associated with early phases of sand movement leading to development of the present coastal dune cordon. As a consequence, these coastal depressions became sheltered from the open Adriatic, changing their sedimentary and ecological environments.

The proposed dating of this stage in the development of the Cesine environment, c. 2110 BP, lies within the Roman period. If the date is accurate, then the phase of sand deposition in the coastal depressions and at least the initial phases of dune accumulation occurred before construction of the harbour at San Cataldo in the 2nd century A.D. and before other developments of Imperial Roman age at San Giovanni (4.2). In preceding periods, including that of the Messapians in the early first millennium B.C., the Cesine coastline may have been more open in aspect. Similar processes have altered the Tavoliere coastline. The Lago Salso and Lago Salpi were open to the sea in Daunian and Roman times, but developing sand barriers gradually closed these lagoons from the sea (Delano-Smith 1976, 1978).

11.1.2 Organic sediments

Above the sand layer in cores 1AG, RV88, SF1 and in the Cesine cores, organic silts and peaty sediments are predominant (chapter 9). Integrated macrofossil and microfossil analyses in cores 1AG, SF1 and the Cesine cores show that locally humid conditions prevailed throughout deposition of these sediments.

Following the argument put forward for the origin of sands in core 1AG (9.5.7iii), organic sediments in this core began to accumulate in the mid-Holocene, when moister, cooler climatic conditions succeeded the dry environment of the early Holocene in southern Europe (9.5.7iv). According to this hypothesis, organic sediments in core 1AG began accumulating in the Neolithic period, corresponding to a stage within the Atlantic period of Holocene climatic change in Europe. Peat initiation at many sites in north-west Italy has been attributed to the development of a moister climate in the mid-Holocene (Cruise 1990), and it is unlikely that humid conditions suitable for organic sediment accumulation would have developed earlier in Salento.

The base of organic silts and peats to the north of Alimini Grande, including those in cores RV88, SF1 and the Cesine cores, probably does not exceed 2 to 3 millennia in

age, as constrained by the period of sand deposition at these locations (11.1.1). Humid to wet ground conditions developed partly as a consequence of dune development along the littoral, impeding drainage of runoff waters to the sea. Rainwater runoff would collect in depressions such as that to the west of Roca Vecchia (5.2.4) and to the north-west of San Foca (5.2.5). At the same time, rising groundwater levels influenced by relative sea-level rise over the past 2 to 3 millennia in this low-lying coastal zone, would eventually give rise to marshy conditions in depressed areas.

Macrofossil and microfossil analyses in core SF1 (9.8.3 & 9.8.4) suggest that shallow freshwater existed in this depression, at first perennially and then seasonally. The high silt content of the core sediments points to significant input of surface runoff and entrained materials to the depression.

In the Cesine reserve, the influence of relative sea-level rise on surface hydrology in the low coastal zone, together with impeded drainage from land to sea caused by the dune cordon, are responsible for the development of marshy conditions. Analyses of sediments, macrofossils and microfossils in cores CS2 (9.12), C3 and C4 (9.13) and CM (9.14), from more landward locations in the Cesine, suggest that organic materials accumulated under humid conditions associated with runoff collection and rising groundwater levels. Molluscan evidence in particular, suggests that groundwater levels sometimes exceeded ground level at these locations, causing standing freshwater to exist at the surface. As in core SF1, high silt contents in these cores are attributed to the transport of allochthonous material to depressed areas by surface runoff.

Analyses of cores C2 (9.10) and CS1 (9.11), from locations beside the present Salapi water-bodies, revealed that the core sediments were deposited in both freshwater and brackish water, throughout the period they represent. The evidence for brackish water implies that sea-level during this time was sufficiently high for marine water to mix with freshwater at the core locations; sea-level was therefore, probably within 2 m of its present level. Macrofossil and microfossil evidence thus provides further support for the proposal that cores C2 and CS1 represent no more than the past 2000 years (9.11.8).

At the location of core PG, from the western shore of Pantano Grande, moist to wet conditions developed following the dry period represented by aeolian sands at the base of the core. Organic sediments and sand were deposited above this layer in fresh- to brackish water. Organic-rich sediments continued to accumulate at this location in the vegetated margin of a water body. The presence of microfossils from brackish water organisms in core PG, above 1.9 m, suggests that marine water was able to reach the core location and mix with freshwater throughout the period represented by this section of the core sediments. The highly saline conditions of the modern lagoon is a recent development, encouraged by artificial drainage of the Cesine marshes.

11.1.3 Lacustrine sediments

Cores AP88 (9.2) and 1AP (9.3) are composed predominantly of lacustrine deposits, together with in-washed soil material. Both cores have a deep section of grey clay/lake-marl at their base, which was deposited in a fresh- to brackish lacustrine environment (9.2.2, 9.3.2). Sediment sequences above this layer differ between the cores, but both contain a distinct shelly layer dominated by *Cerastoderma*. Comparison between the pollen records of both cores suggests that the shell layers may be coeval (9.3.6).

Brackish water has influenced algal microfossil assemblages at both locations throughout the period represented by the core sediments. As explained in 9.2.7, this implies that marine water was able to enter Alimini Piccolo via the Strittu channel, or through subterranean pathways, and subsequently mix with freshwaters of the lake.

Following deposition of the lower lake-marl, fluctuations in relative lake-level are inferred from organic and shore sediments, together with their macrofossil and microfossil contents. This may be accounted for in part by the influx of silts and organic material from the lake margin (9.2.2, 9.3.2). Lake-level may also have fallen during a period of reduced climatic humidity. Recent research cited by Kelly & Huntley (1991) suggests that lake-levels in the Mediterranean region have fallen, overall, since 6000 BP (see 12.4.1).

11.1.4 The absence of volcanic ash layers

None of the sediment cores from the study-area contained volcanic ash layers (6.2.2). Very occasional colourless, glassy fragments occurred in mineral residues of some core samples, possibly resembling tephra, but no pattern was found to their distribution within cores.

The absence of volcanic ash layers is a little surprising since many eruptions occurred during the Holocene in the Campanian volcanic province and from other volcanoes in south-east Italy, together with eruptions in the Hellenic Arc (Keller *et al.* 1978). Mount Etna alone is believed to have erupted nine times between 152 B.C. and 43 B.C. (Stothers & Rampino 1983). Monte Vulture is geographically the closest volcano to the study-area (2.2.4), but it probably last erupted during the Würm glacial (Keller *et al.* 1978).

A sediment core from the Laghi di Monticchio, beside Monte Vulture, contains at least one tephra layer of Holocene age (Watts 1985), but its source has not been identified. Northwards of this location, a core from Holocene sediments beside Lago

di Varano, on the northern side of the Gargano promontory, contains no ash layers (Pasa & Pasa Durante 1962). Elsewhere, the closest cores for comparison with those of the study-area, are from sea-floor locations.

Three cores from the Gulf of Taranto, to the east of Salento, evidently contain no ash layers amongst the Holocene sediment sequence (Belfiore *et al.* 1982). Twenty four cores from the Strait of Otranto were studied by Hesse *et al.* (1971), seven of which were located due west of Otranto, but no ash layers were detected in the Holocene sediments. It is suggested that prevailing winds carried ash eastwards from the southern Italian volcanoes to a zone of the Adriatic north of Salento.

Indeed ash layers are present in cores from the south-east Adriatic basin, to the north of Brindisi and south of the Gargano (van Straaten 1967); the Holocene ash layers are believed to originate from Vesuvius. Bottema and van Straaten (1966) also record Holocene ash layers in core 296 east of Brindisi, and core 290 east of Pescara, but their age and source is not suggested. At least four Holocene ash layers occur in core KET 8218 from the south-east Adriatic, which according to Paterne *et al.* (1988) originate from the Campanian province. Further north, ash layers occur in core 240 from the mid-Adriatic, east of Termoli, one of which is suggested by Bottema (1974b) to represent the Plinian eruption of A.D. 79, and the other may originate from Santorini, between 1500 and 1400 B.C. Bottema and van Straaten (1966) note that ash layers have not been detected in the Adriatic north of Pescara.

It thus appears from sea-core evidence, that the path travelled by volcanic ash-plumes from past eruptions in south-east Italy, was consistently controlled by prevailing winds. In the region of Puglia, Holocene ash falls are apparently restricted to a zone between Brindisi and Pescara. The Gulf of Taranto and the Strait of Otranto, between which lies Salento and the study-area, were apparently by-passed.

11.2 Vegetation change in the study-area

11.2.1 The interpreted pollen record of core 1AG

The enclosed, marshy depression beside the northern end of Alimini Grande, was selected as the optimal location within the study-area for investigating regional vegetation change during the Holocene in this part of Salento (5.2.2). Palynological analyses and an evaluation of sediment origin in core 1AG (9.5), have shown that of all the cores investigated from the study-area, this core provided the longest and least interrupted record of vegetation change.

The lower limit to pollen preservation, and hence of the chronology for vegetation change represented by core 1AG, lies within the aeolian sand layer of proposed mid-Holocene age (9.5.7iii). Six phases of landscape evolution are identified from analyses of the core (9.5.6). A chronology for environmental change since the middle Neolithic period is put forward in section 9.5.8, based upon integrated fossil analyses and the sedimentary record of core 1AG, and upon comparison with the pollen record and radiocarbon-dated levels of core AP88 (9.5.7i). The most significant features of this chronology are summarised here; detailed interpretation is given in 9.5.6 and 9.5.8.

During the middle to late Neolithic period, open herbaceous vegetation dominated the local environment; the occasional or distant presence of deciduous tree species is noted. Dry conditions prevailed in the depression to the north of Alimini Grande, implying that all such depressions in the study-area were probably dry at that time.

More humid conditions developed towards the end of the Neolithic period, in which deciduous scrub or woodland species became more prominent locally, though herbaceous species were still predominant.

A marked expansion of mixed woodland species, dominated by deciduous and evergreen oak, took place during the early Bronze Age, under continuing and possibly increasingly humid climatic conditions. Woodland or scrub with well developed undergrowth is suggested to have extended into the depression, and may be representative of a regional expansion of mixed woodland.

This woodland phase began to decline in the middle Bronze Age, coincident with peak charcoal frequencies in the core sediments, suggesting deliberate clearance of vegetation by fire was at least partly responsible.

Some mixed woodland or scrub remained in the local environment in the late Bronze Age, whilst macchia type shrub communities, including *Pistacia*, *Rhamnus* and Ericaceae increased in prominence. These taxa were formerly present possibly as part of the woodland undergrowth. Areas of open, herbaceous vegetation existed locally, and some parts may have been cultivated with cereals.

A degree of recovery or expansion of both deciduous and evergreen oak is indicated during the Messapian (Iron Age) period and early Roman period. Charcoal frequencies are notably lower during this period, suggesting that vegetation clearance was less extensive, allowing regeneration of scrub and macchia in previously cleared areas. It is also suggested that malarial infestation of the marshy depressions, together with cultural conflict at the beginning of the Roman period, contributed to the abandonment of some areas; cereal cultivation and perhaps pastoral landuse is still represented, however.

By the late Roman period, remnant woodland or scrub was largely removed from the environs of the marshy depression, and macchia coverage was much reduced. The use of fire in vegetation clearance is suggested by high charcoal frequencies maintained from this period to recent times. Olive cultivation registers strongly in the pollen record from probably medieval to recent times.

11.2.2 Correlation between cores of the study-area

Similarities between the pollen record of the upper 1.5 m of core 1AG and pollen records of core AP88 from the lacustrine environment of Alimini Piccolo, and cores C2 and CS1 from the lagoon environment of the Cesine area, are explored in sections 9.5.7i and 9.11.8 respectively. The correlation of these cores is based upon strong similarities between frequency distributions of Quercus pollen, and of certain other pollen taxa.

Core AP88 may be correlated with core 1AG in two ways (9.5.7i), one of which allows for a probable hiatus in the sediments of core AP88, below which pollen zone B1 could represent the mixed woodland phase identified in core 1AG (zone C). This correlation is easily accommodated within the proposed time span of vegetation change represented by core 1AG, beginning in the mid-Holocene. Zone B2 of core AP88 represents a phase of macchia regeneration dominated by Quercus on the south-east side of Alimini Piccolo, similar to that represented by zone E of core 1AG. In both cores, this regenerated macchia-type shrub community is rapidly diminished in a later period leading to the present day.

The pollen record of core 1AP (9.3.4) also represents a decline in macchia vegetation on the north-east side of Alimini Piccolo (9.3.5), closely corresponding to zones B2 and C of core AP88. The pollen record of this core does not extend to earlier phases of vegetation history.

The mixed woodland phase of core 1AG is not represented in cores C2 (9.10) and CS1 (9.11) from the Cesine area, whose pollen records are very similar to each other (9.11.7iii). From analyses of depositional environments at the two core locations, represented by the core sediments and their macrofossil and microfossil contents, it is concluded that both represent the same time period of probably between the past 1500 and 2000 years (9.11.8).

Three phases of vegetation change common to both core locations (C2 & CS1) are interpreted within this period (9.11.7iii, 9.15.2). A predominantly open landscape is suggested to have existed landwards of the Salapi water bodies during the middle to late Roman period, in which herbaceous vegetation or marsh was locally prominent whilst a

macchia type shrub community existed on nearby drier land. Scattered, mixed deciduous tree species, including *Quercus*, existed within the Cesine region. Between the end of the Roman period and probably the 16th century A.D., woody macchia dominated by *Quercus* significantly increased in extent, at least in the local environment. Subsequent large-scale disturbance of the woody macchia over the past 300 to 400 years, produced an expansion of open, herbaceous vegetation. The extent of macchia coverage dwindled, within which *Quercus* became a less significant component.

This sequence of vegetation change represented by assemblage-zones A, B and C in cores C2 and CS1, closely resembles that represented by zones D2, E and F of core 1AG (9.11.8). It may be deduced from this apparent correlation between the cores AP88, C2 and CS1 and the upper 1.5 m of core 1AG, that a phase of macchia regeneration and expansion occurred throughout the study-area during a period of reduced vegetation management by human landuse practices. *Quercus* dominated this macchia community at each of the core locations representing the Alimini lacustrine and marsh basins, and the Cesine lagoonal environment. A subsequent renewed phase of vegetation clearance accompanied by signs of soil disturbance and cultivation, is also evident at each core location. The extent of macchia vegetation was rapidly reduced to restricted zones of limited agricultural potential, such as remain today (3.7.3). Although *Quercus coccifera* frequently occurs within present day macchia in the study-area, *Quercus* has been succeeded as the dominant macchia taxon by more sclerophyllous taxa.

Acceptance of this correlation, however, requires a re-evaluation of the time period represented by the upper 1.5 m of core 1AG. It has been argued that cores C2 and CS1 represent no more than the past 2000 years (9.11.8). The base of zone A in these cores (9.11.7iii) therefore has a probable maximum age of 2000 BP. In core 1AG, the corresponding zone, D2, is attributed to the late Bronze Age and early Messapian period, at around 2800 BP (9.5.8). In the Cesine cores, clearance of the regenerated macchia is attributed to medieval expansion of agriculture at around the 16th century A.D., whilst in core 1AG it is attributed to the late Roman period, c. 7th century A.D. The time differential is comparable at both stages.

On the basis of this comparison, it is concluded that either the proposed chronology for vegetation change interpreted from core 1AG (9.5.8) is around 800 to 900 years too old, or the regeneration and subsequent destruction of macchia occurred at an earlier stage in history in the vicinity of the Alimini than comparable changes in the Cesine environment.

Synchronicity with the proposed chronology for the Cesine cores agrees better with historical information, suggesting that extensive macchia coverage remained in at least

the coastal zone of Salento, until medieval times (4.5, 9.15.2). Further to this argument, the regeneration and expansion of macchia is most likely to have begun towards the end of the Roman period and developed until medieval clearance. Potter (1987) records that by the early 7th century A.D., Roman trade was in sharp decline and resources were lacking to maintain existing services and economic systems in Italy. According to Shaw-Briggs (1910) Roman control of Lecce was lost in the 6th century A.D., and centuries of turbulence followed in which successive groups invaded Salento at the coast, and from land to the north (4.5). Consequently, much land may have been abandoned during this time.

Returning to the early phases of vegetation change represented in only core 1AG (9.5), an alternative chronology to that proposed in 9.5.8, is as follows for phases preceding post-Roman macchia regeneration. The dry environment dominated by herbaceous vegetation (phase 1) may be assigned to the late Neolithic period and initial Bronze Age period, at around 3900 BP. Moister ground conditions and organic sediment accumulation developed within the Bronze Age, and the presence of mixed scrub or woodland increased locally (phase 2). The marked expansion in mixed woodland (phase 3) began at around 2900 BP, towards the end of the Bronze Age, reaching its maximum extent at around 2500 BP. Decline of this woodland began at the transition from Messapian culture to Roman dominance in the region. Some mixed woodland or scrub may have remained during the Roman period, but macchia type shrub communities are suggested to have been more prominent, interspersed with open, herbaceous vegetation and arable land (phase 4). Phase 5 corresponds to the proposed post-Roman regeneration of woody macchia.

Independent means of dating the sediments in core 1AG, by radiocarbon for example, are required to test the chronology proposed here, and that summarised in 11.2.1. Of the few existing scientific studies of Holocene vegetation change in southern Italy, most lack radiocarbon dates and none concern locations comparable to Salento and the study-area (see chapter 12).

Biancofiore (1957) tentatively reconstructed vegetation patterns of Puglia during the Neolithic and Bronze Age periods by combining environmental information interpreted from faunal remains at prehistoric sites in Puglia, with information on climax vegetation in coastal lowlands (Chiarugi 1939). Most of Salento, including the study-area, is depicted by Biancofiore (1957) as a zone of macchia dominated by Quercus ilex, which in some areas formed woodland. He suggests that this vegetation gradually developed from the steppe environment of the Upper Palaeolithic period, interpreted from studies of Grotta Romanelli by Blanc (1921, 1928). Results of the present research suggest that dry conditions persisted in the study-area, during the Holocene, until the end of the Neolithic period. Only then did macchia and mixed woodland,

dominated by both evergreen and deciduous Quercus, develop extensively in this part of Salento. Evidence for Holocene climatic change in the Mediterranean region is reviewed in 12.4.1.

11.2.3 Human impact on the study-area landscape

The earliest signs of human impact on the study-area landscape, appear in core 1AG. A sharp decline in the mixed oak woodland (phase 3), beginning in the middle Bronze Age (9.5.8), or in the Messapian/early Roman period (11.2.2), is attributed to deliberate woodland or scrub control or clearance, involving fire (9.5.6).

Commensurate with this decline, cereal-type pollen and pollen taxa representing plants of disturbed ground, became more prominent (9.5.6), suggesting that areas were cleared in order to expand agricultural land. Carbonised seeds recovered from a deposit dated to the 8th century B.C. at the Roca Vecchia site, suggest that Hordeum was among crops grown by the Messapian community (10.1.4i). The pollen assemblage within sediments from a well at this site, dated to the 3rd/4th century B.C., suggest that cereals were cultivated in a locally open landscape during the early Roman period (10.1.4ii).

Cleared areas were maintained until the Messapian/early Roman period (9.5.8) or, more probably, the late Roman period (11.2.2), when woody macchia dominated by Quercus was permitted to regenerate during a period of apparent neglect (11.2.2). Similar change occurred in the vicinity of Alimini Piccolo (9.2, 9.3), and in the Cesine area (9.10, 9.11), suggesting that a period of macchia regeneration occurred regionally, at least in the coastal zone, as a consequence of disrupted economic landuse (11.2.2). Increasing demand for arable and pastoral land in the medieval period most likely initiated the decline in woody macchia interpreted from the pollen records of cores AP88, 1AP, 1AG, C2 and CS1. The use of fire as a means of vegetation clearance is again implicated around the location of core 1AG (9.5.6), but charcoal frequencies are not high during this period in the other cores.

The fact that ground conditions at the location of core 1AG became wetter during clearance of the woodland or scrub vegetation (9.5.6) may in part result from increased surface-runoff, as a consequence of this clearance. Removal of natural vegetation cover will have significantly altered surface hydrology in the study-area, as explained in 3.6.4.

Seasonal rainfall-runoff on exposed slopes is a major agent of soil erosion in this region (3.6.4), and soil loss will have accelerated during clearance phases. In core 1AG, silts are interspersed with autochthonous organic remains, obscuring any clear

signs of increased soil erosion from surrounding basin slopes. The transport and deposition of silts by runoff in shallow depressions of the study-area is most evident in core SF1 (9.8.3), where surface-runoff on open slopes of the depression has transported soil and underlying calcareous silt to the core location.

Thus vegetation clearance will have precipitated changes in surface drainage and, together with soil disturbance by agricultural practices, will have accelerated soil loss by exposing soils to runoff and deflation. The impact of early subsistence economies on the study-area landscape is considered in the context of palaeoeconomic evidence from Puglia, in 12.4.2 and 12.4.3.

Chapter 12

PRESENT RESEARCH CONCLUSIONS IN THE CONTEXT OF HOLOCENE ENVIRONMENTAL CHANGE IN CENTRAL-SOUTHERN EUROPE

12.1 Introduction

Conclusions of the present research into Holocene environmental change in the study-area, are compared in this chapter with findings from existing studies concerning other parts of the central-southern Mediterranean. Four fundamental aspects of changing environmental conditions in the Holocene period are discussed:

- i) The nature and chronology of vegetation change;
- ii) Patterns of climate change, and the effect on vegetation and surface hydrology;
- iii) Economic practices and the human impact on the landscape;
- iv) Holocene sea-level rise in the central Mediterranean, and its impact on the study-area.

12.2 Late Quaternary vegetation-change in the central Mediterranean

In this section, the interpretation of Holocene vegetation change in the study-area (chapter 11) is compared with the findings of other studies in peninsular Italy and in the central Mediterranean area. Since significant differences in climate and vegetation exist at present between the central Mediterranean and zones to the west and east, palynological studies from Spain and the Near East are not included in this discussion.

Even within peninsular Italy, considerable variations exist in the climate and vegetation of different zones, in relation to altitude and latitude (De Philippis 1937; Chiarugi 1939; Pignatti 1979). Figure 12.1 illustrates how vegetation belts are influenced by altitude and latitude along a north-south transect through the Apennines. According to the classification of vegetation belts by Pignatti (1979), the study-area lies within the 'mediterranea arida' belt (Fig. 12.1). As most existing studies of late Pleistocene and Holocene vegetation change in Italy are based on upland locations, this zonation of vegetation is important when comparing past vegetation histories with the study-area.

The locations of all sites mentioned from Italy and neighbouring seas, are illustrated in Fig. 12.2. Those from other central Mediterranean locations are illustrated in Fig. 12.3 (see 12.2.5).

12.2.1 Southern Italy

Existing studies of late Quaternary vegetation history in southern Italy are confined to upland locations in the southern Apennines and Calabria (Table 12.1), with the exception of the study beside Lago di Varano (Pasa & Pasa Durante 1962) in northern Puglia (Fig. 12.2).

The coastal plain core-site beside Lago di Varano is geographically the closest and most comparable of all existing studies in southern Italy, to core locations within the study-area of the present research. However, the north-facing aspect of the coast and the vegetation of the Gargano massif, rising abruptly to the south, will have influenced the local climate and pollen rain at the core location. It is not surprising, therefore, that the pollen record at this site includes *Fagus* and *Acer*, which do not feature in pollen analyses of the present study. Despite inherent differences in the biogeography of the Gargano and Salento, it is possible that climatic change interpreted from the Lago di Varano pollen record by Pasa & Pasa Durante (1962) reflects that interpreted from core 1AG (9.5).

From the base of the Lago di Varano core to 1.15 m below ground level, aeolian sands containing a low ratio of arboreal to non-arboreal pollen, are suggested to represent arid conditions. Muds and silts above the sands are attributed to humid climatic conditions, in which mixed woodland developed. An apparent return to arid conditions is signified in the upper 0.5 m of the core by a decrease in arboreal pollen, apart from pine. No time-scale is put forward by Pasa & Pasa Durante (1962) for this sequence, though the overall core depth of 1.5 m suggests to the present author that the sediments are of Holocene age.

These three phases may correspond to the arid conditions represented by zone A of core 1AG (9.5.5ii) and subsequent humid conditions in which mixed oak woodland developed, represented by zones B and C. The decline of this woodland is attributed to anthropic action (9.5.5ii) rather than a return to more arid conditions, but a concurrent decrease in climatic humidity cannot be discounted.

An impression of early post-glacial vegetation on the western side of the Gargano massif is provided by pollen analyses of sediments from Grotta Paglicci, dated to between 15500 BP and 14500 BP (Satta & Renault-Miskovsky 1985). Steppe vegetation is suggested to have dominated the promontory, interrupted by scattered

pinus and possibly evergreen oaks. Herbaceous vegetation dominated the low land to the west, where sparse deciduous oaks and alder may have existed beside water-courses.

Dry, steppe vegetation was apparently also dominant at approximately 600 m a.s.l. on the slopes of Monte Vulture in the southern Apennines (2.2.4), during the glacial and early post-glacial period. Here, the pollen analyses by Watts (1985) of lake-margin sediments beside the larger of the Laghi di Monticchio, provide the most detailed existing record of late Pleistocene and Holocene vegetation change in southern Italy. Present vegetation at this site is dominated by beech woodland, lying within the 'sub-atlantic (montana)' vegetation belt of Pignatti (1979; see Fig. 12.1). Changes in vegetation composition recorded by Watts (1985) may not, therefore, be representative of changes in neighbouring Puglia; nevertheless, some useful comparisons can be made with core 1AG.

A marked transition from dry, steppe vegetation to a phase of Betula and Quercus expansion is attributed to increased climatic humidity at the beginning of the Holocene; these arboreal taxa are assumed to have survived in limited, local areas during arid periods. At the same time, steppe communities continued to exist into the early Holocene (Watts 1985). Increased climatic humidity is likely to have influenced vegetation earlier at this montane location than in the lowland, karst environment of Salento. Arboreal taxa may have expanded at a later stage of the Holocene in the latter location, as suggested by the pollen record of 1AG (9.5.8).

Quercus was the dominant arboreal taxon throughout the subsequent forest development at both locations in question. As represented in zones B and C of core 1AG, Tilia and Fraxinus were significant components of the expanding mixed woodland at Laghi di Monticchio. Corylus, Ostrya, Hedera and Vitis are also associated with the oak woodland phase at both locations.

Watts (1985) does not explain the steady, net decline of Quercus pollen frequencies in the pollen record, but a marked expansion in Abies, Ostrya and locally occurring Alnus may contribute to a relative fall in Quercus pollen percentages at Laghi di Monticchio; radiocarbon dates are not available for the Holocene part of this core. Forest clearance by man has affected the Monticchio region only in recent times (Watts 1985).

The pollen diagram produced in an earlier study of Laghi di Monticchio by Ferrarini & Totaro (1978) bears little close resemblance to that by Watts (1985), even though their core locations are apparently similar. The early Holocene expansion of Betula is not represented in the first pollen record, and Quercus is always less prominent than Fagus. The present author feels that this diagram may represent the latter half of the Holocene, rather than the entire Holocene as proposed by Ferrarini & Totaro (1978).

Broad similarities are therefore identified between the pattern of Holocene vegetation change in the vicinity of Monte Vulture, and zones A, B and C of core 1AG, related to a transition from arid to humid climatic conditions. Owing to differences in altitude and latitude between the two locations, however, the climate-induced vegetation changes in Salento probably occurred relatively later.

Other studies of late Quaternary vegetation change in southern Italy are focussed on Calabria (Table 12.1), at sites which also lie within the 'sub-atlantic (montana)' vegetation belt (Fig. 12.1). Among these, Grüger's analyses of Cánolo Nuovo (1977) provide the longest pollen record, spanning the late Pleistocene and part of the Holocene. As at Laghi di Monticchio, predominantly herbaceous vegetation of the late Pleistocene is succeeded by an expansion of woodland in the early Holocene, comprised principally of deciduous Quercus and Betula. Fagus and Abies are more prominent in the early Holocene at Cánolo Nuovo than at Laghi di Monticchio, but Grüger notes a hiatus in core sediments representing the Pleistocene/Holocene boundary. The middle to late Holocene period is also unrepresented in this pollen diagram.

Some information on the late Holocene period is provided by investigations of vegetation change at Monte Sirono, within the 'sub-atlantic (montana)' belt in Basilicata, close to the Calabrian border (Table 12.1). Biancofiore (1957) cites the work of Chiarugi (1937) and De Lorenzo & Dainelli (1923), in which climax forests of Abies alba are suggested to have dominated this location during the mid Holocene. These forests diminished in the Sub-Atlantic period, when Fagus coverage expanded. Chiarugi (1937) suggests that instability in the montane forests was induced by climatic change, and the Abies decline is not wholly attributable to human activity.

Between Monte Sirono and Cánolo Nuovo, on the Sila Grande, woods dominated by Abies alba and Fagus are shown to have alternated with woods dominated by Pinus nigra, in accordance with climatic changes over the past 1200 years (Ferrarini 1978).

Changes in climatic humidity and perhaps temperature, appear to have induced vegetation changes within the Holocene period in the montane parts of southern Italy. Anthropogenic activities have probably influenced the rate and nature of these changes in recent millennia, but seem to be of secondary importance. Whilst vegetation composition is very different in the low-altitude region of Salento, these climatic changes are likely to have affected vegetation history here also.

12.2.2 Central Italy

Much of the existing detailed information on post-glacial change in vegetation and climate in Italy comes from palynological studies of sediments within volcanic crater-lakes to the north of Rome (Table 12.2; Fig. 12.2). Despite their greater distance from the study-area than sites described in southern Italy, they are usefully compared with the pollen record of core 1AG by virtue of their lower altitudes.

The principal phases of vegetation change interpreted from lakes Vico, Monterosi, Martignano and Lagaccione by their respective authors, are summarised in Table 12.3 against a common Holocene chronology. At each site, *Artemisia* and Gramineae steppe persisted in the cold, arid conditions of the post-glacial until the onset of warm and more humid conditions in the early Holocene. This climatic transition is marked in all but the Lagaccione study, by a peak in *Corylus* pollen frequencies and the beginnings of mixed deciduous woodland at around 11000 BP (Frank 1969; Bonatti 1970; Kelly & Huntley 1991). The early deciduous woodland at all four locations formed an open canopy, with steppe vegetation persisting alongside into the early Holocene. According to the pollen diagram from Lago di Vico (Frank 1969), *Betula* was significant in the early Holocene, as it was at Laghi di Monticchio (Watts 1985) and Cánolo Nuovo (Grüger 1977).

Mixed deciduous woodland dominated by deciduous oak subsequently developed at each of the crater-lake locations, and persisted until a decline in woodland between c. 4000 BP and c. 3000 BP. Frank (1969) attributes this decline to anthropic action, but Bonatti (1970) and Kelly & Huntley (1991) suggest that a change in climate towards drier environmental conditions was principally responsible. An earlier regression in woodland development is noted at Lago di Vico and Lago di Martignano, before the warm, humid climatic optimum at c. 6000 BP. At the latter site, Kelly & Huntley (1991) identify a peak of sclerophyllous pollen taxa at c. 6700 BP.

A comparable sequence of post-glacial environmental change is interpreted from the drained crater-lake, Valle di Castiglione (Table 12.2), situated in an open basin 20 km east of Rome (Alessio *et al.* 1986; Follieri *et al.* 1988). Here, a short-lived period of increased precipitation at c. 11000 BP is suggested to have preceded the climatic amelioration of the Holocene. In the interval, a developing mixed woodland, including *Corylus*, evergreen and deciduous *Quercus*, *Betula* and *Tilia* was abruptly replaced by steppe vegetation, including *Artemisia*, Gramineae and Chenopodiaceae (Alessio *et al.* 1986). According to Kelly & Huntley (1991), a similar phase at Lago di Martignano, dated to c. 11000 BP, possibly represents a late-glacial stadial.

After c. 10800 BP, a predominantly deciduous forest expanded around Valle di Castiglione under humid and warm conditions. Steppe vegetation was still evident

during the early Holocene, however, owing to further climatic oscillations (Alessio *et al.* 1986). An increase in Mediterranean, sclerophyllous vegetation is noted after 3200 BP, pointing to the development of warmer and drier conditions. Parallel evidence for climatic change at this site was interpreted from molluscan assemblages (Alessio *et al.* 1986). Follieri *et al.* (1988) argue that the sudden fall in arboreal pollen frequencies after 3480 BP was caused by climatic change and not by man, since analogous phases exist in the Pleistocene pollen record from Valle di Castiglione.

At a lower altitude, broad patterns of environmental change from the late Pleistocene to the mid-Holocene, have been interpreted from the 'Mezzaluna core' within the Agro Pontino coastal plain, south of Rome (Eisner *et al.* 1986); a more detailed analysis is provided by Hunt & Eisner (1991). Again, steppe vegetation including *Artemisia* and Gramineae prevailed in the late glacial, and the late glacial stadial is also evident at this location (Hunt & Eisner 1991). Open woodland and herbaceous vegetation prevailed during the early Holocene. Dense, mixed oak woodland is suggested to have developed in this location only after c. 7600 BP, when climatic humidity increased significantly (Hunt & Eisner 1991). A return to drier conditions is suggested to have begun at c. 6500 BP (Hunt & Eisner 1991) and as a consequence, more sclerophyllous, macchia-type vegetation gained prominence (Eisner *et al.* 1986). This change in vegetation appears to have been precipitated by climatic conditions rather than human impact.

A change to warm, dry conditions in the later Holocene is not recorded in pollen analyses by Ferrarini & Marraccini (1978) in the Farma valley, southern Tuscany (Table 12.2). In the nearby Feccia valley, however, pollen of herbaceous and dwarf shrub taxa are predominant in late Holocene deposits, though these may reflect medieval or later human impact (Gilbertson *et al.* 1983).

The most complete studies to date of post-glacial vegetation change in the central Apennines are, to the present author's knowledge, those of Chiarugi (1936, 1939). Many arboreal pollen spectra from analysed lake and peat sediments in the 'Etruscan' Apennines (Chiarugi 1936) closely resemble those of Lago di Monticchio (Watts 1985) in the southern Apennines (12.2.1). Mixed woodland dominated by *Betula* and *Quercus* developed in the early Holocene, whilst *Abies* and *Fagus* became more significant in the middle to late Holocene. In the central Apennines, however, the development of *Abies* and *Fagus* forest largely replaced the *Quercus* forest, whereas at Lago di Monticchio *Quercus* remained the dominant taxon throughout the Holocene.

Though distant from Salento, the study of Holocene environmental change in the Lagoon of Venice (Horowitz 1966/67) is situated on the Adriatic coast, in common with the study-area. Beginning at c. 6000 BP, the pollen record at this site suggests that well developed deciduous forests, including *Quercus*, *Carpinus*, *Fagus* and *Tilia*,

existed locally until the end of a warm, humid phase corresponding, possibly, to the late Atlantic period (Horowitz 1966/67). Vitis was present within the woodland community, as it is in zones B and C of core 1AG, representing mixed woodland (9.5.5ii). A very dry phase followed, possibly coinciding with the lower Sub-Boreal. Warm, dry conditions persisted until a reversion to cooler, humid conditions of the Sub-Atlantic (Horowitz 1966/67).

Further inland, beside the Po plain near Vicenza, a pollen record from Fimon (Lona 1960) suggests that early Holocene vegetation change in this region was very similar to that observed in central Italy. Following a dry period dominated by herbaceous vegetation, woodland began to develop with an expansion of Corylus. Quercus later became the dominant taxon in a mixed woodland, together with Ulmus and Tilia.

12.2.3 Sea core studies

Pollen analyses of marine deposits from the Adriatic Sea and from the Gulf of Taranto (Table 12.1; Fig. 12.2) provide further evidence of Holocene vegetation changes for comparison with findings from the study-area. Marine pollen spectra are inherently more prone to distortion than those from terrestrial sites (Koreneva 1966; Bottema & van Straaten 1966; Bates 1981). Despite this, major floristic changes on land may be interpreted from sea cores.

Pollen in the Adriatic is derived principally from eastern Italy, western Yugoslavia and Albania. In core 270, from the southeast Adriatic basin, a dry, cold phase of herbaceous vegetation including Artemisia preceded the Holocene (Bottema & van Straaten 1966). Quercus and Corylus are present in the early Holocene. Quercus subsequently became the dominant element of a mixed woodland community including Corylus, Fagus, Ulmus and Tilia. Similar communities are also represented in core 296 (Bottema & van Straaten 1966).

A middle to late Holocene pollen record is interpreted by Bottema (1974b) from core 240, on the Adriatic shelf (Table 12.1). Deciduous woodland dominated by oak is suggested to have occurred at lower and middle altitudes, until c. 2800 BP. Bottema (1974b) suggests that the subsequent expansion of Mediterranean sclerophyllous vegetation was probably due to clearance of woodland areas by man; at the same time, pollen of Plantago and cereal-type pollen became more frequent. This broad pattern and chronology of vegetation change compares well with that interpreted from core 1AG (9.5.8, 11.2.2).

Three cores from the Gulf of Taranto (Belfiore *et al.* 1982) provide a composite pollen record which is suggested to span three to four climatic phases, but dates are

lacking. The record begins with high percentages of Quercus pollen, together with Abies, Tilia and Ulmus, suggestive of a humid climate. A subsequent fall in Quercus frequencies and a net dominance of Pinus is suggested to represent a drier period; pine, however, is often over-represented in marine sediments (Koreneva 1966). Belfiore *et al.* (1982) suggest that the predominance of Compositae pollen in the upper part of the pollen record may be attributed to human impact on the vegetation in southern Italy, besides or instead of climatic aridity. Much pollen would enter the Gulf of Taranto from Calabria, Basilicata and the Murge area of Puglia. Little may be expected to derive from the more southerly and largely river-less Salento.

12.2.4 How does the record of environmental change in the study-area compare with pollen records from southern and central Italy?

Considerable similarity has been identified between existing post-glacial pollen records from mountainous southern Italy (12.2.1), central Italy (12.2.2) and marine sediments (12.2.3). None of these locations are comparable to the relatively low latitude, low altitude, semi-arid region of Salento, represented for the first time by core 1AG.

All the cited studies which cover the late Pleistocene and early Holocene (Tables 12.1 & 12.2), indicate that a dry, steppe-type vegetation prevailed at the end of the Pleistocene period, regardless of location or altitude. The transition to more humid climatic conditions in the early Holocene is marked in these studies by an early expansion of Betula at the high altitude sites of Laghi di Monticchio and Cánolo Nuovo (12.2.1), or of Corylus at the lower altitude, crater-lake sites and Valle di Castiglione near Rome, at Fimon and in core 270 from the Adriatic. In each case Quercus was also present in this early phase. Those studies with radiocarbon dates, place the transition at between 11000 BP and 10000 BP.

At Laghi di Monticchio, and at most of the sites in central Italy, this early woodland is of open character, with steppe vegetation continuing to be evident in the early Holocene pollen record. Alessio *et al.* (1986), Kelly & Huntley (1991) and Hunt & Eisner (1991) record a brief return to steppe-dominated vegetation at the start of the Holocene, which possibly corresponds to the late-glacial stadial of northern Europe. Most of the cited studies observe that the arboreal taxa of the early woodland expansion must have survived in locally compatible niches within the arid, late Pleistocene environment. Indeed, Satta & Renault-Miskovsky (1985) note a sparse presence of Quercus in lowland, northern Puglia between 15500 BP and 14500 BP.

The sediment and pollen sequences in core 1AG suggest that dry environmental conditions certainly existed at this location in the early Holocene, and appear to have

persisted until the middle Holocene period (9.5.8). Only then did moist ground conditions develop at the core location. Herbaceous vegetation was predominant in the dry period, represented by zone A (9.5.5ii), but Artemisia was absent from this pollen-assemblage zone. Arboreal taxa, namely Quercus, Corylus and Fraxinus, were sparsely present during this period, suggesting that some trees survived in locally amenable parts within the dry environment, as has been proposed in other parts of southern and central Italy (12.2.1, 12.2.2). Locally humid conditions would have existed in the low-lying basins of the Alimini lakes, even during phases of low lake-level. The early woodland phase represented by zone B in core 1AG (9.5.5ii) is open in character, as it is in most of the cited studies, but Quercus dominated the woodland pollen-assemblage from the outset at this location; there is no early peak of Corylus or of any other arboreal taxon.

With continued climatic amelioration, mixed deciduous woodland dominated by Quercus species, expanded at each of the cited terrestrial locations; Abies alba and Fagus succeeded the early dominance of Betula and Quercus at high altitudes (12.2.1). At lower altitude sites, Quercus continued to be dominant, and was commonly associated with Tilia, Fraxinus, Corylus, Ostrya/Carpinus orientalis, Ulmus, Hedera and Vitis.

This woodland assemblage closely resembles that of the woodland phase (zone C) in core 1AG (9.5.5ii). According to the two proposed chronologies for environmental change represented by core 1AG, this woodland began to expand at c. 3700 BP, in the early Bronze age (9.5.8), or at c. 2900 BP (11.2.2). It thus appears that woodland with similar characteristics to that which prevailed in central Italy during most of the Holocene, developed considerably later in the study-area and probably the rest of Salento. The marked aridity of Salento, compared to central Italy and higher altitudes in southern Italy, may largely account for this retarded woodland development. Although major changes in climatic humidity may have occurred more or less synchronously throughout Italy during the Holocene, a considerable time-lag could have elapsed before moist conditions could be maintained at the ground surface in the karst-platform areas of Salento. Holocene sea-level rise has also been an important factor in the establishment of localised moist to wet areas in the study-area (chapter 9).

Many of the central Italian studies suggest that the well-developed woodland communities began to decline between 4000 BP and 3000 BP, at the onset of drier climatic conditions; human activities are not thought to have initiated this decline (12.2.2). A change to drier conditions in the late Holocene is also noted at Lago Varano (12.2.1) and at the Lagoon of Venice (12.2.2), whilst instability in montane vegetation zones of southern Italy during this period is attributed to climatic oscillations

(12.2.1). Mediterranean sclerophyllous vegetation-communities consequently expanded at most sites (12.2.2).

At Valle di Castiglione, the change to a drier climate, causing woodland to decline in favour of sclerophyllous vegetation, is placed between 3480 BP and 3200 BP. This radiocarbon-dated event coincides with the proposed date of c. 3300 BP for the beginning of woodland decline represented by core 1AG, based upon an evaluation of sedimentary history at the core location (9.5.8); according to the second proposed chronology for core 1AG, however, woodland decline began at c. 2500 BP (11.2.2).

As in the cited studies from central Italy and the Lagoon of Venice, sclerophyllous taxa became more prominent in the pollen record of core 1AG, following the woodland phase (zones D, E & F, 9.5.5ii). In core 1AG, however, anthropic activities are strongly implicated in the decline of woodland vegetation, owing to concurrently high charcoal frequencies (phase 3, 9.5.6) and increased frequencies of cereal-type pollen and pollen of disturbed ground. Algal microfossils in core 1AG suggest that the environs of the core location became wetter, rather than drier at this time (phase 4, 9.5.6). It is possible, however, that changes in surface and sub-surface hydrology, brought about by changes in vegetation coverage and changes in relative sea-level rise influencing groundwater levels, could account for the maintenance of locally moist areas whilst climatic humidity decreased.

The present author suggests that vegetation-management practices have played a major role in the decline of woodland in the study-area, influencing the timing and extent of subsequent macchia expansion. Whilst a drier climate may have prevailed at the same time, no direct evidence for this exists within microfossil assemblages from core 1AG (9.5.3).

12.2.5 Vegetation development in the study-area compared with other parts of the central Mediterranean

Most studies of late Pleistocene and Holocene environmental change elsewhere in the Mediterranean region, are based upon upland locations, as is the case in Italy. The majority of these mainly palynological studies, reveal a broadly similar pattern of post-glacial vegetation development to that of central and southern Italy. That is a dry, steppe-type environment prevailed during the late Pleistocene, and was succeeded by more humid conditions in the Holocene, in which woodland or forest developed, dominated by species of *Quercus*.

Details of this pattern are complex. Significant variation exists between regions of the Mediterranean in the timing and rate of vegetation change, and in the detailed

composition of vegetation communities. These variations reflect differences in altitude, latitude and continentality of the locations investigated. The few studies from low altitude or semi-arid areas are given most attention in this comparison with the study-area; the location of all mentioned sites are shown in Fig. 12.3.

i) Greece

Several palynological investigations at relatively low altitude are based on locations in the Plain of Drama, north-eastern Greece, at a comparable latitude to central Puglia. The core from Tenaghi Philippon provides the longest record of late Quaternary vegetation change in Greece (van der Hammen *et al.* 1965; Wijmstra 1969). At this location, an expansion of mixed deciduous and evergreen woodland dominated by oak, is suggested to have begun at c. 13500 BP, succeeding the dry steppe vegetation of the late Pleistocene (Wijmstra 1969). Within the early Holocene period, most low and middle altitude areas of Greece were covered by oak forest (van Zeist & Bottema 1982).

Close to Tenaghi Philippon, cores from Lake Philippi provide more detailed palynological information for environmental change over the past 8500 years (Greig & Turner 1974, Turner & Greig 1975). Human influence on the vegetation is only evident in the pollen record after 2500 B.C., when an expansion of evergreen scrub amongst the woodland is suggested by increased frequencies of Ericaceae pollen. Oak woodland was still predominant in the second millennium B.C., when olive cultivation and woodland management becomes apparent in the pollen record. A further study at Gravouna, north-eastern Greece, suggests that oak forest disappeared within the past 2000 years, or even in the medieval period (Greig & Turner 1974; Turner & Greig 1975). Based upon studies of vegetation history in north-western Greece, Bottema (1974a) suggests that large areas of northern Greece were still forested during the 18th century A.D.

Further south at Lake Viviis in Thessaly, another lowland site, palynological analyses by Bottema (1979) suggest that the decline of oak-dominated woodland in this area within the past 3000 to 4000 years, was caused by man. Greig & Turner (1974) also observe that in more southerly locations of Greece, such as Lake Kopais, deforestation commenced at an earlier period than in north-western Greece.

Though at a more southerly latitude than the study-area, a pollen record from Crete (Bottema 1980b), at a location close to present sea-level near Aghia Galini, suggests that oak woodland was also prevalent here in the mid-Holocene. The woodland included both evergreen and deciduous oak, *Tilia*, *Hedera* and *Vitis*, in common with

zone C of core 1AG. From a sea-core to the east of Crete, the decline of this woodland is dated to c. 7000 BP, and attributed to human activities associated with pastoral practices (Rossignol & Pastouret 1971).

Differences in population pressure, combined with geographic differences in climatic humidity, may explain these regional variations in mid to late Holocene vegetation history (Greig & Turner 1974). Though the cause of woodland decline may be primarily due to human action, prevailing climatic humidity at a specific location will influence the ability of original vegetation to regenerate. Greig & Turner (1974) suggest that humidity levels have remained sufficiently high in northern Greece for woodland to regenerate if disturbance by man and animals is reduced or ceased. In southern and drier parts of Greece, however, humidity levels are sufficient only for evergreen oak and sclerophyllous scrub regeneration, following destruction of the original forest cover.

As in the analyses of core 1AG (9.5.5ii), these studies from Greece suggest that human practices were responsible for changing vegetation patterns in the mid to late Holocene period, rather than climatic change. Van Zeist & Bottema (1982) similarly conclude that changes in the composition of Greek forests over the past 3500 years are due mainly to human activity. This contrasts with the widely perceived climatic initiation of woodland decline in central Italy, between 4000 BP and 3000 BP (12.2.3).

ii) Dalmatia

The Holocene pollen record from Malo Jezero on the island of Mljet, southern Dalmatia (Beug 1967), is quite different from those of Greece. This is at least partly explained by altitude-related differences in climate. Malo Jezero has much in common with the Alimini, in the study-area. Both are lakes occupying dolines in a karst area, situated within the eu-Mediterranean vegetation zone, beside the Adriatic.

Beug (1967) identifies four phases within the pollen record of Malo Jezero, which approximately cover the period 9000 BP to 2000 BP. Deciduous oak forests incorporating Corylus and Tilia prevailed until c. 5600 B.C., when a period of vegetation dominated by Juniperus and Phillyrea developed. These evergreen taxa suggest that drier climatic conditions existed between 5600 B.C. and 4300 B.C. (Beug 1967), although this would correspond to the supposedly more humid Atlantic period.

Quercus ilex woodland began to expand at c. 4300 B.C., together with other evergreen taxa, including Ericaceae. In the final phase of the pollen record, high Pinus frequencies join those of Quercus ilex. Beug (1967) attributes the last two phases of

vegetation change to human activity, and suggests that the pollen record contains no evidence for Sub-Boreal climatic deterioration.

Whilst the deciduous oak forest indicated in the first phase at Malo Jezero is similar in composition to that represented by zone C of core 1AG (9.5.5ii), the age of this phase is several millennia earlier than that proposed for zone C. Little similarity can be seen between the subsequent vegetation histories at the two locations, save the conclusion that human activity was the prime cause of mid to late Holocene vegetation change.

12.3 Conclusions on Holocene vegetation history in the central Mediterranean

Pollen records from varied locations within the central Mediterranean region show similar underlying patterns of vegetation change during the late Pleistocene and Holocene period. Differences in the timing of these changes between locations are largely explained by differences in altitude, latitude and the continental or oceanic influence on climate. In most of the cited studies from Italy, Greece and Dalmatia, marked changes in climatic humidity are directly responsible for vegetation change in the late-Pleistocene and early Holocene period. Opinions differ, however, as to the primary cause of vegetation changes in the mid to late Holocene period.

Most studies in central and southern Italy suggest that increasing climatic aridity within the period 6000 BP to 3000 BP, initiated a widespread decline in mixed oak woodland, encouraging the expansion of sclerophyllous shrub taxa. Human activities are generally thought to have been of secondary significance, and in some cases only a recent factor in vegetation change. The recognition of similar phases of woodland decline in the Pleistocene record from Valle di Castiglione (Follieri *et al.* 1988), adds emphasis to the climatic argument for woodland decline.

By contrast, studies from varied locations in Greece (12.2.5i) and Dalmatia (12.2.5ii) conclude that woodland decline in the mid to late Holocene was precipitated by human management of vegetation and economic practices. Whilst no clear evidence is put forward from these studies for an increase in climatic aridity in the latter part of the Holocene, regional differences in humidity have influenced vegetation history, following woodland disturbance. In this way, woodland has not regenerated following clearance in the southerly and drier parts of Greece, but given way to sclerophyllous scrub expansion. In the relatively humid areas of northern Greece, humidity levels have remained sufficiently high to permit woodland regeneration. This partly explains

why woodland decline is apparent several millennia earlier in pollen records from southern locations.

None of the studies of vegetation history in Italy or the central Mediterranean, are from locations as arid and at such low altitude as the study-area in Salento. Even so, the pattern of Holocene vegetation change represented by core 1AG, is to an extent similar to patterns in central and southern Italy (12.2.4) and in Greece (12.2.5i). Climatic humidity, surface hydrology and human activities in the landscape are identified as critical factors in determining the time and nature of vegetation change in the study-area.

Because of the relative aridity and karst nature of this area, the effect of increasing climatic humidity on vegetation patterns during the early Holocene was probably less immediate here than in other parts of Italy. A delay may be expected before increased climatic humidity, coupled with the effect of Holocene sea-level rise on groundwater levels, could translate into moister ground conditions (12.2.4). Hence, mixed woodland expanded in the study-area during the mid Holocene (11.2.2). It is possible that some arboreal taxa survived the dry, early Holocene and preceding periods in relatively moist refugia within the Alimini basins. The woodland represented by zone C of core 1AG is of similar composition to that which developed in many parts of central Italy and lowland Greece during the early to mid Holocene period.

Human activities are considered primarily responsible for the decline of woodland in the study-area, comparing well with the cited studies from Greece and Dalmatia. Unlike these other studies, the argument for human rather than climatically induced woodland decline in the study-area, is strongly supported by integrated analyses of charcoal and algal microfossil frequencies. The ability of this climax vegetation to regenerate has not only been influenced by prevailing climatic humidity, but also by changes in surface hydrology as a result of human practices of land and vegetation management, together with sea-level rise. These combined factors favoured the expansion of sclerophyllous taxa and macchia communities; present environmental conditions in the study-area and Salento are clearly suitable for mixed oak woodland to survive, where protected from disturbance by man and grazing animals (2.7.1, 3.4).

The substantiality of this argument for Holocene vegetation change in the study-area, amidst the regionally different patterns emerging from this discussion, is further evaluated in section 12.4 in the context of Holocene climatic change in the Mediterranean region, and the development of subsistence economies in south-east Italy.

12.4 Climatic change and human impact during the Holocene in south-east Italy: a review of the evidence

12.4.1 Holocene climatic change in the central and southern Mediterranean region

Climatic change within the Holocene period is commonly inferred from reconstructed vegetation history, based on pollen analytical data. Vegetation is, however, proxy evidence for climate. Ritchie (1986) lists other important influences on vegetation patterns, including topography, plant life-cycle characteristics and anthropogenic factors. Together these factors modify the spatial and temporal response of vegetation to climatic changes (Ritchie 1986; Webb 1986).

Even so, the climatic phases commonly interpreted from pollen diagrams in north-western Europe, after the sequence of Blytt & Sernander (Pre-Boreal, Boreal, Atlantic, Sub-Boreal, Sub-Atlantic), have also been discerned within many pollen diagrams from central and southern Europe. Magny (1982) notes, however, that whilst this chronology may apply to spatially distant parts of Europe, the nature of climatic change varies regionally according to shifts in the polar and tropical air-masses within the atmospheric circulation of the northern hemisphere. The Holocene pollen records discussed from peninsular Italy, Greece and Dalmatia (12.2) certainly reveal regional differences in climatic interpretations, especially pertaining to the middle and late Holocene.

Two questions relating to climate are of most concern to the present research. Firstly, could arid conditions have persisted longer into the early Holocene (Boreal) phase in Salento and the study-area? Secondly, was the study-area influenced by a marked return to drier climatic conditions in the 4th and 3rd millennium BP, contributing to the decline of mixed oak woodland?

In response to the first question, it has been argued in 12.2.4 and 12.3 that the development of moist ground-surface conditions is likely to have lagged considerably behind the onset of more humid climatic conditions in this karst region. Even in north-western Italy, Cruise (1990) suggests that conditions suitable for peat initiation only developed in the mid-Holocene, following a change to a cooler, moister climate after the reported Holocene thermal maximum between 9000 BP and 6000 BP (COHMAP 1988; Guiot 1987). This evidence contrasts with the more commonly inferred humid climatic conditions of the early Holocene in other parts of the central Mediterranean region (12.2)

With regard to the second question, significant change in vegetation communities between the 5th and 2nd millennium BP, reconstructed from pollen diagrams in parts of the central Mediterranean region, have commonly been attributed to a return to drier

climatic conditions (12.2), or at least to the development of a more pronounced dry season in the prevailing climate. Palynological studies from southern France (Guiot 1987) similarly suggest that climate became drier after 4500 BP, and particularly after 2500 BP. Although there is little such evidence from Greece (12.2.5i; Beug 1982), studies of soil stratigraphy in Greece (Paepe & Mariolakos 1986) suggest that drought periods became more frequent after c. 2700 BP.

More direct evidence for declining climatic humidity in the Mediterranean region during the latter half of the Holocene, is provided by studies of lake-level change. Studies of African lake-levels, particularly north of the equator, have shown that levels rose in the early Holocene, reaching maximum levels between 9000 BP and the middle Holocene (Street & Grove 1976, 1979; Kutzbach & Street-Perrott 1985; Ritchie *et al.* 1985). These same studies report widespread decline in African lake-levels beginning in the 5th millennium BP, directly attributed to decreasing precipitation associated with major shifts in rainfall regimes (Street & Grove 1976).

Broadly similar lake-level fluctuations occurred in Lake Fucino, central Italy, and are attributed to Holocene climatic variations associated with the Earth's orbit (Giraudi 1989). A synthesis of Mediterranean lake-level studies by Harrison & Digerfeldt, referred to by Kelly & Huntley (1991), also points to generally higher lake-levels than present, at c. 6000 BP. In the present research, changing levels of Alimini Piccolo have been interpreted from microfossil analyses of core sediments (9.2, 9.3), but in this location sea-level rise and subterranean karst drainage are major factors in determining lake-level, besides any climatic change. Difficulties in inferring climatic change from lake-level data in karst areas are noted by Lamb *et al.* (1989).

Lake-level and vegetational evidence for a generally warmer and wetter climate in north Africa and Eurasia in the first half of the Holocene, between c. 12000 BP and 6000 BP, has been explained in terms of a strengthening of the northern monsoons, caused by greater seasonal extremes of insolation (COHMAP 1988). A reversal of this trend since c. 5000 BP caused general decline in climatic humidity. Current research attributes this significant change in Holocene climate primarily to changes in incoming solar radiation due to variations in the Earth's orbit, known as the 'Milankovitch effect' (Kutzbach & Street-Perrott 1985; Wigley & Kelly 1990).

The occurrence of sapropel layers in Holocene marine sediments of the Adriatic, Ionian and eastern Mediterranean Seas, corroborate lake-level evidence for major climatic change in the Holocene period. These sediments are produced in stagnant bottom-waters, caused by the creation of stable stratification in the water column, arising from significant influx of low-salinity surface waters. The most recent Holocene sapropel layer is dated to between 9000 BP and 8000 BP in the south-east

Adriatic (van Straaten 1971), in the Straights of Otranto (Hesse & von Rad 1971; Hesse *et al.* 1971) and in the Ionian Sea (Rossignol *et al.* 1982; Stanley 1978).

According to Rossignol *et al.* (1982) this stagnation was caused by the influx of rainfall-runoff from equatorial Africa, via the River Nile to the Mediterranean Sea, consequent to the rainfall maxima between 9000 BP and 8000 BP. It follows, however, that the formation of sapropel in the Straights of Otranto, close to the study-area, does not necessarily relate to contemporary climatic conditions in southern Italy.

In conclusion, there is evidence from different parts of the central and southern Mediterranean region for major changes in climate during the Holocene. These changes are primarily related to the effect of variations in the earth's orbit on atmospheric circulation patterns in the northern hemisphere. Consequently, marked differences exist in the nature of climatic change between regions of the Mediterranean, especially with regard to humidity and precipitation patterns. Local variants, including relief and continentality further modify a region's climate. Lake-level evidence from north Africa concurs with palynological evidence from parts of the Mediterranean region for the development of drier climatic conditions at varying stages after 5000 BP, but evidence for such is geographically discontinuous.

12.4.2 The nature and chronology of human impact on the environment of Puglia

The present landscape of the study-area and most of Puglia has been profoundly modified by human landuse. First signs of human impact in this region are most likely associated with the development of agricultural practices. Despite the wealth of known archaeological sites in Puglia, information on associated subsistence economies is generally limited. Where recovered, faunal remains and carbonised plant remains suggest that this region is very important to investigations of early agricultural development in Italy. The hypotheses put forward by Whitehouse (1968) on the chronological development of settlement and economy in relation to the environment of southern Italy, provide a useful framework which is largely supported by more recent palaeoeconomic evidence from Puglia.

Known Upper Palaeolithic and Mesolithic sites in Puglia are mostly concentrated around the coast, from which faunal evidence suggests that economies were based on hunting small animals and collecting shellfish, especially in the Mesolithic period (Whitehouse 1968). These sites remained in use during the early Neolithic period, and include the rock shelter sites beside the Alimini lakes (4.5).

Whitehouse (1984) suggests that there is no clear evidence for domesticated cereals or cultivated plants in south-east Italy until c. 5500 B.C. By this date a subsistence

economy based upon mixed farming was widely practised, and a particularly high density of ditched villages was established on the Tavoliere Plain during the Neolithic period, as first recorded from aerial photography (Bradford 1949). Factors behind this fundamental economic development are discussed by Peroni (1967), Whitehouse (1968), Barker (1985) and Barker *et al.* (1987).

Studies of the relationship between these sites and the Tavoliere environment (Cassano & Manfredini 1986; Sargent 1983; Jarman & Webley 1975) show that many are located at ecotones, within easy access of both light soils associated with the *crosta* (see 2.4.3) suitable for cultivation with simple technology, and also to grazing land. From a number of these Neolithic sites, cereal remains including *Triticum monococcum*, *Triticum dicoccum* and *Hordeum vulgare* (see Evett & Renfrew 1971) and artefacts related to agriculture, as well as faunal remains including mostly sheep bones, have been recovered (Sargent 1983). It is likely that some transhumant movement of stock to upland summer pastures in the Gargano and southern Apennines was also embraced by the Neolithic economy (Jarman & Webley 1975; Sargent 1983). South of the Tavoliere, remains of *Triticum monococcum*, *Triticum dicoccum* and *Hordeum* have been recovered from at least five Neolithic sites on the low Adriatic coastal strip of alluvial soils (2.2.3) between Bari and a point east of Ostuni (Costantini 1984; Coppola & Costantini 1983).

Whitehouse (1971) suggests that while agricultural development took place in favoured lowland areas, some peripheral groups continued to subsist by economies Mesolithic in character. Examples from Salento include the sites Grotta del Fico and Grotta delle Prazziche on the Ionian coast, where hunting, gathering and the collection of shellfish declined during the Neolithic period in favour of an economy based on sheep and goat stock. Some crop cultivation may have been included towards the end of the Neolithic (Whitehouse 1971). Comparable subsistence remains were recovered from the Neolithic site of Cala Colombo, near Bari (Giove *et al.* 1977).

Evidence from some lowland and coastal areas of Puglia thus suggest that cereal cultivation began in this region within the 6th millennium B.C. Stock rearing, mainly of sheep, was also a dominant element in Puglian economies from the beginning of the Neolithic period (Castelletti *et al.* 1987). Both principal elements of this mixed farming economy were practised earlier in this region than in other parts of Italy (see Barker *et al.* 1987) and it follows that the impact of human activities on natural vegetation patterns and the landscape was probably earliest in the south-east of Italy.

Palynological investigations of the Tavoliere sediments would help determine the rate and nature of these man-induced environmental changes. Such studies may also contribute to understanding the apparent 'abandonment' of many settlements on the plain in the 4th millennium B.C., lasting until the Iron Age (Whitehouse 1981).

Whitehouse (1968) suggests that soil degradation and loss through generations of farming, combined with a change to drier climatic conditions and also cultural change, caused a shift towards upland settlement and increased emphasis on pastoral economy; socio-economic factors are considered most important by Cipolloni Sampò (1982).

Climatic change is the most favoured single factor for this shift in population and economic emphasis (Whitehouse 1984; Jarman & Webley 1975) but it has been pointed out that a change to wetter ground conditions could hinder cultivation as much as enhanced seasonal aridity (Whitehouse 1984). Altered surface hydrology on the plain and in the uplands, caused by vegetation clearance and sediment movement, combined with rising sea-level during the latter half of the Holocene causing rivers to aggrade and possibly causing the water-table to rise, may have created wetter ground conditions in the plain. Palynological investigations of sediments from carefully selected locations of the Tavoliere, following the methodology of the present research project, would not only provide information on changing vegetation patterns and human influence, but would also detect change in surface moisture conditions through the analysis of non-pollen microfossils, particularly algal remains.

Cultural factors became increasingly influential over subsistence patterns in later prehistory. Whitehouse (1968) recognises an economic dichotomy in the Bronze Age of Puglia. Inland populations practised a mainly pastoral economy based on sheep and goat herding, while some other groups occupied coastal locations and developed an economy based on mixed farming, marine resources and trade across the Adriatic.

During the Roman period, the Tavoliere became an important cereal producing region (as it is today, 2.8) as well as a winter grazing area for stock, mainly sheep (Cassano & Manfredini 1983; Sargent 1983; Barker 1981; Jarman & Webley 1975). Large-scale transhumant pastoralism involving the Tavoliere as an area of lowland winter pasture, became more important in the Imperial Roman period (Jarman & Webley 1975).

Information summarised thus far is sufficient to place the present research conclusions concerning human impact on the study-area landscape (11.2.3), in the context of known patterns of prehistoric subsistence economy in Puglia.

12.4.3 Concluding remarks on Holocene climate and subsistence economies in south-east Italy, with respect to environmental change in the study-area

Given the karst hydro-geology of the study-area (3.4, 3.5) and the regional variations in Holocene climatic change (12.4.1), it is credible that dry conditions prevailed in this area during the early Holocene, as interpreted from the sediments of core 1AG (9.5.7iii). The impact of human activities on the study-area environment quite likely

became widespread at a later stage than in the Tavoliere plain, where lowland, alluvial soils with surface drainage from the Apennines was favoured by Neolithic farmers. Available palaeoeconomic evidence suggests that during the Neolithic period, much of Puglia outside the Tavoliere was best suited to pastoral economies based mainly on sheep and goat (12.4.2).

As described in 2.9, the scarce availability of freshwater in the Murge and in large areas of western and southern Salento where Cretaceous limestones outcrop, has probably always limited settlement and economic development. In parts of central and eastern Salento, however, perched groundwater reserves are accessible within low-lying areas of sandy calcareous rocks (2.9, 4.5). The study-area lies within this terrain, and prehistoric populations were doubtless attracted by freshwater supplies accessible from springs and through excavating wells in the soft calcarenite, once suitable technology was developed.

Neolithic artefacts have been found within the study-area, but subsistence evidence is so far lacking (4.5). The pattern of known Bronze Age settlement (4.5) concurs with the view of Whitehouse (1968) that some groups developed coastal settlements during this period, associated with trade across the Adriatic (12.4.2). D'Andria (1988) suggests that the later Messapian peoples traded pastoral products from Salento for exotic goods.

Evidence for cereal cultivation is provided for the first time in the study-area by the present research. Pollen evidence from core 1AG suggests that cereal production increased in the middle Bronze Age or in the Messapian/early Roman period (11.2.3). According to Whitehouse, cereal production formed part of the subsistence economy of coastal populations during the Bronze Age. In the Tavoliere, production was intensified in the Roman period (12.4.2), if not earlier, and it may follow that cereal cultivation expanded in other suitable areas at the same time, including the study-area.

This comparison with existing information on patterns of prehistoric subsistence economy in Puglia, adds support to the conclusion, based upon the present research, that wooded parts of the study-area were cleared deliberately for agricultural purposes (11.2.3). The marked decline in woodland interpreted from analyses of core 1AG, beginning between the middle Bronze Age and late Iron Age (11.2.3), was primarily caused by human activities, rather than climatic change.

12.5 The impact of Holocene sea-level rise on the study-area

Sea-level rise has significantly influenced environmental change in the study-area since at least the middle Holocene. This conclusion is founded on sedimentological analyses within the present research, particularly in the environments of the Cesine and Alimini. Aeolian sands in cores 2AP and 3AP from the western side of Alimini Piccolo, and in core 1AG to the north of Alimini Grande, are associated in this study with a phase of dune accumulation consequent to a middle Holocene stage of sea-level rise (9.5.7iii, 11.1.1). In several cores from the Cesine reserve, and from basins between the Alimini and the Cesine, an ingress of marine water is implied prior to formation of the most recent dune cordon, at c. 2110 BP (11.1.1).

By penetrating the coastal calcarenite and karst systems, sea-level rise has also influenced groundwater levels in parts of the study-area and contributed to the consequent development of marshy conditions in coastal depressions. Surface drainage has been further impeded indirectly by sea-level rise, particularly in the Cesine reserve, through the development of coastal dune cordons.

Some implications of Holocene sea-level rise for settlement in the coastal margin have been identified in earlier chapters. Submerged and partially submerged remains of Roman constructions between San Cataldo and the Cesine area point to significant relative sea-level rise in the past two millennia (4.2, 11.5). The fact that certain natural inlets along the calcarenite cliff-coastline between San Foca and Otranto were in use as harbours since at least the late Bronze Age (4.5) suggests, however, that sea-level was sufficiently high for boats to land close to the present cliff coastline at c. 900 B.C. or earlier. It is evident from ongoing cliff-collapse, truncated cliff-top remains and offshore stacks that much land and prehistoric remains have been lost through marine erosion of the cliff base (3.6.6). An indirect influence of sea-level on population in the study-area is the malarial infestation of coastal marshy areas, beginning possibly in the second century B.C. and lasting until the 1940's (2.9).

Holocene sea-level change has influenced drainage, vegetation and population patterns in the study-area. In addition, the land area and coastal configuration between San Cataldo and Otranto have been modified by marine transgression, associated with the pattern of Holocene sea-level rise and the relief of submerged land adjacent to the study-area.

12.5.1 Holocene sea-level change

The rate and pattern of Holocene sea-level change in the Mediterranean region, and elsewhere, remains a much debated subject. Aside from regional differences in relative sea-level rise caused by tectonic and isostatic movement of the Earth's crust and changes in the geoid (sea-surface topography; Mörrner 1987), opinions still differ as to the pattern of the glacio-eustatic element of sea-level rise.

Mediterranean sea-levels are generally believed to have been between 100 m and 90 m below present levels during the last glacial maximum (Nilsson 1983). Most curves of post-glacial sea-level change, based on studies in the Mediterranean (see Pirazzoli 1987) and elsewhere (see Kidson 1982), suggest that sea-level had reached between 60 m and 50 m below present levels by c. 10000 BP. There is general consensus that sea-level rise continued at a relatively rapid rate until c. 5000 BP, when levels reached around 5 m below present.

Three main schools of thought exist concerning the eustatic element of sea-level rise in the past 5 millennia (Bintliff 1977; Kidson 1982). The first maintains that there has been no major sea-level change over the past 2 to 5 millennia. The second suggests that over the same period, levels have oscillated several metres above and below present sea-levels. From a review of existing studies, Kidson (1982) concluded that there is no convincing evidence that eustatic sea-level has exceeded existing levels during the Holocene. The third suggests that since c. 5000 BP there has been a slow but fairly constant eustatic rise in sea-level.

Many studies of sea-level change around the Mediterranean favour the third model, upon which regional tectonic movements and differences in the geoid may be superimposed. These studies are often based on the degree of submergence of datable man-made features with a specific relationship to sea-level, for example, Roman fish tanks. In this way Pirazzoli (1976) calculated an average sea-level rise of 0.75 m per millennium since Roman times, along the coast between Marseilles and Formia, Italy. Bintliff (1977) cites similar studies from around the Mediterranean which point to an average sea-level rise of 2 m in the past 2 millennia. Galili *et al.* (1988) provide evidence off the Carmel coast of Israel for a comparable rate of sea-level rise over the past 6 millennia.

Fleming, however, concluded from similar analyses around the western Mediterranean (1969), Peloponnese (1968) and Aegean (1971) that tectonic subsidence accounted for all but 0.5 m, at most, of submergence over the past 2000 years. In a reassessment of Fleming's data, Bintliff (1977) contends that allowing for regional differences in tectonic movement, the data actually signifies a glacio-eustatic element of

sea-level rise of around 1 m per millennium since Roman times, in agreement with other studies.

Thus, much evidence from the Mediterranean suggests there has been a glacio-eustatic element of sea-level rise of up to 1 m per millennium over probably the past 5 to 6 millennia. Sources of error in these determinations are many however (see Kidson 1982), and regional differences in tectonic stability, isostasy and the geoid are often significant components of Holocene sea-level change relative to land-level.

12.5.2 Adriatic bathymetry and relative sea-level change

Regional differences in the tectonic situation around the Adriatic will have influenced relative sea-level change. The Gargano peninsula, for example, continues to be uplifted (2.2.1), whereas the northern Adriatic, in the region of the Po, continued to subside until at least 3000 BP (Bortolami *et al.* 1977). The configuration of the Adriatic geoid further adds considerable spatial variation to sea-level. Pirazzoli (1987) notes that there is more than 15 m difference in elevation between the Ionian sea-surface and the northern Adriatic sea-surface. Geoid gradients are particularly steep near zones of plate subduction (Fig. 12.4), and since the central Mediterranean is tectonically active, sea-surface topography may be gradually changing (Pirazzoli 1987). The magnitude of tectonic and geoidal elements of relative sea-level change in the Adriatic regions are not known. An impression of the likely impact of relative sea-level rise on coastal lands around the Adriatic is based, in this discussion, on the basic pattern of Holocene glacio-eustatic sea-level rise (12.5.1).

As illustrated in Fig. 12.5, Adriatic bathymetry is such that sea-level rise from around 100 m below present levels (12.5.1) will have dramatically altered the extent of lowland at the sea's margins, particularly in the north. Consequently rising sea-level would have had a major impact on population and resource distribution in these coastal lowlands throughout the Holocene. The 100 m isobath varies considerably in distance from the present coastline, and is actually closest adjacent to the coast of Puglia, between Bari and Capo Santa Maria di Leuca (Fig. 12.5); this coastal stretch includes the study-area. A more detailed bathymetric chart of the southern Adriatic (Fig. 12.6) shows that this stretch of coast has regressed a relatively short distance since the beginning of the Holocene, assuming that sea-level was then around 50 m to 60 m below its present level (12.5.1).

12.5.3 The submergence of land off-shore from the study-area

An impression of the extent to which Holocene relative sea-level rise has altered the land area and coastline between San Cataldo and Otranto, is given here by relating the generally accepted glacio-eustatic sea-level curve (12.5.1) to nearshore bathymetry. Sediment accumulation on the sea-floor will have distorted the isobaths to some extent.

The 50 m isobath shown in Fig. 12.7 may approximate the coastline at the beginning of the Holocene. It suggests that land extended furthest from the present coastline in the vicinities of the Cesine and Alimini, at distances respectively reaching up to 2.5 km and 3.5 km. Both the 10 m and 5 m isobaths show that marine transgression has been greatest beside the Alimini and Cesine regions. Between San Foca and the Alimini dunes, and between the outlet of Alimini Grande and Otranto, both isobaths lie mostly within 200 m of the present shoreline (Fig. 12.7). The latter two coastal stretches correspond to the Pliocene cliff sections (3.2) along which a number of small inlets have served as natural harbours and landings since the late Bronze Age (4.5). In many places the 5 m isobath is very close to the present shoreline, suggesting that only cliff-collapse has altered these sections of coastline over the past five millennia or more.

Throughout the Holocene, loss of land from the study-area has been greatest adjacent to low stretches of coastline, at present marked by dune cordons bordering the Alimini and Cesine areas. Freshwater issues from springs in both areas today, and it is likely that similar freshwater supplies existed in the adjacent land that is now submerged. The accessibility of freshwater, together with marine resources in these low-lying areas, may have attracted prehistoric groups. Underwater archaeological survey for prehistoric remains might profitably be focussed on these areas, although any features may lie beneath sands and sediments. Beside the tracts of cliff coastline, archaeological remains from the past 10000 years may be expected mainly within 500 m of the present shore, probably having been displaced by cliff-collapse.

The sediment, macrofossil and microfossil analyses of cores from the Cesine area (9.9 to 9.15), together with the submergence of Roman remains between San Cataldo and San Giovanni (4.2), do provide evidence for sea-level rise in the past 2 millennia. A relative rise of around 1 m per millennium (12.5.1) accords well with the proposed chronology of sedimentation in parts of the Cesine (9.9.5, 9.15.1). As explained in 4.2, one submerged construction suggests that relative sea-level has risen more than 2 m in the past 2000 years. There remains the possibility that this zone of Salento has undergone some subsidence over the same time period, but this has yet to be shown (3.3). If the submerged remains could be accurately dated and confidently related to sea-level contemporary with their times of construction, then the magnitude of relative sea-level rise could be calculated, and the neotectonic situation better understood.

Chapter 13

CONCLUSION**13.1 Completion of the research aims**

Motivated by a conspicuous lack of palaeoenvironmental information in an area of distinct archaeological importance, the present research set out to provide the first detailed scientific analysis of Holocene environmental change in peninsular south-east Italy. The study-area in Salento has a long history of human settlement, in which the qualities of readily accessible freshwater, easily excavable bedrock for construction, and an approachable coastline with natural harbours have attracted settlement in prehistoric and historic time.

The overall aim of the present research, to determine how and at what rate the environment of the study-area has changed in the presence of prehistoric and historic populations, has largely been achieved according to the strategy outlined in 1.3. Research conclusions specific to the study-area are presented fully in chapter 11, and the significance of these conclusions in the context of existing records of Holocene environmental change in the central Mediterranean region are discussed in chapter 12. To sum up, the main conclusions in response to specific questions identified for investigation in 1.1 are recapitulated here.

13.1.1 Holocene vegetation change in the study-area

On the basis of geomorphological survey, depositional environments were identified and the late Pleistocene and Holocene sedimentary sequence determined for the study-area. Red earths are identified as the earliest unconsolidated deposits in the study-area and represent arid conditions in the late Pleistocene. At the base of core 1AG, the presence of red earth confirmed that this core from the marsh basin to the north of Alimini Grande, contains the longest and most complete record of environmental change in the study-area. As anticipated, the core analyses provide both regional and local information on changing vegetation and environmental conditions. From an evaluation of the origin of sands and red earth at the base of the core, the beginning of the microfossil record in core 1AG is placed in the middle/late Neolithic period, corresponding to the mid-Holocene.

Six phases of landscape evolution are identified from the prehistoric period to the present (see 11.2). Dry ground conditions prevailed at this location during the middle to late Neolithic period and possibly into the early Bronze Age; open herbaceous vegetation was dominant at least locally. Moist ground conditions subsequently developed at the core location. Mixed deciduous scrub and woodland species became locally more prominent, though herbaceous species still dominated the local landscape. A marked expansion of mixed woodland species dominated by deciduous and evergreen Quercus took place during the Bronze Age, under possibly increasingly humid ground and climatic conditions.

High charcoal frequencies coincident with a phase of sharp woodland decline beginning in the middle Bronze Age or Messapian/early Roman period, suggest that woodland and scrub was deliberately cleared or controlled involving the use of fire. Cereals and plants of disturbed ground gain prominence in this phase, suggesting that areas were cleared to expand agricultural land. Cleared areas were maintained until a point in time, probably coinciding with the late Roman period, when woody macchia dominated by Quercus species regenerated during a period of apparent neglect in the landscape. Subsequent decline in the woody macchia is attributed to increasing demand for arable and pastoral land during medieval times.

A similar phase of woody macchia expansion and later decline until modern times, is also interpreted from the pollen records of cores from Alimini Piccolo and from the Cesine region, at opposite ends of the study-area. This suggests that a period of macchia regeneration occurred regionally, at least in the coastal zone, as a consequence of disrupted economic landuse. At each of the core locations suitable for full palynological analysis, detailed information has been provided on changes in the local depositional environment and local vegetation history.

13.1.2 Mechanisms for vegetation and environmental change

Climatic humidity, surface hydrology and human activities are identified as critical factors in determining the timing and nature of vegetation change in the study-area. Surface hydrology is intimately linked with climatic humidity, relative sea-level and human activity, and varies according to spatial differences in the hydrogeology of the study-area.

It is concluded from analyses of core 1AG that the distinct change at around the late Neolithic period, from dry to moist conditions in which organic sedimentation was initiated, primarily reflects change in climatic humidity. Under these humid conditions mixed woodland expanded. According to most other studies of Holocene

environmental change in Italy and other parts of the central Mediterranean, the major transition from dry, steppe conditions in the post-glacial to humid conditions occurred early in the Holocene period. The present author suggests that dry ground conditions persisted longer into the Holocene in the study-area, and possibly in the rest of Salento, due to the karst nature of this region (12.2.4, 12.3).

Human activities of vegetation clearance and control precipitated the sharp decline in woodland vegetation in the study-area at around the middle Bronze Age or Messapian/early Roman period, and maintained a predominantly open landscape in subsequent prehistoric and historic time (11.2.3). This contrasts with vegetation histories interpreted from a number of locations in central Italy, where a distinct woodland decline in favour of sclerophyllous vegetation, between the 4th and 3rd millennia BP, is commonly attributed to the return of drier climatic conditions (12.2.4).

Holocene sea-level rise has been a further important mechanism for environmental change in the study-area (see 13.1.4).

13.1.3 The effect of changing vegetation patterns on soils and drainage

With the development of mixed woodland or scrub in the study-area, organic-rich soils may be expected to have developed beneath the trees and undergrowth. Today, organic-rich soils are confined to enclosed, marshy depressions, mixed with silts washed in from the exposed catchment slopes. In prehistory, when clearings were initially made in the natural vegetation cover, soils with good humic content were available for cultivation. Their availability may have been short-lived. The removal of natural vegetation and disturbance of soils by agricultural practices will have induced changes in surface drainage, and exposed soils to runoff and deflation (11.2.3). Seasonal rainfall runoff is identified as a major agent of soil erosion in this region. Runoff water and entrained silts contribute to marshy conditions in depressed areas inland and in the Cesine coastal lowland, and contribute to the build up of sediment in the Alimini lakes, particularly at the margins of Alimini Piccolo.

13.1.4 The impact of Holocene sea-level rise on the coastline and on ground conditions in the coastal margin

Relative sea-level rise has significantly influenced environmental change in the study-area since at least the middle Holocene (see 12.5). Residual dune sands on the western side of Alimini Piccolo, and aeolian sands above red earth in core 1AG, have been associated in the present research with a mid-Holocene phase of sand mobilisation and dune formation on the Adriatic littoral. Although sea-level in the mid-Holocene was probably around 5 m below its present level, according to models of eustatic sea-level rise, the coastline in the vicinity of the Alimini probably lay mostly within 200 m offshore from its present position (as shown in Fig. 12.7).

The development of marshy conditions in depressions beside the coast is also partly attributed to late Holocene sea-level rise, forcing groundwater levels to rise within the calcarenite in the coastal margin. The development of coastal dune cordons (starting at c. 2110 BP), particularly along the Cesine and Alimini coastlines, further contributed to the development of marshy conditions in these areas by impeding surface drainage to the sea. From the present research, marshy conditions are suggested to have developed in the Cesine region within approximately the past 2000 years, prior to which this lowland coastal area was probably more open to the sea.

Sea-level reached sufficiently high levels relative to land in the late Holocene for saline water to influence low coastal areas and to enter Alimini Grande. Submerged Roman remains offshore between San Cataldo and the Cesine area, point to significant relative sea-level rise in the past 2 millennia. Throughout the Holocene, loss of land through marine submergence has been greatest adjacent to the present Cesine and Alimini coastlines. Sections of coastline with Pliocene calcarenite cliffs have altered in configuration by cliff-collapse, an ongoing process.

13.2 Significance of the present research

13.2.1 Palaeoenvironmental contributions

The semi-arid, karst, calcareous environment of the study-area does not readily appeal to Quaternary palynological investigation, but the present research has demonstrated that palynological techniques can be successfully applied for purposes of environmental reconstruction in carefully selected sites. The research project is the first to undertake systematic analyses of depositional environments within Salento, providing information on changes in vegetation and local environmental conditions in the Holocene.

Interpretation of the sedimentological and palynological record in core 1AG emphasises the changing relative importance of climate and human influence on vegetation change in the study-area during the Holocene. In common with many existing studies of Holocene vegetation history in Italy, a marked change from arid to increasingly humid climatic conditions permitted mixed woodland dominated by oak species to expand, albeit at a later stage of the Holocene in the study-area. In contrast to existing vegetation histories, however, human activities are highlighted in the present research as the prime cause of woodland decline in the study-area, which may be representative of the rest of Salento.

Concerning the late Pleistocene landscape of the study-area, new data is put forward in support of an aeolian origin for the red earths. Analyses of sediment stratigraphy in core 1AG also provides the first information on peat and organic-rich sediment initiation in south-east Italy. Aside from the detailed information concerning depositional and vegetation history in the study-area, the present research also provides the first evidence for cereal cultivation in Salento in prehistory, in the form of pollen from core samples and dated well-sediment, and carbonised grains from archaeological contexts.

13.2.2 Methodological contributions

In pursuit of the research aims, this study has shown how integrated analyses of sediments, pollen and other microfossils provide more detailed information on local environmental conditions than pollen analysis alone, thereby providing a sounder basis for environmental reconstruction. Variations in sediment source and local depositional environments are highlighted by the non-pollen microfossil assemblages. With this evidence for local conditions, the local elements of pollen assemblages are more confidently differentiated from regional elements.

Analyses of modern mud and surface-samples from the study-area form a foundation for the interpretation of fossil pollen and non-pollen assemblages (see chapter 8). New data is provided by the present research on the representation of vegetation communities and dominant elements of Mediterranean vegetation by fossil assemblages in semi-arid climatic conditions. Information is also provided on the dispersal and taphonomy of significant pollen taxa in the study-area. In particular the modern pollen analyses emphasise the under-representation in fossil assemblages of many dwarf shrub taxa characteristic of macchia.

The study of non-pollen microfossil distributions from a range of depositional environments in the study-area, show that certain microfossil groupings 'characterise'

different environments, providing a valuable tool in the study of environmental change. The interpretive value of individual microfossil forms are indicated by analyses of modern sediment samples (see chapter 8). Among them, a dinoflagellate-cyst recorded as 'Genus A' and believed by the present author to be a new cyst species, was discovered in predominantly fresh and low salinity waters. Important new information is provided on the distribution of *Concentricystes* cf. *circulus*, a microfossil of uncertain affinity. Before now, the occurrence of this microfossil in late Quaternary sediments has been associated with fluvial conditions; however it was found in samples from varied depositional environments in the study-area under conditions ranging from dry to wet.

Presentation of the microfossil data in the form of conventional 'pollen diagrams' effectively indicates local environmental changes represented within a sediment core. The use of square-roots for displaying absolute frequency data, reduces to a practical scale the large range of values typically obtained, whilst effectively illustrating significant difference in the data.

The combined pollen and microfossil data from the modern surface-samples and the sediment cores, together with the photographic illustrations of selected forms (see plates 1 to 12) provide useful reference material for future palaeoenvironmental research.

13.3 Limitations of the present research

Much of the chronology put forward for environmental change in the study-area is based upon deductions made according to a widely accepted model for the eustatic element of sea-level rise in the middle to late Holocene. Independent means of dating are needed to test the proposed chronology. The vegetation history determined from core 1AG merits a series of radiocarbon dates, since this core represents important new evidence for Holocene vegetation history in south-east Italy, with further significance in the context of the central Mediterranean region. Dating organic sediments within the core would also allow closer association of the vegetation history with the archaeological record of the study-area.

It is possible that the records for environmental change in the study-area obtained from Alimini Piccolo and from the marsh basin to the north of Alimini Grande, are limited in length by difficult accessibility to sediments in these locations. The present records from Alimini Piccolo are limited in cores AP88 and 1AP from the lake margins, by poor microfossil preservation in calcareous clays at the bases of the cores. Longer sediment sequences, potentially yielding a longer palaeoenvironmental record

may exist in areas beneath the lake. To locate deeper sediments would necessitate systematic core sampling in transects across the lake, using equipment operated from a boat. With power assisted coring equipment it may also be possible to obtain a deeper core from the marsh basin north of Alimini Grande, confirming or otherwise that the red clay at the base of core 1AG does lie directly above bedrock.

Palynological analyses of archaeological contexts within the study-area were of limited success. It has been shown, however, that information on past economies is available from carbonised plant remains. Systematic sampling of prehistoric and historic contexts from Roca Vecchia and from other sites within and beyond the study-area could provide much useful information that is so far lacking.

13.4 Further work

Following on from the data and conclusions of the present research, further work would be highly worthwhile on both past environmental conditions in south-east Italy, on modern pollen taphonomy in this region and the 'characterisation' of modern depositional environments by microfossil assemblages.

The present research in the study-area has shown that relative sea-level has risen significantly in the past 2 millennia. As identified in 12.5.3, offshore archaeological investigation at San Cataldo, and probably beside the Alimini and Cesine areas could provide data on relative sea-level rise and the possibility of neotectonic movement in the region.

The important broad vegetation changes represented by core 1AG, and the correlation of the upper part of the core with cores from Alimini Piccolo and the Cesine area may be representative of vegetation change in Salento, but further parallel studies from other locations in Salento are needed to test this standpoint. Potentially suitable areas for palynological analysis exist in places along the low coastline between San Cataldo and Brindisi to the north. These are coastal marsh environments similar to the Cesine area, though less extensive. Comparative analyses on the western side of Salento may be successful to the south of Ugento, within a large area of drained marsh behind dune cordons on the Ionian coast, known as 'Fontanelle' (not to be confused with the Neolithic site of Fontanelle on the Adriatic coast near Ostuni, see Coppola & Costantini 1983).

Integrated sediment, pollen and non-pollen microfossil analyses at carefully selected locations within the Tavoliere Plain could contribute much information towards understanding prehistoric human impact in this area. The economic importance of the

area, since at least the Neolithic period, is well known and it is possible that human activities had widespread impact on this landscape earlier than in Salento. As suggested in 12.4.2, analyses comparable to the present study could shed light on the apparent 'abandonment' of the plain during the Bronze Age.

The worth of recording and interpreting non-pollen microfossil evidence together with pollen has been demonstrated by the present research. Recognised assemblages have great potential to provide information on past environmental conditions. Further systematic sampling in modern depositional environments would improve upon current understanding of their spatial distributions and ecological relationships with the environment, thereby enhancing their value in palaeoenvironmental investigations.

Multivariate statistical analyses could be usefully applied to the modern assemblage data, to assist in determining associations between microfossils and also between assemblages and environmental variables. Among the various techniques of multivariate analysis (see for example, Birks & Gordon 1985; Gauch 1982), ordination methods including principal components analysis or detrended correspondence analysis are probably most applicable. A large data set of microfossil occurrence in modern and fossil sediments has already been collated within the present research, upon which appropriate multivariate analyses would help improve the interpretive value of observed microfossil groupings.

Appendix A

PREPARATION PROCEDURE FOR PALYNOLOGICAL SAMPLES

Equipment required:

25 ml measuring cylinder

250 ml pyrex beakers (one per sample)

hotplate with sand bath

sieve with 100 μm mesh nylon bolting cloth

sieve with 7 μm mesh nylon bolting cloth

large swirling dish (clock glass), preferably plastic 400 mm diameter

5ml short form capillary pipettes (one per sample)

5ml plastic sample tubes with stoppers and volume marks

5% potassium hydroxide (KOH) solution

anhydrous tetra-sodium pyrophosphate ($\text{Na}_4\text{P}_2\text{O}_7$)

10% hydrochloric acid (HCl) solution

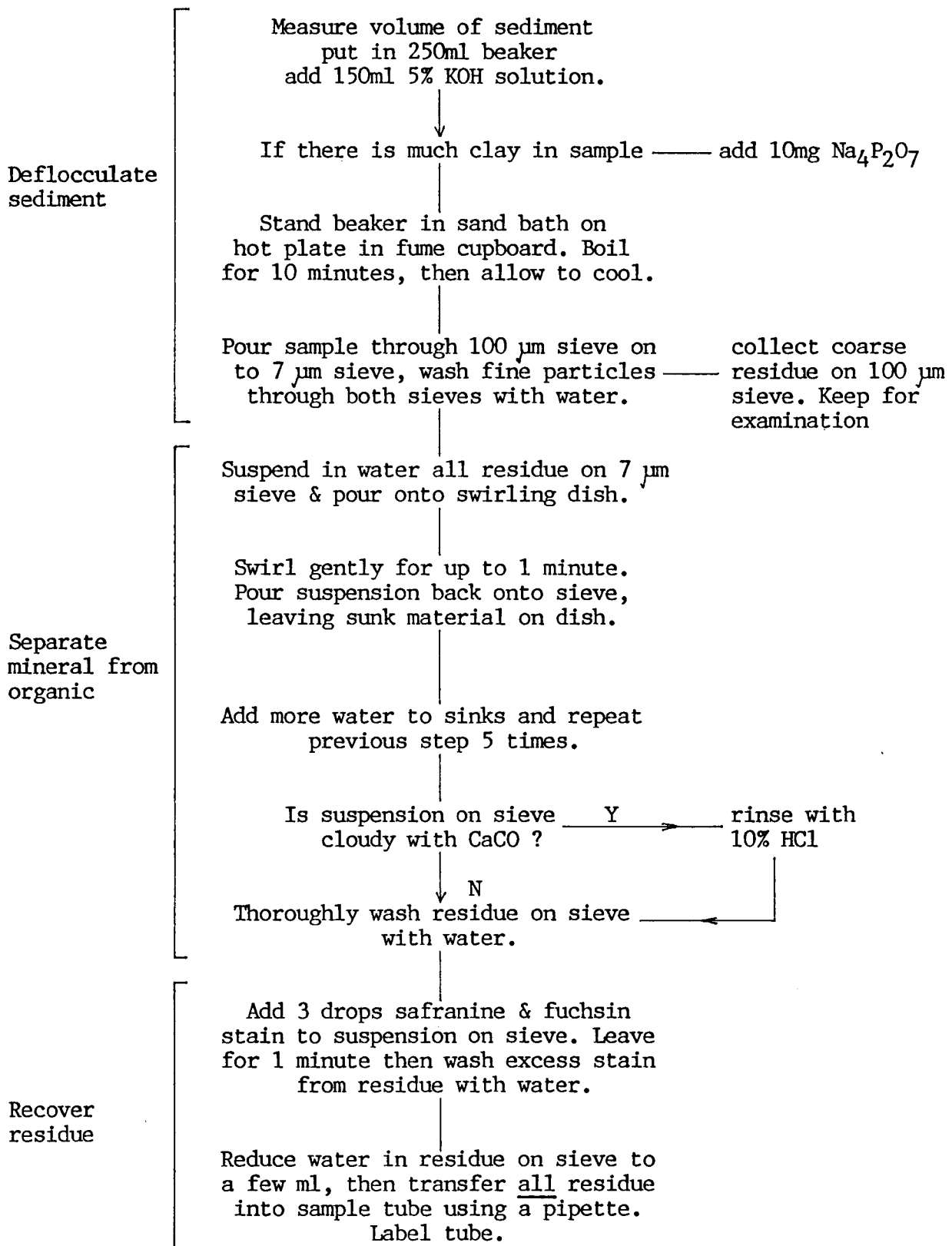
1:1 mixed stain of Safranin O & Fuchsin basic in alcohol

Facilities required

Fume cupboard suitable for strong mineral acids and oxidising agents.

Filtered water supply.

Preparation Procedure for Palynological Samples.



N.B Filtered water is used at all times

Retting procedure used to prepare modern pollen reference slides

Objective: to destroy the intines of pollen grains, leaving the sporopollenin exine in a state comparable to fossil pollen.

Several anthers of an identified species were placed in a small beaker or plastic pot.

Enough tap water was added to submerge the anthers. The anthers contain microorganisms which will attack the less resistant intines of pollen grains.

Each pot was covered with Nascofilm, to allow passage of air to and from the pot, and left standing at room temperature for four weeks.

Pot contents were then washed through a 100 μm sieve on to a 7 μm sieve (using filtered water) to separate coarse organic material from pollen sized material.

The organic residue with pollen on the 7 μm sieve was stained and collected into a sample tube, as in the sediment processing procedure.

Residues were mounted in glycerol jelly.

Procedure for determining particle-size distributions of sand fractions

Particle-size analyses were carried out on 60g samples of air-dried sediment samples.

- 1) Place sample in a 1 litre pyrex beaker and fill with sodium hexametaphosphate solution.
- 2) Stir and leave sample to disaggregate for 12 hours.
- 3) Wash sample on a 63 μm sieve to extract silt and clay sized particles from the sand. (Extracted fine material may be collected and its particle-size distribution measured by the hydrometer method).
- 4) Collect the remaining sand fraction and dry thoroughly.
- 5) Pour sample on to a sieve stack arranged in $\frac{1}{4}$ ϕ intervals, from 0 ϕ to 4 ϕ , and shake on a mechanical shaker for 10 minutes.
- 6) Weigh the sand fraction retained by each sieve.

Appendix B

Vegetation zones in the Cesine Reserve: principal species composition, excluding those species given in 5.6.2**(after Medagli 1981)**

Woodland undergrowth:

<u>Lonicera implexa</u>	<u>Asparagus acutifolius</u>	<u>Ligustrum vulgare</u>
<u>Rubus fruticosus</u>	<u>Pistacia lentiscus</u>	<u>Arum maculatum</u>
<u>Daphne gnidium</u>	<u>Rosmarinus officinalis</u>	<u>Myrtus communis</u>
<u>Arbutus unedo</u>	<u>Rhamnus alaternus</u>	<u>Erica vagans</u>
<u>Smilax aspera</u>	<u>Tamus comunis</u>	<u>Hedera helix</u>

Macchia:

a) zone inland of the Salapi:

<u>Cupressus sempervirens</u>		
<u>Rosmarinus officinalis</u>		<u>Erica vagans</u>
<u>Cistus incanus</u>	<u>Cistus salvifolius</u>	<u>Arbutus unedo</u>
<u>Pistacia lentiscus</u>	<u>Juniperus oxycedrus</u>	<u>Myrtus communis</u>

b) zone beside Pantano Grande:

<u>Erica vagans</u>	<u>Rosmarinus officinalis</u>	<u>Olea oleaster</u>
<u>Cistus incanus</u>	<u>Cistus salvifolius</u>	<u>Rubia peregrina</u>
<u>Prunus spinosa</u>	<u>Asparagus acutifolius</u>	

c) zone beside the drainage channel:

<u>Rosmarinus officinalis</u>	<u>Acacia cyanophylla</u>
-------------------------------	---------------------------

Marsh:

a) around water-bodies:

<u>Typha latifolia</u>	<u>Iris pseudacorus</u>	Umbelliferae
Rubiaceae		

b) drier saline areas:

<u>Juncus inflexus</u>	<u>Carex diversicolor</u>	<u>Carex hispida</u>
<u>Scirpus maritimus</u>	<u>Scirpus holoschoenus</u>	<u>Schoenus nigricans</u>

c) inland areas:

<u>Lythrum salicaria</u>	<u>Polygonum hydropiper</u>	<u>Typha latifolia</u>
<u>Convolvulus sepium</u>	<u>Pulicaria dysenterica</u>	<u>Scirpus lacuster</u>
<u>Alisma plantago-aquatica</u>	<u>Apium nodiflorum</u>	
<u>Iris pseudacorus</u>	<u>Orchis laxiflora</u>	<u>Mentha aquatica</u>

Coastal sands:

a) beach:

<u>Cakile maritima</u>	<u>Euphorbia peplis</u>
------------------------	-------------------------

b) dune:

<u>Otanthus maritima</u>	<u>Inula crithmoides</u>	<u>Eryngium maritimum</u>
<u>Euphorbia peplis</u>	<u>Pancreatium maritimum</u>	<u>Daucus pumilus</u>
<u>Echinophora spinosa</u>	<u>Crithmum maritimum</u>	<u>Euphorbia paralias</u>
<u>Medicago marina</u>	<u>Plantago maritima</u>	<u>Scolymus hispanicus</u>

Some herbaceous plants of cultivated areas:

<u>Cyclamen neapolitanum</u>	<u>Ophrys aranifera</u>	
<u>Narcissus serotinus</u>	<u>Urginea maritima</u>	<u>Briza minor</u>
<u>Eryngium campestre</u>	<u>Silybum marianum</u>	<u>Carthamus lanatus</u>
<u>Carlina corymbosa</u>	<u>Arisarum vulgare</u>	<u>Gladiolus communis</u>
<u>Silene conica</u>	<u>Silene gallica</u>	<u>Borago officinalis</u>
<u>Sideritis romana</u>	<u>Chrysanthemum coronarium</u>	
<u>Legousia speculum-veneris</u>		

BIBLIOGRAPHY

- Aaby, B. (1983) Forest development, soil genesis and human activity illustrated by pollen and hypha analysis of two neighbouring podzols in Draved Forest, Denmark. Danmarks Geologiske Undersøgelse ser II, No.114.
- Aaby, B. & Berglund, B.E. (1986) Characterisation of peat and lake deposits. In Handbook of Holocene Palaeoecology and Palaeohydrology. ed. B.E. Berglund, 231-246. Chichester: John Wiley & Sons.
- Accorsi, C.A., Bandini Mazzanti, M. & Forlani, L. (1981) Il paesaggio vegetale collegato con gli insediamenti neo-eneolitici dell'area di Spilamberto (Modena) in base ad analisi palinologiche. In Il Neolitico e l'Eta del Rame. Ricerca a Spilamberto - S. Cesario 1977-1980. ed. B. Bagolini, 43-60. Casa di Risparmio di Vignola.
- Accorsi, C.A. & Forlani, L. (1976) Schede per una Flora Palinologica Italiana. Contributo n.4: Schede di nuova impostazione. Archivio Botanico e Biogeografico Italiano 20(1/2), 58-111.
- Alessio, M., Allegri, L., Bella, F., Calderoni, G., Cortesi, C., Dai Pra, G., De Rita, D., Esu, D., Follieri, M., Improta, S., Magri, D., Narcisi, B., Petrone, V. & Sadori, L. (1986) 14C Dating, geochemical features, faunistic and pollen analyses of the uppermost 10 m core from Valle di Castiglione (Rome, Italy). Geologica Romana 25, 287-308.
- Almagià, R. (1920) Monumenta Italiae Cartografica. Firenze
- Amico, A. & Macchia, F. (1964) Itinerario botanico nel Salento meridionale. Estratto Annali Facoltà Di Agraria, Università Di Bari XVIII, 31-60.
- Andersen, S.Th. (1973) The differential pollen productivity of trees and its significance for the interpretation of a pollen diagram from a forested region. In Quaternary Plant Ecology ed. H.J.B. Birks & R.G. West, 109-115. Oxford: Blackwell Scientific Publications.
- Andrew, R. (1984) A practical pollen guide to the British Flora. Quaternary Research Association, Technical Guide No. 1. Cambridge.
- Arobba, D. (1976) Schede per una Flora Palinologica Italiana. Contributo n.3: Raccolte della costa tirrenica. Archivio Botanico e Biogeografico Italiano 20(1/2), 9-56.

- Aubert, J., Charpin, H. & Charpin, J. (1959) Étude palynologique de quelques Oléacées de Provence. Pollen et Spores 1, 7-13.
- Barber, H.G. & Haworth, E.Y. (1981) A Guide to the Morphology of the Diatom Frustule. Scientific Publication no.44. Freshwater Biological Association.
- Barker, G. (1981) Landscape and Society: Prehistoric Central Italy. London: Academic Press.
- Barker, G. (1985) Prehistoric Farming in Europe. Cambridge: Cambridge University Press.
- Barker, G., Biagi, P., Castelletti, L., Cremaschi, M. & Nisbet, R. (1987) Sussistenza, economia ed ambiente nel Neolitico dell'Italia settentrionale. In Il Neolitico in Italia. Volume 1. Atti della XXVI Riunione Scientifica, Firenze 7-10 novembre 1985, 103-118.
- Bates, C.D. (1981) Pollen Stratigraphy from Deep Sea Cores in the Cilicia Basin, North-East Mediterranean. University of Cambridge: PhD thesis (unpublished).
- Battarbee, R.W. (1986) Diatom Analysis. In Handbook of Holocene Palaeoecology and Palaeohydrology. ed. B.E. Berglund, 561-593. Chichester: John Wiley & Sons
- Baum, B.R., Basset, I.J. & Crompton, C.W. (1971) Pollen morphology of Tamarix species and its relationship to the taxonomy of the genus. Pollen et Spores 13(4), 495-521.
- Behre, K-E. (1981) The interpretation of anthropogenic indicators in pollen diagrams. Pollen et Spores 23(2), 225-245.
- Belfiore, A., Bonaduce, G., Damblon, F., Garavelli, C., Mascellaro, P., Masoli, M., Mirabile, L., Moncharmont, M., Moretti, M., Nuovo, G., Ozer, A., Pennetta, M., Pescatore, T., Placella, B., Pugliese, N., Russo, B., Senatore, M.R., Sgarrella, F., Spezie, G-C., Strel, M., Thorez, J., Tramutoli, M. & Vultaggio, M. (1982) La sédimentation holocène du golfe de Tarente (Italie méridionale): approche stratigraphique et paléoclimatique basée sur l'étude de trois carottes de sondage. Bulletin de la Societe Geologique de France XXIV(3), 581-588.
- Belloni, S., Martinis, B. & Orombelli, G. (1972) Karst of Italy. In Important Karst Regions of the Northern Hemisphere. ed. M. Herak & V.T. Springfield, 85-128. Amsterdam: Elsevier.
- Benninghoff, W.S. (1962) Calculations of pollen and spore density in sediments by addition of exotic pollen in known quantities. Pollen et Spores 4, 332-333.
- Bernardini, M. (1955) Panorama Archeologico dell'Estremo Salento. Trani: Adriatica.

- Beug, H-J. (1961a) Beiträge zur postglazialen Floren- und Vegetationgeschichte in Süddalmatien: Der See "Malo Jezero" auf Mljet. Flora 150(4), 632-655.
- Beug, H-J. (1961b) Leitfaden der Pollenbestimmung. 1. Stuttgart: Gustav Fischer Verlag.
- Beug, H-J. (1967) On the forest history of the Dalmatian coast. Review of Palaeobotany and Palynology 2, 271-279.
- Beug, H-J. (1982) Vegetation history and climatic changes in central and southern Europe. In Climatic Change in Later Prehistory ed. A.F. Harding, 85-102. Edinburgh: Edinburgh University Press.
- Biancofiore, F. (1957) Dati ecologici nell'economia della Puglia preistorica. Rivista di Anthropologia XLIX, 101-134.
- Bintliff, J.L. (1977) Natural Environment and Human settlement in Prehistoric Greece B.A.R. S28(i).
- Birks, H.H. (1970) Studies in the vegetational history of Scotland. I. A pollen diagram from Abernethy Forest, Inverness-shire. Journal of Ecology 58, 827-846.
- Birks, H.J.B. & Birks, H.H. (1980) Quaternary Palaeoecology. London: Edward Arnold.
- Birks, H.J.B. & Gordon, A.D. (1985) Numerical Methods in Quaternary Pollen Analysis. London: Academic Press.
- Blanc, G.A. (1921) Grotta Romanelli. I. Stratigrafia dei depositi e natura e origine di essi. Archivio per l'Antropologia e l'Etnologia di Firenze 50, 65-103.
- Blanc, G.A. (1928) Grotta Romanelli. II. Dati ecologici e paleontologici. Archivio per l'Antropologia e l'Etnologia di Firenze 58, 365-525.
- Bonatti, E. (1970) V. Pollen sequence in the lake sediments. In Ianula: An account of the history and development of the Lago di Monterosi, Latium, Italy. ed. G.E. Hutchinson, 26-31. Transactions of the American Philosophical Society 64, 5-175.
- Boney, A.D. (1975) Phytoplankton. Studies in Biology 52. London: Edward Arnold.
- Bonfiglio, L. (1972) Il Tirreniano di Bovetto e Ravagnese presso Reggio Calabria. Quaternaria 16, 137-147.
- Bonny, A.P. (1972) A method for determining absolute pollen frequencies in lake sediments. New Phytologist 71, 393-405.
- Bortolami, G.C., Fontes, J.Ch., Markgraf, V. & Saliege, J.F. (1977) Land, sea and climate in the northern Adriatic region during late Pleistocene and Holocene. Palaeogeography, Palaeoclimatology and Palaeoecology 21, 139-156.

- Bottema, S. (1974a) Late Quaternary Vegetation History of Northwestern Greece. Groningen: University press.
- Bottema, S. (1974b) Implications of a pollen diagram from the Adriatic Sea. Geologie en Mijnbouw 53(6), 401-405.
- Bottema, S. (1975) The interpretation of pollen spectra from prehistoric settlements (with special attention to the Liguliflorae). Palaeohistoria 17, 17-35.
- Bottema, S. (1979) Pollen analytical investigations in Thessaly (Greece). Palaeohistoria 21, 19-40.
- Bottema, S. (1980a) On the history of the walnut (Juglans regia L.) insoutheastern Europe. Acta Botanica Neerlandica 29(5/6), 343-349.
- Bottema, S. (1980b) Palynological investigations on Crete. Review of Palaeobotany and Palynology 31, 193-217.
- Bottema, S. & van Straaten, L.M.J.U. (1966) Malacology and palynology of two cores from the Adriatic sea floor. Marine Geology 4, 553-564.
- Bowen, D.Q. (1978) Quaternary Geology. Oxford: Pergamon Press.
- Bradbury, J.P. (1975) Diatom stratigraphy and human settlement in Minnesota. Geological Society of America. Special Paper 171, 74 pp.
- Bradford, J.S.P. (1949) 'Buried landscapes' in southern Italy. Antiquity 23, 58-72.
- Braggio Morucchio, G. & De Vincenzi, L. (1980) Schede per una Flora Palinologica Italiana. N.61-66. Archivio Botanico e Biogeografico Italiano 56(1/2), 55-69.
- Braggio Morucchio, G. & De Vincenzi, L. (1981) Schede per una Flora Palinologica Italiana. N.80-84. Archivio Botanico e Biogeografico Italiano 57(1/2), 17-28.
- Braggio Morucchio, G., Cornara, L. & Mariotti, M. (1988) Modern pollen rain and vegetation relationships in microinsular Mediterranean environments. 1. Zannone Island (Pontian Archipeligo - Italy). Pollen et Spores 30(3-4), 471-484.
- Brasier, M.D. (1980) Microfossils. London: Unwin Hyman.
- Brown, C.A. (1960) Palynological Techniques. Baton Rouge.
- Brugam, R.B. (1978) Human disturbance and the historical development of Linsley Pond. Ecology 59(1), 19-36.
- Burden, E.T., McAndrews, J.H. & Norris, G. (1986) Palynology of Indian and European forest clearance and farming in lake sediment cores from Awenda Provincial park, Ontario. Canadian Journal of Earth Science 23, 43-54.
- Butzer, K.W. (1964) Environment and Archaeology. London: Methuen.

- Cali, L.S. (1971) Flora e vegetazione delle dune fra S. Cataldo e Torre Specchia Ruggeri (Lecce). Archivio Botanico e Biogeografico Italiano XLVII, 107-123.
- Carano, E. (1934) Il suolo e la flora delle Puglie. Atti della Società Italiana per il Progetto delle Scienze. XXII Riunione, Bari 12 -18 ottobre, 1933. Roma.
- Carney, H.J. (1982) Algal dynamics and trophic interactions in the recent history of Frains Lake, Michigan. Ecology 63(6), 1814-1826.
- Carnicelli, S., Ferrari, G.A., Madagli, D. (1989) Les accumulations carbonatées de type "calcrete" dans les sols et formations superficielles d'Italie méridionale. Méditerranée 2.3, 51-59.
- Cassano, S.M. & Manfredini A. (1983) Studi sul Neolitico del Tavoliere della Puglia B.A.R. S60.
- Cassano, S.M. & Manfredini A. (1986) Ricognizione e indagine sul territorio. Programma di indagine territoriale sul Tavoliere Dialoghi di Archeologia 3 ser. anno 4(2), 179-186.
- Castelletti, L., Costantini, L. & Tozzi, C. (1987) Considerazioni sull'economia e l'ambiente durante il Neolitico in Italia. In Il Neolitico in Italia. Volume 1 Atti della XXVI Riunione Scientifica, Firenze 7-10 novembre 1985, 37-55.
- Causton, D.R. (1988) An Introduction to Vegetation Analysis. London: Unwin Hyman.
- Chiarugi, A. (1936) Ricerche sulla vegetazione dell'Etruria Marittima. . Cicli forestali postglaciali nell'Appennino Etrusco attraverso l'analisi pollinica di torbe e depositi lacustri presso l'Alpe delle Tre Potenze e il M. Rondinaio. Nuovo Giornale Botanico Italiano 43, 1-61.
- Chiarugi, A. (1937) Prime notizie sui cicli forestali postglaciali nell'Appennino lucano. Nuovo Giornale Botanico Italiano XLIV, 274.
- Chiarugi, A. (1939) La vegetazione dell'Appennino nei suoi aspetti d'ambiente e di storia del popolamento montano. Società Italiana per il Progresso delle Scienze XXVII, 9-45.
- Ciaranfi, N. (1983) Osservazioni geologiche e morfologiche sull'entroterra del Golfo di Manfredonia. In Studi Sul Neolitico del Tavoliere della Puglia. eds. S.M. Cassano & A. Manfredini, 202-222. B.A.R. S160.
- Ciaranfi, N., Cinque, A., Lambiase, S., Pieri, P., Rapisardi, L., Richetti, G., Sgroso, I. & Tortorici, L. (1981) Proposta di zonazione sismotettonica dell'Italia meridionale. Rendiconti de la Società Geologica Italiana 4, 493-496.

- Cipolloni Sampò, M. (1982) Ambiente, economia, e società dall'eneolitico all'età del bronzo in Italia sud-orientale. Dialoghi di Archeologia anno 4(2), 27-38.
- Clapham, A.R, Tutin, T.G. & Warburg, E.F. (1962) Flora of the British Isles. Cambridge: Cambridge University Press.
- Clark, R.L. (1982) Point count estimation of charcoal in pollen preparations and thin sections of sediments. Pollen et Spores 24, 523-535.
- Coesel, P.M. (1979a) Desmids of the broads area of N.W- Overijssel (The Netherlands) I. Acta Botanica Neerlandica 28(6), 257-279.
- Coesel, P.M. (1979b) Desmids of the broads area of N.W.-Overijssel (The Netherlands) II. Acta Botanica Neerlandica 28(6), 385-423.
- COHMAP Members (1988) Climatic changes of the last 18000 years: Observations and model simulations. Science 241, 1043-1052.
- Colamonico, C. (1916) La distribuzione della popolazione nella Puglia centrale e meridionale secondo la natura geologica del suolo. Bolletino della Societa Geografica Italiana 5, 201-234 & 402-429.
- Colamonico, C. (1939) La più antica carta regionale della Puglia. Iapigia 10, 401-445. Bari.
- Congedo, R. (1972) Istituzione di un parco regionale nel litorale Adriatico della Penisola Salentina. Atti del II Simposio Nazionale sulla conservazione della natura. 26-30 aprile 1972. Bari. Bari: Cacucci.
- Congedo, R. (1974) La Vallonea. Natura ed Arte. Galatina.
- Congedo, R. (1984) Salento Scrigno d'Acqua. Martina Franca: Lacaita.
- Cook, S.F., & Heizer, R.F. (1965) Studies on the Chemical Analysis of Archaeological Sites. University of California Press, Berkeley and Los Angeles.
- Coppola, D. & Costantini, L. (1983) Le Néolithique ancien littoral et la diffusion des céréales dans les Pouilles durant le VI millénaire: les sites de Fontanelle, Torre Canne et le Macchie. In Premières Communautés Paysannes en Méditerranée occidentale Colloque du C.N.R.S, Montpellier, 1983.
- Costantini, L. (1984) Cereali carbonizzati e impronte del Neolitico pugliese. Atti del 3 Convegno sulla Preistoria-Protostoria e Storia della Daunia, 27-29 novembre 1981, San Severo, 107-111.
- Cotecchia, V., Dai Pra, G. & Magri, G. (1969) Oscillazioni Tirreniane e Oloceniche del livello mare nel Golfo di Taranto, corredate da datazione col metodo del radiocarbonio. Geologia Applicata e Idrogeologia 4, 93-148.

- Cotecchia, V., Tadolini, T. & Tulipano, L. (1983) Sea water intrusion in the planning of ground water resources protection and utilization in the Apulia region (southern Italy). Geologia Applicata e Idrogeologia **18(2)**, 367-382.
- Cristofolini, R., Ghisetti, F., Scarpa, R. & Vezzani, L. (1985) Character of the stress field in the Calabrian Arc and southern Apennines (Italy) as deduced by geological, seismological and volcanological information. Tectonophysics. **117**, 39-58.
- Crivellari, D. (1950) Inchiesta sulla distribuzione del genere Quercus in Puglia. Nuovo Giornale Botanico Italiano n.s. **LVII**, 335-350.
- Cruise, G.M. (1990) Holocene peat initiation in the Ligurian Apennines, northern Italy. Review of Palaeobotany and Palynology **63**, 173-182.
- Cushing, E.J. (1967a) Late-Wisconsin pollen stratigraphy and the glacial sequence in Minnesota. In Quaternary Palaeoecology eds. H.E. Wright & E.J. Cushing, 59-88. New Haven & London: Yale University Press.
- Cushing, E.J. (1967b) Evidence for differential pollen preservation in late Quaternary sediments in Minnesota. Review of Palaeobotany & Palynology **4**, 87-101.
- Cwynar, L., Burden, E. & McAndrews, J.H. (1979) An inexpensive method for concentrating pollen and spores from fine-grained sediments. Canadian Journal of Earth Sciences **16**, 1115-1120.
- Dakaris, S.I., Higgs, E.S & Hey, R.W. (1964) The climate, environment and industries of Stone Age Greece; Part 1. Proceedings of the Prehistoric Society **30**, 199-244.
- D'Andria, F. (1980) S. Foca (Lecce). Scavo di un impianto costiero di età Romano-Imperiale. Studi di Antichità **2**, 79-88. Lecce.
- D'Andria, F. (1988) Messapi e Peuceti. In Italia Omnium Terrarum Alumna by A.M. Chieco Bianchi et al., 653-715. Milan: Scheiwiller.
- Danin, A., Gerson, R. & Garty, J. (1983) Weathering patterns on hard limestone and dolomite by endolithic lichens and cyanobacteria: supporting evidence for eolian contribution to Terra Rossa soil. Soil Science **136(4)**, 213-217.
- Davis, M.B. (1963) On the theory of pollen analysis. American Journal of Science **261**, 897-912.
- Davis, M.B. (1966) Determination of absolute pollen frequency. Ecology **47(2)**, 310-311.
- Davis, M.B. (1968) Pollen grains in lake sediments: redeposition caused by seasonal water circulation. Science **162**, 796-799.

- Davis, M.B, Brubaker, L.B. & Beiswenger, J.M. (1971) Pollen grains in lake sediments: Pollen percentages in surface sediments from southern Michigan. Quaternary Research 1, 450-467.
- Dauncey, K.D.M. (1952) Phosphate content in soils on archaeological sites. The Advancement of Science 9, 33-36.
- De Giorgi, C. (1882) La provincia di Lecce. Bozzetti di Viaggio 2. Congedo Editore (1975).
- De Giorgi, C. (1895) Il lago di Limini in Terra d'Otranto. Rivista di Geografia Italiana 2, 409-414 & 496-508. Firenze.
- Delano-Smith, C. (1976) The Tavoliere of Foggia (Italy) an aggrading coastland and its early settlement patterns. In Geoarchaeology. eds. D.A. Davidson & M.L. Shackley, 197-212. London: Duckworth.
- Delano-Smith, C. (1978) Coastal sedimentation, lagoons and ports in Italy. In Papers in Italian Archaeology 1. eds. H.Mc.K. Blake, T.W. Potter & D.B. Whitehouse, 25-33. B.A.R. S41(i).
- Delano-Smith, C. (1981) Valley changes: some observations from recent field and archive work in Italy. In Archaeology and Italian Society. eds. G. Barker & R. Hodges, 239-247. B.A.R. S102.
- Delano-Smith, C. (1987) The Neolithic environment of the Tavoliere. In Apulia. Volume 1: Neolithic Settlement in the Tavoliere. ed. G.D.B. Jones, 3-26. Reports of the Research Committee of the Society of Antiquaries of London XLIV.
- De Magistris, L.F. (1942) La prima carta della malaria in Italia. Rivista di Geografia Italiana, Note e comunicazioni, fasc. III, 99-101.
- De Marco, A., Gentile, A. & Nuovo, G. (1983) Aspetti dinamici e composizionali degli apporti attuali nel Lago Alimini Piccolo presso Otranto (Puglia). Bolletino della Societa Geologica Italiana 102, 407-417. Roma.
- De Philippis, A. (1937) Classificazioni ed indici del clima, in rapporto alla vegetazione forestale Italiana. Nuovo Giornale Botanico Italiano n.s. XLVI, 1-169.
- De Simone, L.G. (1875) Note di Climatologia Salentina. Lecce.
- Dimbleby, G.W. (1985) The Palynology of Archaeological Sites. London: Academic Press.
- Dimbleby, G.W. & Evans, J.G. (1974) Pollen and land snail analysis of calcareous soils. Journal of Archaeological Science 1, 117-133.

- Dorning, K.J. (1990) A palynological strew mount specimen examination system for palynomorphs studied with the optical microscope and scanning electron microscope. Abstracts of 23rd Annual Meeting of American Association of Stratigraphic Palynologists 10-13 October, 1990. Banff, Alberta, Canada. p.8.
- Downie, C. & Singh, G. (1969) Dinoflagellate cysts from estuarine and raised beach deposits at Woodgrange, Co. Down, N. Ireland. Grana Palynologica 9, 124-132.
- Edwards, K.J. (1979) Palynological and temporal inference in the context of prehistory, with special reference to the evidence from peat and lake deposits. Journal of Archaeological Science 6, 255-270.
- Eisner, W., Kamermans, H. & Wymstra, A.T. (1986) The Agro Pontino Survey: Results from a first pollen core. Dialoghi di Archeologia 2, 145-153.
- Elhai, H. (1959) Analyse pollinique de deux tourbières Normandes. Pollen et Spores 1, 59-76.
- Esteban, M. & Klappa, C.F. (1983) Subaerial exposure environment. In Carbonate Depositional Environments. eds. P.A. Scholle, D.G. Bebout & C.H. Moore, 1-92. Tulsa: American Association of Petroleum Geologists Memoir 33.
- Evet, D. & Renfrew, J. (1971) L'agricoltura neolitica italiana: una nota sui cereali. Rivista di Scienze Preistoriche 26, 403-409.
- Evitt, W.R. (1963) Occurrence of freshwater alga Pediastrum in Cretaceous marine sediments. American Journal of Science 261, 890-893.
- Fabricius, F. & Schmidt-Thomé, P. (1971) Contribution to recent sedimentation on the shelves of the southern Adriatic, Ionian and Syrtis Seas. In The Mediterranean Sea. ed. D.J. Stanley. 333-343. Stroudsburg: Dowden, Hutchinson & Ross.
- Farr, K.M. (1988) Palynomorphs and Palynodebris Distributions in Modern Estuarine Sediments. University of Aberdeen, Ph.D. thesis (unpublished).
- Faegri, K. (1966) Some problems of representativity in pollen analysis. The Palaeobotanist 15, 135-140.
- Faegri, K. & Iversen, J. (1964) Textbook of Pollen Analysis. Oxford: Blackwell Scientific Publications.
- Ferrarini, A. (1978) Analisi polliniche di fanghi di acquitrini della Sila Grande. Informatore Botanico Italiano 10(1), 40-43.
- Ferrarini, E. & Marraccini, L. (1978) Pollini fossili in depositi lacustridella valle della Farma (Toscana meridionale). Atti della Societa Toscana di Scienze Naturali Mem. Ser B, 85, 29-34.

- Ferrarini, A. & Totaro, M. (1978) Analisi polliniche di depositi lacustri delle pendici del M. Vulture in Basilicata. Giornale Botanico Italiano 112 (3), 209-213.
- Fieller, N.R.J., Gilbertson, D.D., & Timmins, D.A.Y. (1987) Sedimentological analysis of the shell-midden sites. In Excavations on Oronsay; Prehistoric Human Ecology on a Small Island. ed. P.R. Mellars, Edinburgh University Press.
- Fleming, N.C. (1968) Holocene earth movements and eustatic sea level change in the Peloponnese. Nature 217, 1031-1032.
- Fleming, N.C. (1969) Archaeological evidence for eustatic change of sea level and earth movements in the western Mediterranean during the last 2000 years. Geological Society of America Special Paper No. 109
- Fleming, N.C. (1971) Eustatic and tectonic factors in the relative vertical displacement of the Aegean coast. In The Mediterranean Sea. ed. D.J. Stanley, 189-201. Stroudsburg: Dowden, Hutchinson & Ross.
- Follieri, M., Magri, D. & Sadori, L. (1988) 250,000-year pollen record from valle di Castiglione (Roma). Pollen et Spores 30(3-4), 329-356.
- Franco, M.C. (1981) Note sui sistemi urbani nella Puglia preistorica. In La Città Come Sistema, 479-488. Atti della LVI Riunione della Società Italiana per il Progresso delle Scienze, Lecce, 11-14/11 1981.
- Frank, A.H.E. (1969) Pollen stratigraphy of the Lake of Vico (central Italy). Palaeogeography, Palaeoclimatology and Palaeoecology 6, 67-85.
- Frey, D.G. (1960) The ecological significance of cladoceran remains in lake sediments. Ecology 41(4), 684-699.
- Galiberti, A., Di Lernia, S., Fiorentino, G. & Guarascio, M. (1991) New data about the Neolithic mine of the Defensola (Puglia, Italy). Abstracts of the VI International Flint Symposium, Spain October 1991, 145-148.
- Galili, E., Weinstein-Evron, M. & Ronen, A. (1988) Holocene sea-level changes based on submerged archaeological sites off the Northern Carmel coast in Israel. Quaternary Research 29, 36-42.
- Gauch, H.G., Jr., (1982) Multivariate Analysis in Community Ecology. Cambridge: Cambridge University Press.
- Gilbertson, D.D., Holyoak, D.A., Hunt, C.O. & Paget, F.N. (1983) Palaeoecology of late Quaternary floodplain deposits in Tuscany: The Feccia Valley at Frosini. Archaeologia Medievale X, 340-350.

- Gilbertson, D.D., Kent, M. & Pyatt, F.B. (1985) Practical Ecology. London: Unwin Hyman.
- Gile, L.H, Peterson, F.F. & Grossman, R.B. (1966) Morphological and genetic sequences of carbonate accumulation in desert soils. Soil Science **101(5)**, 347-360.
- Giove, C., Ferri, D., De Lucia, A., Scattarella, V. & Pesce Delfino, V. (1977) La fauna della comunità neolitica di Cala Colombo. In La Comunità Neolitica di Cala Colombo Presso Torre a Mare (Bari) by A. De Lucia et al., 179-252. Bari: Società di Storia Patria per la Puglia. Documenti e monografie vol XLII.
- Giraudi, C. (1989) Lake levels and climate for the last 30,000 years in the Fucino area (Abruzzo-Central Italy) - A review. Palaeogeography, Palaeoclimatology, Palaeoecology **70**, 249-260.
- Goudie, A. (1973) Duricrusts in Tropical and Subtropical Landscapes. Oxford: Clarendon Press.
- Goulden, C.E. (1970) The fossil flora and fauna (other than silicious fossils, pollen and Chironomid head capsules). In Ianula: An account of the history and development of the Lago di Monterosi, Latium, Italy. by G.E. Hutchinson et al., 102-111. Transactions of the American Philosophical Society **64(4)**, 5-175.
- Grassi, D., Romanazzi, L. & Spilotro, G. (1975) Caratteristiche geotecniche delle terre rosse della Puglia in relazione alla composizione chimico-mineralogica ed ai diversi tipi di depositi. Geologia Applicata e Idrogeologia **X**, 309-337.
- Gray, T.R.G. & Williams S.T. (1971) Soil Micro-organisms. London: Longman.
- Greig, J.R.A. & Turner, J. (1974) Some pollen diagrams from Greece and their archaeological significance. Journal of Archaeological Science **1**, 177-194.
- Groves, E. (1887) Flora della costa meridionale della Terra d'Otranto. Nuovo Giornale Botanico Italiano **19**, 110-223.
- Grüger, E. (1977) Pollenanalytische Untersuchung zur würmzeitlichen Vegetationsgeschichte von Kalabrien (Süditalien). Flora **166** s, 475-489.
- Guerricchio, A. & Zezza, F. (1982) Esempio di mapping da foto aeree e da immagini da satellite in zone carsiche: La Penisola Salentina. Geologia Applicata e Idrogeologia **XVII**, 507-526.
- Guiot, J. (1987) Late Quaternary climatic change in France estimated from multivariate pollen time series. Quaternary Research **28**, 100-118.
- Haddad, M. (1969) Quelques pollens de la flore Libanaise. Pollen et Spores **11(1)**, 39-63.

- Hall, S.A. (1981) Deteriorated pollen grains and the interpretation of Quaternary pollen diagrams. Review of Palaeobotany & Palynology 32, 193-206.
- Hall, V.A. (1991 for 1990) Some problems encountered in identifying Phragmites pollen in modern and fossil pollen assemblages. Circea 8(1), 17-19.
- Harland, R. (1983) Distribution maps of recent dinoflagellate cysts in bottom sediments from the North Atlantic Ocean and adjacent seas. Palaeontology 26, 321-387.
- Havinga, A.J. (1964) Investigation into the differential corrosion susceptibility of pollen and spores. Pollen et Spores 6(2), 621-635.
- Havinga, A.J. (1967) Palynology and pollen preservation. Review of Palaeobotany & Palynology 2, 81-98.
- Havinga, A.J. (1971) An experimental investigation into the decay of pollen and spores in various soil types. In Sporopollenin eds. J. Brooks et al., 446-479. London: Academic Press.
- Hearty, P.J. & Dai Pra, G. (1985) Aminostratigraphy and ^{230}Th - ^{234}U dating of Quaternary shorelines in the Puglia region of southeast Italy. Proceedings of the Fifth International Coral reef Congress, Tahiti 1985 3, 163-169.
- Hesse, R. & von Rad, U. (1971) Undisturbed large diameter cores from the Strait of Otranto. In The Mediterranean Sea ed. D.J. Stanley, 333-343. Stroudsburg: Dowden, Hutchinson & Ross.
- Hesse, R., von Rad, U. & Fabricius, F.H. (1971) Holocene sedimentation in the Strait of Otranto between the Adriatic and Ionian Seas (Mediterranean). Marine Geology 10, 293-335.
- Higgs, E.S. & Vita-Finzi, C. (1966) The climate, environment and industries of Stone Age Greece: Part II. Proceedings of the Prehistoric Society 32, 1-29.
- Holmes, P.L. (1990) Differential transport of spores and pollen: a laboratory study. Review of Palaeobotany & Palynology 64, 289-296.
- Horowitz, A. (1966/67) Palynological studies in the Lagoon of Venice. Memoria Biogeografica Adriatica 7, 17-27.
- Horowitz, A. & Baum, B. (1967) The arboreal pollen flora of Israel. Pollen et Spores 9(1), 71-93.
- Hoshaw, R.W. (1968) Biology of the filamentous conjugating algae. In Algae, Man and Environment ed. D.F. Jackson, 135-184. Syracuse, New York: Syracuse University Press.

- Hunt, C.O. (1985) Recent advances in pollen preparation techniques: a brief review. In Palaeobiological Investigations eds. N.R.J. Fieller, D.D. Gilbertson & N.G.A. Ralph, 181-187. Oxford: B.A.R. S266.
- Hunt, C.O. (1987) Comment: the palynology of fluvial sediments: with special reference to alluvium of historic age from the Upper Axe Valley, Mendip Hills, Somerset. Transactions of the Institute of British Geographers N.S. 12, 364-367.
- Hunt, C.O. & Eisner, W.R. (1991) Palynology of the Mezzaluna core. In The Agro Pontino Project. Methods and Preliminary Results eds. A. Voorrips, S.H. Loving & H. Kamermans, 49-59. Amsterdam: University of Amsterdam Monograph 6.
- Huntley, B. & Birks, H.J.B. (1983) An Atlas of Past and Present Pollen Maps for Europe: 0-13000 Years Ago. Cambridge: Cambridge University Press.
- Hutchinson, G.E. (ed.) (1970) Ianula: An account of the history and development of the Lago di Monterosi, Latium, Italy. Transactions of the American Philosophical Society 64(4), 5-175.
- Ingravallo, E. (1980) La stazione Mesolitica di S. Foca. Studi di Antichità 2, 59-77.
- Jacobson, G.L.Jr. & Bradshaw, R.H.W. (1981) The selection of sites for palaeovegetational studies. Quaternary Research 16, 80-96.
- Janssen, C.R. (1966) Recent pollen spectra from the deciduous and coniferous-deciduous forests of northeastern Minnesota: a study in pollen dispersal. Ecology 47, 804-825.
- Janssen, C.R. (1968) Myrtle Lake: a late- and post-glacial pollen diagram from northern Minnesota. Canadian Journal of Botany 46, 1397-1408.
- Jarman, M.R. & Webley, D. (1975) Settlement and landuse in Capitanata, Italy. In Palaeoeconomy ed. E.S. Higgs, 177-221. Cambridge: Cambridge University Press.
- Jennings, J.N. (1985) Karst Geomorphology. Oxford: Basil Blackwell.
- Jones, G.D.B. (1987) Apulia. Volume 1: Neolithic settlement in the Tavoloiere. Reports of the Research Committee of the Society of Antiquaries of London, XLIV
- Keller, J., Ryan, W.B.F, Ninkovich, D. & Altherr, R. (1978) Explosive volcanic activity in the Mediterranean over the past 200 000 yrs as recorded in deep-sea sediments. Geological Society of America Bulletin 89(4), 591-604.
- Kelly, M.G. & Huntley, B. (1991) An 11 000-year record of vegetation and environment from Lago di Martignano, Latium Italy. Journal of Quaternary Science 6(3), 209-224.

- Kelts, K. & Hsü, K.J. (1978) Freshwater Carbonate sedimentation. In Lakes: Geology, Chemistry, Physics. ed. A. Lerman, 295-322. New York: Springer.
- Kidson, C. (1982) Sea level changes in the Holocene. Quaternary Science Reviews 1, 121-151.
- Koreneva, E.V. (1966) Marine palynological researches in the USSR. Marine Geology 4, 565-574.
- Kutzbach, J.E. & Street-Perrott, F.A. (1985) Milankovitch forcing of fluctuations in the level of tropical lakes from 18 to 0 kyr BP. Nature 317, 130-134.
- Lamb, H.F., Eicher, U. & Switsur, V.R. (1989) An 18,000-year record of vegetation, lake-level and climatic change from Tigalmamine, Middle Atlas, Morocco. Journal of Biogeography 16, 65-74.
- Largaiolli, T., Martinis, B., Mozzi, G., Nardin, M., Rossi, D. & Ungaro, S. (1969) Note Illustrative della Carta Geologica D'Italia. Foglio 214 Gallopoli. Roma: Servizio Geologico D'Italia.
- Lehman, J.T. (1975) Reconstructing the rate of accumulation of lake sediment: The effect of sediment focussing. Quaternary Research 5, 541-550.
- Lona, F. (1960) Studio pollinologico del deposito lacustre di Fimon (Vicenza). Memorie Biogeografico Adriatico 5, 13-17.
- Lona, F. & Bertoldi, R. (1972) La storia della Plio-Pleistocene Italiano in alcune sequenze vegetazionali lacustri e marine. Atti della Accademia Nazionale dei Lincei Memorie 11 (sezione 3), 1-45.
- Love, L.G. (1964) Early diagenetic pyrite in fine grained sediments and the genesis of sulphide ores. Developments in Sedimentology 2, 11-17.
- Macleod, D.A. (1980) The origin of the red Mediterranean soils in Epirus, Greece. Journal of Soil Science 31, 125-136.
- Magny, M. (1982) Atlantic and Sub-boreal: dampness and dryness? In Climatic Change in Later Prehistory ed. A.F. Harding, 33-43. Edinburgh: Edinburgh University Press.
- Magri, G. & Zezza, F. (1970) I depositi dunari della costa Adriatica tra Monopoli (Bari) e Torre S. Sabina (Brindisi) in rapporto alle oscillazioni del livello marino. Geologia Applicata e Idrogeologia 5, 49-54.

- Maguire, D.J. (1983) The identification of agricultural activity using pollen analysis. In Integrating the Subsistence Economy ed. M. Jones, 5-18. B.A.R. S181.
- Margiotta, B., Palmentola, G. & Dragone, F. (1983) La dinamica del litorale dell'insenatura di Torre Dell'Orso, in Provincia di Lecce. Quaderni di Ricerche del Centro Studi Geotecnici e D'Ingegneria. Lecce 8.
- Marinosci, M. (1870) Flora Salentina. Lecce: Editrice Salentina.
- Maurizio, A. & Louveaux J. (1962) Pollens de plantes mellifères D'Europe III. Pollen et Spores 4, 247-262.
- McMinn, A. (1991) Recent dinoflagellate cysts from estuaries on the central coast of New South Wales, Australia. Micropalaeontology 37(3), 269-287.
- Medagli, P. (1981) La riserva naturale delle "Cesine" in Provincia di Lecce. Osservazioni sull'ambiente vegetale. Quaderni di Ricerche del Centro Studi Geotecnici e D'Ingegneria. Lecce 3.
- Meteorological Office (1962) Weather in the Mediterranean. Volume 1. London: H.M.S.O.
- Moore, P.D. & Webb, J.A. (1978) An Illustrated Guide to Pollen Analysis. London: Hodder & Stoughton.
- Moresi, M. & Mongelli, G. (1988) The relation between the terra rossa and the carbonate-free residue of the underlying limestones and dolostones in Apulia, Italy. Clay Minerals 23, 439-446.
- Mörner, N-A. (1987) Quaternary sea-level changes: Northern hemisphere data. In Sea Surface Studies. A Global Review ed. R.J.N. Devoy, 242-263. London: Croom Helm.
- Morzadec-Kerfourn, M.-T. (1977) Les kystes de dinoflagellés dans les sédiments récents le long des côtes Bretonnes. Revue de Micropaleontologie 20(3), 157-166.
- Murray, J.W. (1979) British Nearshore Foraminiferids. Synopses of the British Fauna. No. 16. London: Academic Press.
- Mustilli, D. (1957) Le città della Messapia ricordate da Strabone. Atti del XVII Congresso Geografico Italiano. 23-29 Aprile 1957, Bari 3, 568-576.
- Nilsson, T. (1983) The Pleistocene: Geology and Life in the Quaternary Ice Age. Dordrecht: D. Reidel.
- Novembre, D. (1964) Sugli insediamenti preistorici e protostorici costiere nel Salento. Paletnologia. Estratto Dall'Annuario 1963-1964, 139-160.

- Novembre, D. (1965) Aree antiche e recenti della macchia nel Salento. Atti del XIX Congresso Geografico Italiano, 1964 Como, 179-193.
- Novembre, D. (1979) Vicende del popolamento e trasformazione del paesaggio. Storia della Puglia 1, 13-32. Bari: Adda.
- Oldfield, F. (1959) The pollen morphology of some of the West European Ericales. Pollen et Spores 1, 19-48.
- Oldfield, F. (1970) Some aspects of scale and complexity in pollen analytically based palaeoecology. Pollen et Spores 12(2), 165-171.
- Orlando, D. (1885) Classificazione delle Opere di Bonificazione delle Paludi e dei Terreni Paludosi nella Provincia di Terra d'Otranto. Lecce: Campanella.
- Paepe, R. & Mariolagos, I. (1986) Paleoclimatic reconstruction in Belgium and in Greece based on Quaternary lithostratigraphic sequences. In Current Issues in Climatic Research eds. A. Ghazi & R. Fantechi, 113-129. Dordrecht: Reidel Publishing Company.
- Pagliara, C. (1987) La Grotta Poesia di Roca (Melendugno-Lecce) Note preliminari. Annali della Scuola Normale Superiore di Pisa. Estratto Classe di Lettere e Filosofia Serie III, vol XVII. Pisa. 267-328.
- Palmentola, G. & Vignola, N. (1980) Dati di neotettonica sulla penisola Salentina (Fogli 204 "Lecce", 213 "Maruggio", 214 "Gallipoli", 215 "Otranto" e 223 "Capo S. Maria di Leuca". Progr. Final. Geodinam. Roma 356, 175-202.
- Pals, J.P., van Geel, B. & Delfos, A. (1980) Palaeoecological studies in the Klokkeweel bog near Hoogkarspel (Prov. of Noord-Holland). Review of Palaeobotany and Palynology 30, 371-418.
- Panelatti, G. (1960) Quelques résultats de palynologie descriptive et analytique pour le Maroc. Pollen et Spores 2(2), 183-234.
- Paoli, P. & Cellai Ciuffi, G. (1976) Schede per una flora palinologica Italiana. Contributo n.2: Raccolte dell'Isola di Montecristo. Archivio Botanico e Biogeografico Italiano 52(1/2), 3-8.
- Parmenter, C. & Folger, D.W. (1974) Eolian biogenic detritus in deep sea sediments: a possible index of equatorial ice age aridity. Science 185, 695-698.
- Pasa, A. (1953) Appunti geologici per la paleogeografia della Puglia. Memoria Biogeografica Adriatica 2, 175-286.

- Pasa, A. & Pasa Durante, M.V. (1962) Analisi di alcuni sedimenti costieri del Lago Varano (Gargano). Estratto dalle Memorie del Museo Civico di Storia Naturale X, 257-264.
- Paterne, M., Guichard, F. & Labeyrie, J. (1988) Explosive activity of the south Italian volcanoes during the past 80,000 years as determined by marine tephrochronology. Journal of Volcanology and Geothermal Research **34**, 153-172.
- Patterson, W.A, Edwards, K.J & Maguire, D.J. (1987) Microscopic charcoal as a fossil indicator of fire. Quaternary Science Reviews **6**, 3-24.
- Peroni, R. (1967) Archeologia della Puglia Preistorica. De Luca Editore.
- Pfleger V. & Chatfield, J. (1988) A Guide to Snails of Britain and Europe. London: Hamlyn.
- Phillips, R. (1987) Seashells and Seaweeds. London: Elm Tree Books.
- Phillips, R. (1988) Mediterranean Wild Flowers. London: Elm Tree Books.
- Piccinno, A. e F. (1978) Otranto, Laghi Alimini - Stazioni Preistoriche. Ricerche e Studi XI, 122-132.
- Pignatti, S. (1979) I piani di vegetazione in Italia. Giornale Botanico Italiano **113**, 411-428.
- Pignatti, S. (1982) Flora d'Italia. Bologna: Edagricole.
- Pigorini, B. (1968) Sources and dispersion of recent sediments of the Adriatic Sea. Marine Geology **6**, 187-229.
- Pirazzoli, P.A. (1976) Sea level variations in the north-west Mediterranean during Roman Times. Science **194**, 519-521.
- Pirazzoli, P.A. (1987) Sea-level changes in the Mediterranean. In Sea Level Changes eds. M.J. Tooley & I. Shennan, 152-181. I.B.G. Special Publications Series No. 20.
- Planchais, N. (1962) Le pollen de quelques Chênes du domaine Méditerranéen Occidental. Pollen et Spores **4(1)**, 87-93.
- Polunin, O. (1980) Flowers of Greece and the Balkans. Oxford: Oxford University Press.
- Polunin, O. & Huxley, A. (1987) Flowers of the Mediterranean. London: Hogarth Press.
- Polunin, O. & Smythies, B.E. (1973) Flowers of South-West Europe. Oxford: Oxford University Press.

Potter, T.W. (1987) Roman Italy. London: British Museum Publications.

327

Polunin, O. & Walters, M. (1985) A Guide to the Vegetation of Britain and Europe.
Oxford: Oxford University Press.

Pope, K.O., Runnels, C.N. & Ku, T-L. (1984) Dating Middle Palaeolithic red beds in
southern Greece. Nature 312, 264-266.

Prentice, C. (1985) Pollen representation, source area, and basin size: Toward a
unified theory of pollen analysis. Quaternary Research 23, 76-86.

Prodi, F. & Fea, G. (1979) A case of transport and deposition of Saharan dust over
the Italian peninsula and southern Europe. Journal of Geophysical Research 84,
6951-6960.

Proudfoot, B. (1976) The analysis and interpretation of soil phosphorous in
archaeological contexts. In Geoarchaeology ed. D.A. Davidson & M.L. Shackley.
London: Duckworth.

Punt, W., Bos, J.A.A. & Hoen, P.P. (1991) Oleaceae. The Northwest European
pollen flora, 45. Review of Palaeobotany & Palynology 69, 23-47.

Racek, A.A. (1970) The Porifera. In Ianula: An account of the history and
development of the Lago di Monterosi, Latium, Italy. by G.E. Hutchinson et al.,
143-149. Transactions of the American Philosophical Society 64(4), 5-175.

Rapp, A. (1983) Are Terra rossa soils in Europe eolian deposits from Africa?
Geologiska Föreningens i Stockholm Förhandlingar 105, 161-168.

Reid, P.C. (1972) The Distribution of Dinoflagellate Cysts, Acritarchs and Pollen in
Coastal Sediments from the British Isles. University of Sheffield, Ph.D. thesis
(unpublished).

Reille, M. (1967) Contribution a l'étude palinologique de la famille des Vitacées.
Pollen et Spores 9(2), 279-303.

Reina, C. (1957) Sulla geomorfologia della regione Pugliese. Atti della XVII
Congresso Geografico Italiano, 23-29 Aprile 1957, Bari Vol 3, 247-255.

Ricchetti, G. & De Fino, M. (1969) Livello con pomici nei cordoni litorali attuali
della costa fra Taranto e il Capo di S. Maria di Leuca (Penisola Salentina)
Bolletino Della Societa Geologica Italiana 88, 329-345.

Ritchie, J.C. (1986) Climate change and vegetation response. Vegetatio 67, 65-74.

Ritchie, J.C., Eyles, C.H. & Haynes C.V. (1985) Sediment and pollen evidence for
an early to mid-Holocene humid period in the eastern Sahara. Nature 314, 352-
354.

- Rivera Núñez, D. & Walker, M.J. (1989) A review of palaeobotanical findings of early *Vitis* in the Mediterranean and of the origins of cultivated grape vines, with special reference to new pointers to prehistoric exploitation in the western Mediterranean. Review of Palaeobotany and Palynology 61, 205-237.
- Roback, S.S. (1970) The Chironomidae. In *Ianula: An account of the history and development of the Lago di Monterosi, Latium, Italy.* by G.E. Hutchinson et al., 150-162. Transactions of the American Philosophical Society 64(4), 5-175.
- Roberts, H. (1981) X-ray radiography. In Geomorphological Techniques. ed. A. Goudie, 101-103. London: George Allen & Unwin.
- Rossi, D. (1969) Note Illustrative della Carta Geologica d'Italia. Foglio 215. Otranto. Rome: Servizio Geologico D'Italia.
- Rossignol, M. (1962) Analyse pollinique de sédiments marins Quaternaires en Israël. Pollen et Spores 4(1), 121-148.
- Rossignol, M. (1969) Sédimentation palynologique récente dans la Mer Morte Pollen et Spores 11(1), 17-38.
- Rossignol, M. & Pastouret, L. (1971) Analyse pollinique de niveaux sapropéliques post-glaciaires dans une carotte en Méditerranée orientale. Review of Palaeobotany and Palynology 11, 227-238.
- Rossignol-Strick, M., Nesteroff, W., Olive, P. & Vergnaud-Grazzini, C. (1982) After the deluge: Mediterranean stagnation and sapropel formation. Nature 295, 105-110.
- Round, F.E. (1973) The Biology of the Algae. London: Edward Arnold.
- Rull, V. (1987) A note on pollen counting in palynology. Pollen et Spores 29(4), 471-480.
- Rybničková, E. & Rybniček, K. (1971) The determination and elimination of local elements of pollen spectra from different sediments. Review of Palaeobotany and Palynology 11, 165-176.
- Sangster A.G. & Dale, H.M. (1964) Pollen grain preservation of underrepresented species in fossil spectra. Canadian Journal of Botany 42, 437-449.
- Sargent, A. (1983) Exploitation territory and economy in the Tavoliere of Apulia. In Studi Sul Neolitico del Tavoliere della Puglia. eds. S.M. Cassano & A. Manfredini, 223-236. B.A.R. S160.
- Satta, S. & Renault-Miskovsky, J. (1985) Le Paléoenvironnement et la paléoclimatologie des Pouilles (sud de l'Italie): Étude pollinique préliminaire des

- niveaux épigravettiens de la Grotte Paglicci. Bulletin de l'Association Francaise pour l'Etude du Quaternaire 22, 219-227.
- Schönfelder, I & Schönfelder, P. (1990) Wild Flowers of the Mediterranean. London: Collins.
- Scourfield, D.J. & Harding, J.P. (1966) A Key to the British Species of Freshwater Cladocera. Scientific Publication No. 9, Freshwater Biological Association.
- Sergi, G.M. (1957) Distribuzione delle dimore rurali sorte per necessità di difesa nel Salento. Atti del XVII Congresso Geografico Italiano. 23-29 Aprile 1957, Bari 3, 368-376.
- Sestini, A. (1984) The Appennines and Sicily. In Geomorphology of Europe. ed. C. Embleton, 341-356. London: Macmillan.
- Shaw-Briggs, M. (1910) In the Heel of Italy. London: Andrew Melrose.
- Sherwood-Pike, M.A. (1988) Freshwater funghi: fossil record and paleoecological potential. Palaeogeography, Palaeoclimatology, Palaeoecology 62, 271-285.
- Smit, A. (1973) A scanning electron microscopical study of the pollen morphology in the genus Quercus. Acta Botanica Neerlandica 22(6), 655-665.
- Sordinas, A. (1983) Quaternary shorelines in the region of Corfu and adjacent islets, western Greece. In Quaternary coastlines and Marine Archaeology. eds. P.M. Masters & N.C. Fleming. London: Academic Press.
- Stanley, D.J. (1977) Post- Miocene depositional patterns and structural displacement in the Mediterranean. In The Ocean Basins and Margins. Vol. 4A The Eastern Mediterranean. eds. A.E.M. Nairn, W.H. Kanes & F.G. Stehli, 77-150. New York: Plenum Press.
- Stanley, D.J. (1978) Ionian Sea sapropel distribution and late Quaternary palaeoceanography in the eastern Mediterranean. Nature 274, 149-152.
- Stevenson, A.C. (1981) Pollen Studies in Semi-Arid Areas; N.E. Iran and S.W. Spain. King's College, University of London. Ph.D. thesis (unpublished).
- Stevenson, A.C. (1985) Studies in the vegetational history of S.W Spain. II. Palynological investigations at Laguna de las Madres, S.W. Spain. Journal of Biogeography 12, 293-314.
- Stevenson, A.C. & Moore, P.D. (1988) Studies in the vegetational history of S.W. Spain. IV. Palynological investigations of a valley mire at El Acebron, Huelva. Journal of Biogeography 15, 330-361.

- Stockmarr, J. (1971) Tablets with spores used in absolute pollen analysis. Pollen et Spores 13(4), 615-621.
- Stothers, R.B. & Rampino, M.R. (1983) Historic volcanism, European dry fogs, and Greenland acid precipitation, 1500 B.C. to A.D. 1500. Science 222, 411-413.
- Street, F.A. & Grove, A.T. (1976) Environmental and climatic implications of late Quaternary lake-level fluctuations in Africa. Nature 261, 385-390.
- Street, F.A. & Grove, A.T. (1979) Global maps of lake-level fluctuations since 30,000 yr B.P. Quaternary Research 12, 83-118.
- Swinburne, H. (1783) Travels in the Two Sicilies, in the years 1777, 1778, 1779 & 1780. 1. London: Elmsley.
- Tadolini, T., Tazioli, G.S. & Tulipano, L. (1971) Idrogeologia della zona delle sorgenti Idume (Lecce). Geologia Applicata e Idrogeologia VI, 41-63.
- Tauber, H. (1965) Differential pollen dispersion and the interpretation of pollen diagrams. Danmarks Geologiske Undersøgelse II(89), 1-69.
- Tebble, N. (1966) British Bivalve Seashells. H.M.S.O: Edinburgh.
- Tippet, H. (1964) General description of the red earth. In The climate, environment and industries of stone age Greece. by S.I. Dakaris, E.S Higgs & R.W. Hey, 221-225. Proceedings of the Prehistoric Society 30, 199-244.
- Tolonen, K. (1986) Charred particle analysis. In Handbook of Palaeoecology and Palaeohydrology. ed. B.E. Berglund, 485-496. Chichester: John Wiley & Sons.
- Troels-Smith J. (1955) Karakterisering af løse jordarter. Characterisation of unconsolidated sediments. Danmarks Geologiske Undersøgelse 4rv 3(10), 1-73.
- Turner, J. (1964a) Surface-sample analyses from Ayrshire, Scotland. Pollen et spores 6, 583-592.
- Turner, J. (1964b) The anthropogenic factor in vegetational history. New Phytologist 63, 73-90.
- Turner, J. & Greig, J.R.A. (1975) Some Holocene pollen diagrams from Greece. Review of Palaeobotany and Palynology 20, 171-204.
- Uggeri, G. (1974) Gli insediamenti rupestri medievali problemi di metodo e prospettive di ricerca. Archeologia Medievale 1, 195-230.
- U.S. Department of Commerce (1979) World Weather Reports 1961-1970 Volume 2, Europe. Asheville: National Oceanic & Atmospheric Administration

- van Benthem, F., Clarke, G.G.S. & Punt, W. (1984) Fagaceae. The north-West European Pollen Flora 33. Review of Palaeobotany & Palynology 42, 87-110.
- van Campo, M. & Elhai, H. (1956) Étude comparative des pollens de quelques Chênes. Application à une tourbière normande. Bulletin de la Société Botanique de France 103(5/6), 254-260.
- van Campo, M. & Quet, L. (1982) Transport par les vents de pollen et de poussières rouges du sud au nord de la Méditerranée. Comptes Rendus de l'Académie des Sciences 295 Ser III, 61-64.
- van der Hammen, T., Wijmstra, T.A. & van der Molen, W.H. (1965) Palynological study of a very thick peat section in Greece and the Wurm glacial vegetation in the Mediterranean region. Geologie & Mijnbouw 44, 37-39.
- van Geel, B. (1972) Palynology of a section from the raised peat bog Weitmarscher Moor, with special reference to fungal remains. Acta Botanica Neerlandica 21, 261-284.
- van Geel, B. (1976) Fossil spores of Zygnemataceae in ditches of a pre-historic settlement in Hoogkarspel (The Netherlands). Review of Palaeobotany and Palynology 22, 337-344.
- van Geel, B. (1978) A palaeoecological study of Holocene peat bog sections in Germany and the Netherlands. Review of Palaeobotany & Palynology 25, 1-120.
- van Geel, B. (1979) Preliminary report on the history of Zygnemataceae and the use of their spores as ecological markers. Proceedings of the IVth International Palynological Conference, Lucknow (1976-1977) 1, 467-469.
- van Geel, B. (1986) Applications of fungal and algal remains and other microfossils in palynological analyses. In Handbook of Holocene Palaeoecology and Palaeohydrology ed. B.E. Berglund. 497-505. Chichester: John Wiley & Sons
- van Geel, B., Bohncke, S.J.P. & Dee, H. (1980/1981) A Palaeoecological study of an upper Late Glacial and Holocene sequence from "De Borchert", The Netherlands. Review of Palaeobotany & Palynology 31, 367-448.
- van Geel, B. & van der Hammen, T. (1978) Zygnemataceae in Quaternary Columbian Sediments. Review of Palaeobotany & Palynology 25, 377-392.
- van Straaten, L.M.J.U. (1967) Turbidites, ash layers and shell beds in the bathyal zone of the southeastern Adriatic Sea. Revue de Géographie Physique et Géologie Dynamique Ser. 2,3, 219-239.

- van Straaten, L.M.J.U. (1971) Holocene stages of oxygen depletion in deep waters of the Adriatic Sea. In The Mediterranean Sea ed. D.J. Stanley, 631-643. Stroudsburg: Dowden, Hutchinson & Ross.
- van der Wiel, A.M. (1982) A Palaeoecological study of a section from the foot of the Hazendonk (Zuid-Holland, The Netherlands), based on the analysis of pollen, spores and macroscopic plant remains. Review of Palaeobotany and Palynology 38, 35-90.
- van Zeist, W. & Bottema, S. (1977) Palynological investigations in western Iran. Palaeohistoria 19, 19-85.
- van Zeist, W. & Bottema, S. (1982) Vegetational history of the eastern Mediterranean and the Near East during the last 20,000 years. In Palaeoclimates, Palaeoenvironments and Human Communities in the Eastern Mediterranean Region in Later Prehistory. ed. J.L. Bintliff & W. van Zeist, 277-295. B.A.R. S133(ii).
- van Zeist, W., Timmers, R.W. & Bottema, S. (1968) Studies of modern and Holocene pollen precipitation in southeastern Turkey. Palaeohistoria 14, 19-39.
- Vines, A.E. & Rees, N. (1972) Plant and Animal Biology. Vol.1. London: Pitman.
- Vita-Finzi, C. (1978) Archaeological Sites in their Setting. London: Thames and Hudson.
- Vlora, A.K. (1963) Contributo allo studio della erosione del suolo in Puglia e dei suoi riflessi economici e sociali. Istituto di Geografia, Facolta di Economia e Commercio - Universita Degli Studi-Bari. Memorie Nuova Serie 1. Bari.
- Waddington, J.C.B. (1969) A stratigraphic record of the pollen influx to a lake in the Big Woods of Minnesota. Geological Society of America Special Paper 123, 263-282.
- Watts, W.A. (1985) A long pollen record from Laghi di Monticchio, southern Italy: a preliminary account. Journal of the Geological Society of London 142, 491-499.
- Webb, T. III. (1986) Is vegetation in equilibrium with climate? How to interpret late-Quaternary pollen data. Vegetatio 67, 75-91.
- Whitehouse, R.D. (1968) Settlement and economy in southern Italy in the Neothermal Period. Proceedings of the Prehistoric Society 34, 332-367.
- Whitehouse, R.D. (1971) The last hunter-gatherers in southern Italy. World Archaeology 2, 239-254.

- Whitehouse, R.D. (1981) Prehistoric settlement patterns in southeast Italy. In Archaeology and Italian Society eds. G. Barker & R. Hodges, 157-165. B.A.R. S102.
- Whitehouse, R.D. (1984) Social organisation in the Neolithic of southeast Italy. In The Deya Conference of Prehistory. Early Settlement in the western Mediterranean Islands and their peripheral areas. eds. W.H. Waldren, R. Chapman, J. Lewthwaite & R.C. Kennard, 1109-1133. B.A.R. S229.
- Wijmstra, T.A. (1969) Palynology of the first 30 metres of a 120 m deep section in northern Greece. Acta Botanica Neerlandica 18(4), 511-527.
- Wigley, T.M.L. & Kelly, P.M. (1990) Holocene climatic change, 14C wiggles and variations in solar irradiance. Philosophical Transactions of the Royal Society of London A330, 547-560.
- Wright, H.E.Jr. (1967) The use of surface samples in Quaternary pollen analysis. Review of Palaeobotany & Palynology 2(1-4), 321-330.
- Wright, H.E.Jr., McAndrews, J.H. & van Zeist, W. (1967) Modern pollen rain in western Iran, and its relation to plant geography and Quaternary vegetational history. Journal of Ecology 55, 415-443.
- Yaalon, D.H. & Ganor, E. (1973) The influence of dust on soils during the Quaternary. Soil Science 116, 146-155.
- Zeuner, F.E. (1952) Dating the Past. London: Methuen.
- Zeza, F. (1969a) Sui depositi di manganese del Capo S. Maria di Leuca (Puglia). Geologia Applicata e Idrogeologia VI, 187-194.
- Zeza, F. (1969b) Interpretazione idrodinamica delle strutture sedimentare nei depositi di spiaggia del litorale Adriatico della Puglia. Geologia Applicata e Idrogeologia IV, 47-61.